Draft Environmental Impact Statement

Troy Mine Revised Reclamation Plan

May 2011

Montana Department of Environmental Quality

Kootenai National Forest
Three Rivers Ranger District

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Draft Environmental Impact Statement
Troy Mine Revised Reclamation Plan

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Abstract: This Draft Environmental Impact Statement for the Troy Mine Revised Reclamation Plan describes the land, people, and resources potentially affected by the proposed revised reclamation activities. The purpose of the proposed revision is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. Alternatives considered in detail include a No Action Alternative (the previously approved 1978 reclamation plan), the Proposed Action (Troy Mine, Inc.'s Revised Reclamation Plan), and an Agency-Mitigated Alternative (the Agencies preferred alternative). This Draft EIS analyzes Troy Mine, Inc.'s revised plan as well as agency-proposed modifications (*e.g.* adit closure, mine water management, water treatment and monitoring, reclamation cover requirements, subsidence monitoring, debris disposal, and road closures). The major state and federal actions include approval of a reclamation plan and any necessary permits to implement the reclamation activities including construction and long-term monitoring.

Reviewers should provide their comments to either KNF or DEQ during the review period of the Draft EIS. The KNF and the DEQ will analyze and respond to the comments jointly and will use the information acquired in the preparation of the final environmental impact statement (Final EIS). Reviewers have an obligation to structure their participation in the National Environmental Policy Act (NEPA) and Montana Environmental Policy Act (MEPA) process so that it is meaningful and alerts the agencies to the reviewers' position and contentions [Vermont Yankee Nuclear Power Corp. v. Natural Resource Defense Council, 435 U.S. 519, 553 (1978)]. Environmental objections that could have been raised at the Draft EIS stage may be waived if not raised until after completion of the Final EIS. [City of Angoon v. Hodel (9th Circuit, 1986) and Wisconsin Heritages, Inc. v. Harris, 490 F. Supp. 1334, 1338 (E.D. Wis. 1980)]. Comments on the Draft EIS should be specific and should address the adequacy of the statement and the merits of the alternatives discussed (40 Code of Federal Regulations (CFR) 1503.3).

Send Comments To: Bobbie Lacklen (Kootenai National Forest) email: TroyMineReclamation@fs.fed.us or Emily Corsi (MT DEQ) email: deqTroyMine@mt.gov or postal addresses listed above.

Comments Due: 45 days after the Notice of Availability is published in the *Federal Register,* which will be on or about May 20, 2011.

Executive Summary

This Executive Summary provides an overview of the contents of the Draft Environmental Impact Statement (EIS) for the Troy Mine Revised Reclamation Plan. The Draft EIS describes the land, people, and resources potentially affected by the proposed revised reclamation activities. This summary does not provide all of the information contained in the Draft EIS. If more detailed information is desired, please refer to the Draft EIS, its appendices, or referenced reports.

ES.1 Introduction

The United States Department of Agriculture (USDA) Forest Service (USFS) Kootenai National Forest (KNF) and the Montana Department of Environmental Quality (DEQ) have prepared this EIS in compliance with the National Environmental Policy Act (NEPA), the Montana Environmental Policy Act (MEPA), the Metal Mine Reclamation Act (MMRA), and with other relevant federal and state laws and regulations.

In 1978, the Montana Department of State Lands (DSL) and KNF issued a Draft and Final EIS that addressed potential impacts from both the operation and reclamation of the Troy Mine, which is operated by Troy Mine, Incorporated (Troy Mine, Inc.). Troy Mine, Inc. was formerly known as Genesis, Incorporated, and documents prepared under the earlier name referenced in this Draft EIS are attributed to Genesis.

In the fall of 1999, DEQ and KNF (the Agencies) initiated a review of the Troy Mine reclamation bond. DEQ and KNF notified the mining company that the approved 1978 reclamation plan needed to be revised and a substantial bond increase would be required. The mining company prepared a revised reclamation plan and the final draft was submitted to the Agencies in March of 2006 (Genesis 2006). The 2006 Revised Reclamation Plan is the subject of this Draft EIS and is referred to as the Proposed Action.

ES.1.1 Project Area Description

The Troy Mine is located about 15 miles south of Troy, Montana, in Lincoln County (Figure ES-1). The nearest towns to Troy are Libby, Montana, located 18 miles to the east and Bonners Ferry, Idaho (ID), located 33 miles to the west. The project area lies within the KNF immediately west and north of Bull Lake and is within the Stanley, Lake, and Ross creek drainages.

The Troy Mine is accessible from Montana Highway 56 (MT 56) and National Forest System Road (NFSR) 4626. The mine permit area covers 2,782 acres of public, private, and patented land. Approximately 57 percent of the project area is on private and patented land, and the other 43 percent is on the KNF.

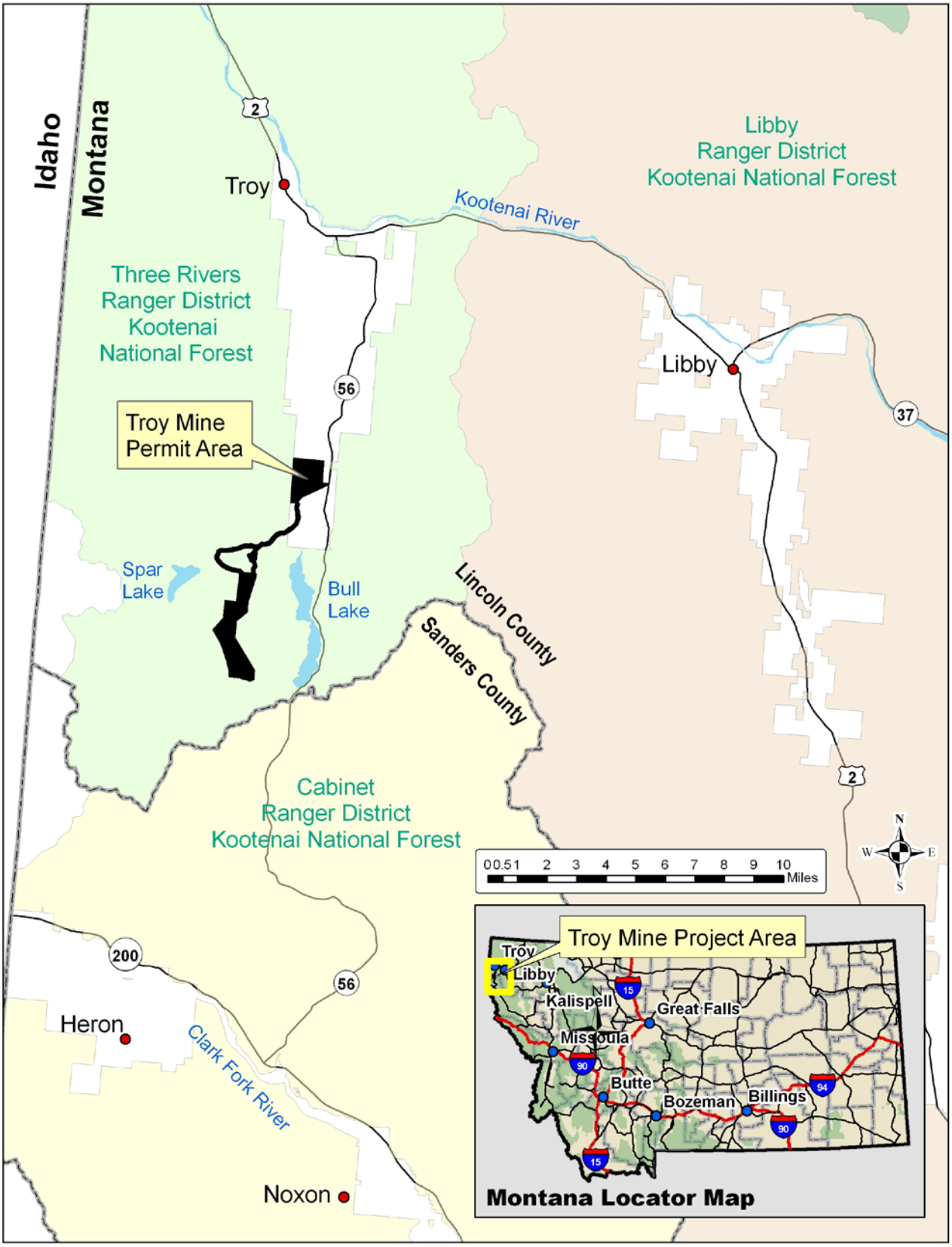


Figure ES-1. Project Area

The mine facilities consist of an underground mine, the mill, and various office facilities; the tailings and reclaim water pipelines; a power line; a tailings impoundment; and associated support facilities. The tailings facility and associated disturbances are on approximately 430 acres of disturbed area on private land owned by Troy Mine, Inc. Both the tailings and reclaim water pipelines and the power line are on National Forest System Lands (NFSL), private, and patented land. The South Adit portal is located on patented land, while the North Adit portal and the mill and office/shop facilities are located on unpatented claims on NFSL. There are approximately 15.6 acres of disturbed land at the portal patios and 34 acres of disturbed lands at the mill site. Associated roads, pipelines and other small disturbed areas exist throughout the project area.

ES.2 Purpose and Need

The purpose of the proposed reclamation plan is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. The approved 1978 reclamation plan does not meet state or federal requirements for mine water discharge. The need for the revised reclamation plan stems from several objectives that need to be met after mine closure:

- Reclamation plans must meet state and federal requirements;
- Protection of surface and groundwater quality;
- Protection of public health and safety;
- Minimization of environmental risk; and
- Restoration of productive land use.

ES.3 Scope of Decisions To Be Made

The major state and federal actions include approval of a reclamation plan and any necessary permits to implement the reclamation activities including construction and long-term monitoring.

ES.3.1 Kootenai National Forest

KNF's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for the Troy Mine. To satisfy this request, KNF must:

- Select an alternative that meets the requirements of 36 Code of Federal Regulations (CFR) 228.8 which directs that all mining operations shall be conducted to minimize adverse environmental impacts on National Forest surface resources where feasible;
- Ensure implementation of the selected alternative would assist in preserving and maintaining forest resources to meet the long-term management goals of the 1987 Land and Resource Management Plan (Forest Plan), as amended; and
- Ensure compliance with other applicable federal laws.

KNF also has responsibility jointly with DEQ to review, analyze, and calculate the reclamation bond amount.

The KNF Forest Supervisor will use the EIS process to develop the information necessary to make an informed decision as required by 36 CFR 228, Subpart A. Based on the information presented and alternatives developed in this EIS, the KNF Forest Supervisor will issue a Record of Decision (ROD) on Troy Mine, Inc.'s proposal.

The ROD would document the Forest Supervisor decision on one of the following:

- No Action Alternative
- Approval of the Revised Reclamation Plan as submitted (the Proposed Action) as an amendment to the existing Plan of Operations for the Troy Mine, or
- Approval of a Revised Reclamation Plan (Agency-Mitigated Alternative), as an amendment to the existing Plan of Operations for the Troy Mine. The amendment would incorporate mitigations and stipulations to meet the mandates of applicable laws, regulations, and policies.

ES.3.2 Montana Department of Environmental Quality

DEQ's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for Troy Mine. To satisfy this request, DEQ must determine whether the Revised Reclamation Plan satisfies the requirements of the MMRA, Title 82, Chapter 4, Part 3, Montana Code Annotated (MCA).

The DEQ Director will use the EIS process to develop the information necessary to determine whether the Proposed Action meets the performance standards of the MMRA, including but not limited to:

- The removal of buildings and other structures at closure consistent with the post-mine land uses;
- Post-closure environmental monitoring programs and contingency plans;
- Compliance with state air and water quality standards.

The DEQ Director would issue a ROD documenting the decision on the reclamation proposal.

ES.4 Public Involvement

At the beginning of the NEPA/MEPA process, the Agencies conducted scoping to solicit public input on the purpose and need and the Proposed Action. A public scoping meeting was held in October 2007. The scoping process is described in a Scoping Report for the project. Based on the comments received during agency and public scoping, a number of major issues were identified that drove the development of alternatives to the Proposed Action.

At the time of the scoping, the project team determined that an environmental assessment (EA) would be produced to document the analysis. During the course of preparing the EA, several potential water quality issues were identified that are of sufficient significance to warrant the preparation of an EIS. These issues include the potential for mine water discharge to impact surface water and potentially

exceed aquatic life standards; the potential for the tailings pipeline to fail potentially resulting in erosion and discharge of contaminants into Stanley or Lake creeks; and issues related to the long-term maintenance of the pipeline. Given these potential issues, the Agencies issued a Notice of Intent to prepare an EIS in the Federal Register on April 14, 2011.

ES.5 Issue Identification and Alternative Development

Issues were identified through the agency and public scoping process, through the Agencies' review of the *2006 Revised Reclamation Plan*, and through interagency discussions on the development of alternatives. Issues were evaluated to determine whether the proposed action or an alternative would result in significant impacts. The Council on Environmental Quality (CEQ) regulations define significant impacts in terms of both context and intensity (40 CFR 1508.27). MEPA also provides direction on determining the significance of impacts similar to the definitions used under NEPA (ARM 17.4.608(1), MCA 75.1.201).

Major issues are those for which:

- there may be potentially significant impacts;
- there is a concern about potential effects directly or indirectly resulting from implementation of the Proposed Action; or
- there is a concern about the effectiveness of proposed mitigation measures.

The major issues identified include:

Water Management

- Adit closure and mine water distribution;
- Water treatment and disposal;
- Groundwater quality;
- Surface water quality; and
- Long-term monitoring of water quality

Reclamation

- Reclamation materials;
- Subsidence;
- Revegetation;
- Infrastructure (buildings and other structural materials and how they will be removed or reclaimed); and
- Topography (disturbed areas)

ES.6 Alternatives

Three alternatives were developed and evaluated in this EIS. The No Action Alternative consists of the 1978 Reclamation Plan that was previously approved and the reclamation work that has been

completed through August of 2010 by Genesis (now Troy Mine, Inc.). The Proposed Action describes the Revised Reclamation Plan submitted by Genesis to the Agencies in March of 2006. The Agency-Mitigated Alternative was developed by the Agencies and is based on issues derived from interagency and public scoping comments on the Proposed Action.

ES.6.1 No Action Alternative

The original reclamation plan was first analyzed in the *1978 Draft Environmental Impact Statement* (DSL and KNF 1978) and later approved by the Agencies. It does not directly address many of the issues identified through scoping.

ES.6.1.1 Water Management

Adit closure and mine water distribution

The No Action Alternative proposes to close the adits by plugging them with concrete. After mine closure, surface and groundwater would be expected to accumulate in the mine, eventually discharge onto the portal patios and infiltrate into groundwater, and ultimately enter Stanley Creek.

Water treatment and disposal

The No Action Alternative does not address water treatment.

Toe ponds at the base of the tailings impoundment capture seepage and embankment runoff which is then pumped to the impoundment. This pumping would not continue long-term after reclamation. Surface drainage would be from the low point of the impoundment surface to an appropriate natural drainage.

Groundwater quality

The No Action Alternative does not address groundwater quality beyond operational monitoring. Groundwater would enter the mine, flood the workings, and eventually exit the mine and discharge into the groundwater system and Stanley Creek.

Surface water quality

Under the No Action Alternative, seven existing water quality monitoring stations on Stanley, Fairway, and Lake creeks would continue to be sampled post-reclamation for flow and water quality three times per year until the Agencies agree that monitoring is no longer necessary.

Other than monitoring, management of water quality is not addressed under the No Action Alternative. Precipitation would enter the mine through fractures, the workings would flood, and the water would eventually exit the mine and discharge into Stanley Creek.

Long-term monitoring of water quality

Monitoring includes periodic water level and water quality sampling of monitoring wells, springs, and areas of groundwater expression in the vicinity of the mine.

As part of the baseline sampling program, two test wells were drilled in July of 1976. Surface water quality has been monitored at seven sites on Stanley, Fairway, and Lake creeks since 1986. Five

additional surface water sites are sampled and represent the farthest upgradient expressions of groundwater in drainages around the mine. These sites were chosen to monitor changes in the quality of groundwater discharging to surface drainages. These monitoring wells and sites would continue to be evaluated to determine potential mine water influence on surface and groundwater under the No Action Alternative.

Surface water quality monitoring as described above would continue post-reclamation three times per year until the Agencies agree that monitoring is no longer necessary.

ES.6.1.2 Reclamation

Reclamation materials

Soil salvaged from the west side of the tailings impoundment would be used to provide an average 12-inch cover over the portal patio at the mine and at those areas where buildings and facilities would be removed.

The surface of the tailings impoundment and the embankment would be covered with 18 inches of stockpiled soil and revegetated. The No Action Alternative does not specifically identify the source of these stockpiled soils. The soil needed to complete reclamation would likely come from the soil stockpiled from the construction of the tailings facility.

Subsidence

Subsidence was not addressed as part of the original 1978 reclamation plan. However, during operations, two surface subsidence features developed along the East Fault and a permit revision was issued to address these subsidence issues. Although the Agencies currently hold a bond for reclamation of possible future surface subsidence, it may not be sufficient to cover mitigation for surface subsidence on steep slopes.

Revegetation

The No Action Alternative proposes a mixture of introduced grasses and legumes, native shrubs, and trees to cover all disturbed areas upon reclamation. Soils would be seeded during the first appropriate growing season after necessary surface grading and preparation has been completed. Areas would be fertilized at 200 lb/acre and mulched on south-facing slopes.

Slopes and benches of the tailings embankment would be capped with an average of 18 inches of reclamation material. The tailings impoundment surface would have 18 inches of stockpiled lacustrine and volcanic ash-derived soil materials spread on the surface.

Ponderosa pine, Douglas-fir, western larch, and shrubs would be planted on embankment benches and the tailings impoundment. A grass and legume seed mix would be applied to provide complete vegetative cover. Container-grown tree seedlings would be planted (680 trees/acre density) with container-grown shrubs interspersed among the trees. In 1997 and 1999, 3,750 trees were planted on the northeast face of the slope below the North Adit.

The No Action Alternative calls for stockpile sites to be revegetated and planted with trees and shrubs after the soil has been used for reclamation.

Fertilization and irrigation would depend on reclamation progress. The operational irrigation system includes large irrigation sprinklers and aluminum sprinkler pipe.

Noxious weeds have invaded disturbed sites at the mill site, the tailings line corridor on road cuts and fills, and along the periphery of the tailings facility. There is a current noxious weed control plan approved by Lincoln County and KNF in place. The No Action Alternative would continue the current noxious weed control plan which includes chemical weed control.

Under the No Action Alternative, there is no provision to monitor dust or to minimize the potential for blowing dust through irrigation or revegetation.

Infrastructure

Buildings and all materials would be removed from the project area under the No Action Alternative including removal of the tailings pipelines, the reclaim water line, and the 115 kV transmission line. Disposition of underground equipment is not addressed in the No Action Alternative.

The No Action Alternative would leave the main mine access road (NFSR 4626) open for public recreation access to Spar Lake and Mt. Vernon although the gate would remain at the mill site limiting motorized access. All other roads would be removed and reclaimed, pending approval of KNF.

Topography

Under the No Action Alternative, the surface of the tailings impoundment would be graded and reworked to provide areas suitable for revegetation, but no changes in the configuration of the tailings embankment are proposed.

The benches at the mill site would be left flat or nearly flat. The cut and fill slopes would be regraded and re-established at 1.5 horizontal to 1 vertical (1.5H:1V) slopes. The northeast face of the slope below the North Adit has already been recontoured and revegetated.

At the mine itself, the slopes of the development rock fill patio would remain at their existing angle-of-repose. The surface and edges of the patios would be graded to both distribute surface water runoff and to prevent erosion.

Regrading of the borrow sites once excavations are complete is not addressed in the No Action Alternative.

ES.6.2 Proposed Action

The Revised Reclamation Plan, which is the Proposed Action under this EIS, was submitted to DEQ and KNF in March of 2006. The Proposed Action would reclaim the land to allow current or historic activities to continue or resume once reclamation has been completed.

Under the Proposed Action, the proposed reclamation would be accomplished in three phases: pre-closure, closure, and post-closure. Pre-closure tasks include on-going monitoring, testing, and evaluations necessary to complete design of reclamation elements. Closure tasks would take place two years after final cessation of mining and would include facility removal, regrading, revegetation, and maintenance of short-term components of the water management plan. Adit plugs would be installed during the closure period. Post-closure tasks would include management of mine water flowing through pipelines, maintenance of pipelines, and monitoring of water quality (mine water and surface/groundwater). Under the Proposed Action, the post-closure phase is estimated to last two to five years after mining ends.

ES.6.2.1 Water Management

Adit closure and mine water distribution

The Proposed Action would seal all mine openings against entry by backfilling with mine development rock or with material obtained during regrading of the portal areas. Backfill would be placed from the adit opening back 30 feet into the adits and tight to the roof. Rock remaining after adit plugging would be graded against the side of the slope to form a wedge. Two concrete non-hydraulic plugs would be constructed in the Service and Conveyor adits to funnel water into the collection pipe for conveyance to the decant ponds. No access to this pipe intake would be provided. No concrete plugs are proposed for the remaining adits.

Under the Proposed Action, the two tailings pipelines would be retained to convey water from the mine site to the decant ponds. Once the mine water is of sufficient quality for direct discharge to Stanley Creek, the portions of the tailings pipelines that are buried less than three feet deep would be removed. In the event that the pipeline in use needs repair, water would be diverted through the other pipeline until the first pipeline is repaired or replaced.

Two separate stream channels would be constructed across the mill pad and down the fill slope. Channels would be armored with coarse rock sides to provide stability in 100-year, 24 hour storms. An energy dissipation basin would be created at the toe of the fill slope.

Drainage from the tailings impoundment would continue to the decant ponds and would not be directed to a natural drainage.

Water treatment and disposal

The Proposed Action would route mine pool water through the tailings pipelines to the decant ponds until natural attenuation processes remove nitrogen and copper compounds to an acceptable background quality. The Proposed Action would also continue to use the toe ponds to capture seepage and embankment runoff. After reclamation, snowmelt and runoff from the toe ponds would be pumped to the impoundment to supply irrigation water for the newly-reclaimed surface, if needed, or directly to the decant ponds.

Groundwater quality

The Proposed Action includes continued use of the decant water disposal system to passively and effectively achieve metal attenuation in the mine water. The monitoring plan would include groundwater monitoring to evaluate potential sources of groundwater seepage from the mine as it floods.

Surface water quality

The Proposed Action water quality monitoring plan includes both annual macroinvertebrate monitoring and water quality and flow monitoring three times per year. This water quality monitoring program would continue under the Proposed Action until such time as the Agencies agree that monitoring is no longer necessary. The surface water quality monitoring sites that would be sampled are the same sites as those identified under the No Action Alternative.

The Proposed Action would also retain the toe ponds as permanent features to provide wildlife and wetlands habitat. After operations have ceased, the toe ponds would be connected by inter-pond channels. Although no discharge from the toe ponds is expected, an armored outfall would nonetheless be installed to protect against erosion. No channel to Lake Creek would be constructed.

Storm water runoff would continue to be directed to the decant ponds and the tailings would be contoured to maintain the general flow direction toward the decant ponds.

Long-term monitoring of water quality

The Proposed Action long-term surface and groundwater quality monitoring plan is the same as the No Action Alternative plan.

ES.6.2.2 Reclamation

Reclamation materials

As necessary, all reclamation materials would have chemical fertilizers added to promote successful revegetation. The Proposed Action would not add organic matter to any reclamation materials.

The Proposed Action would leave the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to provide wildlife and wetlands habitat where they would act as a berm to maintain the toe ponds and to minimize the potential for sediment to reach Lake Creek. Reclamation materials for the tailings impoundment surface would be obtained from the borrow sites which are located east of the impoundment. The tailings facility surface would be covered with an average of 18 inches of growth medium.

The Proposed Action would cover development rock at the portal patios with a 12-inch layer of a finer-grained growth medium from local borrow sources to promote revegetation. However, the Proposed Action does not directly identify potential local borrow source locations.

Under the Proposed Action, the tailings embankment would be inspected annually. This geotechnical monitoring would continue until Troy Mine, Inc. and the Agencies agree to discontinue it.

Subsidence

Subsidence was not addressed as part of the Proposed Action.

Revegetation

Several different plant species mixes would be developed and vegetation types would be applied based on pre-mine occurrence, establishment potential, growth characteristics, soil stabilization qualities, commercial availability, experience from on-site tests, and post-mine land use objectives. Native species would be emphasized and noxious weed-free seed would be used. A wetland mix would be provided for designated areas. Annual ryegrass would be added to forest mixes to provide initial rapid stabilization.

A lower elevation forest mix would be seeded over the majority of the tailings surface, with the addition of some grassland and wetland mix. An upper elevation forest mix would be applied to the portal patios and the mill site office and shop area. Smaller disturbed areas would be planted with a grassland mix and would rely on natural establishment of woody species.

Under the Proposed Action, the borrow sites would be reclaimed after completion of all excavation activities. Impoundment-area borrow sites would be planted with the lower elevation forest species mix and the USFS borrow site would be revegetated with plant species typical of upper elevation forest types.

Fertilizer would be applied except within 200 feet of a perennial stream; mulching would be applied to slopes steeper than 20% with less than 50% coarse fragments. Irrigation may be used during the first season to ensure initial stand development (except for slopes steeper than 10% or upper elevation sites). The operational irrigation system would be used under gravity pressure to irrigate during the first growing season so that pumps would not be needed.

Under the Proposed Action, monitoring of revegetation would occur during the pre-closure and closure phases of mine operation. If poor vegetation growth is noted, additional site remediation would occur.

Similar to the No Action Alternative, the approved noxious weed control plan would continue to be implemented and chemical weed control may continue as needed.

Best Management Practices (BMPs) and irrigation would be used as needed to suppress dust until vegetation is established.

Infrastructure

The Proposed Action would rip asphalt from parking areas and bury it on site with a minimum of three feet of cover material. The buildings would be demolished and materials such as concrete, metal, glass, plastic, and wood would be buried on-site with a minimum of three feet of cover material. Fuel, water, and other tanks would be removed from the site.

Under the Proposed Action, underground equipment would be salvaged if possible. If a salvage market cannot be found, this equipment would be cleaned, all fluids would be removed, and the equipment would be abandoned in place.

The Revised Reclamation Plan states that any existing USFS roads would remain in place per USFS requirements. The Agencies interpret this requirement to mean that no roads are proposed for reclamation under the Proposed Action. The gate would remain in place at the mill site limiting access to non-motorized modes.

The existing storm water collection system would remain in place during the entire building demolition phase, with additional BMPs employed (such as silt fences to control erosion and protect surface water from runoff). The final grading plan would use diversion ditches, culverts, velocity control structures, and riprap in high runoff areas to reduce the potential for sedimentation in Stanley Creek.

All surface pipelines would eventually be removed and salvaged. The two operational 8-inch steel tailings pipelines would be used in succession to pipe mine water to the tailings facility until they wear out or until water quality improves enough to permit discharge into Stanley Creek. Once the pipelines are no longer needed, any sections that are buried less than three feet deep would be removed.

The main power line is the property of Northern Lights Inc. which would have the final decision on removal or preservation of all or portions of the 115-kV power line.

Topography

Slopes of the portal patios would be regraded by pulling the edges up and filling against the cut slope/roadway. Flat areas would be covered with 12 inches of growth medium. The mill site and office and shop areas would be regraded similar to the No Action Alternative except that some demolition debris would be buried on site.

The tailings embankment would be treated in the same manner as under the No Action Alternative. The toe ponds would be connected by inter-pond channels with an armored outfall. Once ore milling has ceased, the tailings impoundment surface is expected to slope to the east in a manner that allows surface water to flow to the eastern edge of the impoundment and into the decant ponds, where it would infiltrate and recharge groundwater. Therefore, no surface regrading would occur under the Proposed Action.

Impoundment-area borrow sites would be graded to reduce slopes to 2H:1V and to establish upper slope diversion ditches. The USFS borrow site would be regraded to blend in with the surrounding topography.

When mine water is no longer routed to the tailings facility, the decant ponds would be regraded to form one shallow depression which would be able to capture runoff from the tailings facility surface and to prevent surface water runoff from leaving the impoundment.

ES.6.3 Agency-Mitigated Alternative

The Agency-Mitigated Alternative is based upon the Proposed Action, but includes additional mitigation measures and monitoring requirements that address major issues identified during the earlier scoping and Interdisciplinary Team (IDT) review process.

ES.6.3.1 Water Management

Adit closure and mine water distribution

The Agency-Mitigated Alternative would plug the South Adit with development rock for approximately 130 feet into the adit (100 feet farther than the Proposed Action). Concrete intake structures would be installed in both the Service and Conveyor adits to capture mine water and to funnel it to the collection pipelines. Closure devices would be installed to prevent unauthorized public access to the Service and Conveyor adits and to allow for periodic cleanout of the intake structures.

A new, buried, mine water pipeline with an automatic leak detection system would replace the two existing 8-inch surface tailings pipelines. The original 10-inch reclaim water line would remain in place for use as an emergency water conveyance line and it also would be retrofitted with a leak detection system. The new pipeline would be buried or double-lined at stream crossings to minimize risk to surface and groundwater systems. In the unlikely event that the pipeline capacity of both lines is exceeded, mine water would flow over the concrete intake structures in the Service and Conveyor adits and would pass through the rock backfill.

A channel would be constructed from the Service and Conveyor adits to the mill site stream channels for emergency overflow from the adits in case the design capacities are ever exceeded. At the mill site and office and shop areas, only one stream channel would be constructed (rather than two under the Proposed Action). The channel would be lined with an impervious liner and rock used in the channel would be sized for the 100-year flow and would not include development rock.

Should mine water be of sufficient quality for direct discharge to surface water without treatment, it would be rerouted to a designed channel to discharge to Stanley Creek. At that time, both the new mine water and the old reclaim pipelines buried less than three feet deep would be removed, and the pipeline corridor and decant pond would be reclaimed.

Water treatment and disposal

Under the Agency-Mitigated Alternative, the ponds would be maintained as deep ponds in order to maintain geochemical functions that facilitate metals attenuation. A berm would be created to prevent storm water runoff from the tailings impoundment surface from draining directly to the decant ponds.

Groundwater quality

The Agency-Mitigated Alternative would be the same as the Proposed Action and continue the seepage pumping activities at the toe ponds until water quality standards are met. Any monitoring wells would be plugged and abandoned per ARM 36.21.810.

Surface water quality

There would be additional monitoring of seeps and springs at the mine during closure to verify whether state water quality standards have been met.

Long-term monitoring of water quality

In addition to the water quality monitoring described for the Proposed Action, the Agency-Mitigated Alternative would include post-closure water quality monitoring for a minimum of five years after mine water discharge actually commences. One additional surface water monitoring site would be added on upper Stanley Creek and four additional monitoring wells in the vicinity of the decant ponds would be added to verify that geochemical conditions in the area of mine water discharge are maintained.

ES.6.3.2 Reclamation

Reclamation materials

The Agency-Mitigated Alternative would use the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to cover the tailings facility. The lowest portion of the vegetated outer slopes of the stockpile would be maintained to minimize water runoff and to prevent sediment from leaving the majority of the disturbed stockpile surface. A field review of existing reclamation would be conducted to determine if additional soil would need to be spread on the embankment face and benches where soil is thin and revegetation is not adequate.

At the mill site, the Agency-Mitigated Alternative growth medium soil would be the same as in the Proposed Action, but the USFS borrow area material would not be used because of the presence of rush skeletonweed. Both the North and South portal patios would be covered with growth medium from the mine and mill areas.

Growth material would be amended with an agency-approved, wood-based, organic amendment to raise the organic matter content to achieve 1,100 lbs of nitrogen per acre. At the tailings impoundment, this organic amendment would be tilled in to a depth of six inches and at the mine and mill site it would be tilled into the top 12 inches of reclamation material.

Growth medium would be placed on the tailings impoundment in one lift to prevent compaction. All growth media placed for reclamation would be ripped to loosen soil before seeding takes place.

Geotechnical monitoring of the tailings embankment would be conducted by a qualified professional engineer for a minimum of five years after reclamation is completed.

Subsidence

The existing surface subsidence feature that has not achieved a level of stability and utility comparable to the pre-disturbance condition would be reclaimed prior to mine closure. The reclamation bond would be increased to address the possibility of future subsidence on steep terrain. Annual inspections would be conducted to identify new surface subsidence features.

Revegetation

Species mixes would be adjusted to account for site-specific conditions as proposed under the Proposed Action. However, a wetland mix would not be used on the tailings impoundment and trees would be planted there as described in the No Action Alternative. Seed sources for native plant species would be

from northwestern Montana to the extent that these species are commercially available at the time of reclamation. Chemical fertilizers would not be used under the Agency-Mitigated Alternative.

The Agencies would perform a field review of previously reclaimed areas to determine if areas need additional cover materials, revegetation, or reseeding.

Noxious weeds would be controlled in conformance with the approved weed control plan.

Revegetated areas would be monitored until the requirements for bond release are met. Monitoring would also continue until vegetation is sufficiently established to maintain air quality.

Infrastructure

Asphalt from the parking lots and other paved areas would be crushed and used for road gravel on NFSR 4626 or hauled to an approved landfill off NFSL. All demolition materials, whether originating above or below ground, would be disposed of off NFSL in appropriate disposal areas to comply with the Montana Solid Waste Act. Underground equipment would be removed or abandoned in place as under the Proposed Action except that any equipment on NFSL would be removed.

Roads would either be maintained to minimize sediment delivery to surface waters or they would be treated per KNF specifications. Specific road treatments by road segment are described in the Draft EIS.

Water diversion culverts at the mill site would have both ends plugged with concrete, and culverts under roads would be left in place.

Topography

Portal patios would be regraded similar to the Proposed Action, but all growth medium for the mine and mill area would be salvaged from the mill site fill or from the borrow area east of the impoundment. All demolition debris would be disposed of off NFSL in appropriate disposal areas.

All drainage channels would be constructed from imported non-mineralized rock rather than from mine development rock to minimize the potential for metal leaching. Alignment of the larger drainage channel would be down the angle-of-repose mill fill slope. A third channel would be designed from the Service and Conveyor adits to connect with the mill site drainage channels for overflow from the adits if the design capacities are ever exceeded.

A qualified engineer would annually monitor and verify the stability of the embankment for a minimum of five years after reclamation is completed. All eroded or bare areas on the embankment would be repaired by spreading 12 inches of the stockpiled growth medium. The toe ponds would be treated as under the Proposed Action except that non-native fish species may be removed.

Grading of borrow sites and decant ponds would be as described in the Proposed Alternative.

ES.7 Environmental Consequences

The following sections provide a summary of the effects of implementing each alternative. Information is focused on activities and effects where different levels of effects can be distinguished between alternatives. Detailed effects analyses for each alternative are found in Chapter 3 of the Draft EIS.

Reclamation activities were found to have minimal to no effect on several of the resource areas analyzed and there were minimal differences between the potential effects of each alternative. These resource areas include air quality, cultural resources affiliated with tribal groups, traditional cultural properties, historic resources, land use, recreation, socioeconomics, sound, and visual scenery. Many of these same resource areas would experience a net positive benefit from reclamation over the long-term, including air quality, land use, recreation, socioeconomics, sound, and visual scenery. These resource areas are not discussed further in this summary and a more detailed description of potential effects is found in Chapter 3 of the Draft EIS.

Resource areas where there could be potentially substantial impacts under one or more alternatives include fish, geology, hydrology, reclamation materials, transportation, vegetation, and wildlife. The differences in potential effects between alternatives for these resource areas are described in the sections below. Potentially substantial impacts are summarized in Table ES-1.

ES.7.1 Fish

Potential impacts on fish could occur from sediment delivery to creeks and from water quality impacts.

The No Action Alternative and the Agency-Mitigated Alternative would temporarily increase sediment delivery to Stanley, Ross, and Lake creeks during reclamation activities but would reduce sediment loads and improve fish habitat over the long-term through road treatment. Sediment increases in Ross and Lake creeks would be small relative to existing sediment loads and would not result in measurable effects to cutthroat or bull trout habitat or populations**.** The Agency-Mitigated Alternative would introduce the smallest amount of sediment to stream channels due to design features and mitigation measures such as timing restrictions within Riparian Habitat Conservation Area (RHCAs).

The Proposed Action would deliver the greatest amount of sediment to streams because roads would not receive treatment under this alternative. Any additional sediment from these sources would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact water quality for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment.

The No Action Alternative would discharge mine water directly to Stanley Creek that could exceed current surface water quality standards and could potentially impact macroinvertebrate, tailed frog, and brook trout abundance. Both the Proposed Action and the Agency-Mitigated Alternative would route mine water discharge to the decant ponds where natural attenuation mechanisms would provide long-term water quality treatment. The Proposed Action would use the existing tailings pipelines which are 30 years old. These pipelines have the potential to break allowing a large volume of adit water and sediment to reach Stanley Creek and/or Lake Creek until the pipeline could be shut off and repaired.

The Agency-Mitigated Alternative would mitigate this potential effect by constructing a new pipeline with an automatic leak detection system and would retain the existing buried line as a backup system. The Agency-Mitigated Alternative would include long-term maintenance of the water treatment/management system and monitoring of seeps and springs to detect potential water quality issues in a timely manner. The Agency-Mitigated Alternative would avoid potential surface water impacts by using only rock with little or no potential for near-neutral metal leaching in reconstructed stream channels.

ES.7.2 Geology

Geology effects include consideration of how the geochemical composition of the geologic materials would affect revegetation success, mitigation for potential subsidence events, and effects of reclamation on topography.

In all three reclamation alternatives, the geology and geochemical composition would have minimal impact on revegetation success. There are some differences between alternatives in the selection of materials for reclamation in different parts of the project area. Under the Agency-Mitigated Alternative, no additional measures would be required to mitigate geochemical impacts to reclamation success. The use of the rocky glacial and the lacustrine and volcanic ash-derived soils as growth media would minimize root contact with mined materials. This would effectively minimize the potential effects of plant uptake of metals from the development rock and tailings.

After mine closure, another subsidence event could occur regardless of the alternative selected. However, only the Agency-Mitigated Alternative includes an adequate range of practicable mitigation measures to address potential subsidence events.

Similarly, all three alternatives would provide a net positive effect to local topography through increased soil stability, erosion resistance, and storm water control. Regrading would not return the mine area or the tailings impoundment area to pre-mine conditions, but revegetation would soften the man-made appearance. The portal patio slopes would resemble talus slopes, and the tailings impoundment would resemble a terrace above Lake Creek. The Agency-Mitigated Alternative would use the most appropriate technology currently available including engineering and reclamation practices that have been proven effective to stabilize soils, minimize erosion, and to limit infiltration into mined materials containing metals.

ES.7.3 Hydrology

The No Action Alternative would not comply with the Federal Clean Water Act, Montana Water Quality Act, USFS policy, or with the Kootenai National Forest Plan because untreated mine water that would exceed water quality standards would be discharged to surface water. Moreover, moderate to high sediment delivery is likely from the mill site, mine portals, and from the tailings impoundment following the proposed reclamation.

In contrast, mine water disposal under either the Proposed Action or the Agency-Mitigated Alternative would reduce potential water quality impacts to Stanley Creek and to upper Lake Creek. Under both the

Proposed Action and the Agency-Mitigated Alternative, the mine discharge would be routed to the decant ponds for treatment. At the decant ponds, the water would infiltrate and be treated by natural attenuation mechanisms along the groundwater flow path to reduce concentrations of constituents of concern to levels that would meet water quality standards. There is a greater risk of short-term water quality violations under the Proposed Action because of the higher risk of accidental discharge of mine water from failure of the tailings pipeline to Stanley or Lake creeks. The likelihood of surface water quality impacts would be further reduced under the Agency-Mitigated Alternative by installing a new buried mine water pipeline with a leak detection and backup system for mine water transport.

Stanley and Lake creeks have been listed on the TMDL 303d list as impaired streams. Probable causes of impairment of Stanley Creek are copper and nutrients. Probable causes of impairment of Lake Creek are nutrients, sediment, and physical substrate habitat alterations. Because nitrate concentrations would decrease after blasting ceases, closure and reclamation of the mine would reduce nutrient loading to surface water under all alternatives. After mine closure, there would be reduced risk of spills of mine tailings into surface water under all alternatives. The No Action Alternative would result in increased copper loading from mine water discharge to Stanley Creek and would not accomplish the goals of the TMDL program. Both the Proposed Action and the Agency-Mitigated Alternative would reduce the potential for loading of copper to Stanley Creek.

Reclamation of mine roads on NFSL under the No Action and Agency-Mitigated alternatives would reduce sedimentation and siltation in Lake Creek over the long-term. The Proposed Action would not reduce sedimentation and siltation in Lake Creek over the long-term because it would not treat unneeded roads. Under the Proposed Action, sediment would also originate from stream erosion across the mill site. Any additional sediment from untreated roads and stream erosion across the mill site would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact beneficial uses for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment.

ES.7.4 Reclamation Materials

All three alternatives would provide reclamation of disturbed sites. The growth medium replacement plans for the tailings impoundment under the No Action and Agency-Mitigated alternatives would produce the best long-term results in terms of soil quality and plant productivity. The necessary volume of soil already exists in the soil stockpiles, and the glacial outwash borrow materials would not be needed under either of these alternatives. No additional disturbance would occur in the glacial outwash borrow areas under these two alternatives. The Agency-Mitigated Alternative would use BMPs not included in the No Action Alternative to minimize potential impacts of erosion to Lake Creek and to the toe ponds that could possibly result from use of stockpiled materials. Under the No Action Alternative there may still be issues with erosion of fine-grained soils that would not be stable on slopes over eight percent in the mine and mill area.

The No Action Alternative and the Proposed Action would use chemical fertilizers as needed to improve productivity. The Agency-Mitigated Alternative would use organic, wood-based amendments to improve the nitrogen content of the growth media. The Agency-Mitigated Alternative would also

require appropriate soil testing to identify other amendments, such as organic fertilizer, that may be needed to increase soil quality and revegetation success.

The MMRA requires the reclamation of all disturbed lands to comparable stability and utility as that of adjacent lands. The No Action and Agency-Mitigated alternatives would reclaim all mining lands to comparable stability and utility; however, the Agency-Mitigated Alternative would achieve these goals more effectively and would use the soil materials that were stockpiled prior to construction of the tailings impoundment. The Proposed Action would not produce comparable utility on the reclaimed tailings impoundment.

ES.7.5 Transportation

Under all three alternatives there would be a substantial reduction in traffic after reclamation activities are completed. This reduction in traffic would reduce road maintenance costs on local road networks.

The Proposed Action maintains the existing road system and related road maintenance costs. The No Action and Agency-Mitigated alternatives implement BMPs on 19.2 miles of road needed for long-term access (includes stabilization for intermittent stored service) and decommission 6.5 miles of unneeded road, thereby reducing long-term road maintenance costs as compared to the Proposed Action. The Agency-Mitigated Alternative further reduces long-term road maintenance costs by replacing the 6 miles of paved surface on NFSR 4626 with gravel.

ES.7.6 Vegetation

There would be little new disturbance from implementing any of the reclamation alternatives. In general, all three alternatives would revegetate areas that have been disturbed for over 30 years. Disturbed lands would be covered with a growth medium to promote vegetation and would be reseeded or planted, thereby returning the land to a more natural, mostly vegetated state. Under all three alternatives, most of the site would eventually become reforested, but the diverse native plant communities that were originally present would never fully re-establish. The loss of many native species would limit wildlife habitat on public and private lands for some species, and it would take several decades for a forest-dominated habitat to develop on reclaimed lands.

Potential issues and differences between alternatives with respect to vegetation include the seed and plant mixes proposed, the use of soil amendments to promote plant growth, the use of various borrow materials that have differing amounts of noxious weed seed, and the treatment of invasive, noxious weeds.

The No Action Alternative proposes one seed and plant mix that would be used on all disturbed sites regardless of elevation. This mix includes non-native grasses and legumes and because the No Action Alternative includes planting of non-native species, it would not comply with the Forest Service Northern Region Native Plant Policy. The No Action Alternative would not meet current standards for public lands, and thus would be considered not feasible as far as revegetation is concerned.

The Proposed Action includes five different seed/planting mixtures of native grasses, legumes, shrubs, and trees proposed for site-specific use on the basis of pre-mine species occurrence, establishment potential, growth characteristics, borrow stabilization qualities, commercial availability, experience gained from previously completed reclamation activities, and post-mine land use objectives. Seed and plant mixes would be used with consideration for differences in plant communities based on elevation. Under the Agency-Mitigated Alternative, these seed and plant mixes would be required to use seed sources native to northwestern Montana.

Both the No Action Alternative and the Proposed Action would use chemical fertilizers to promote plant growth. The Agency-Mitigated Alternative adds an agency-approved, wood-based, organic amendment in the top six inches of reclamation materials at the tailings impoundment, and in the top 12 inches of reclamation materials at the mine portals, and mill site. Approximately 1,100 lbs/acre of organic nitrogen would be added to the growth medium in this fashion.

Use of the USFS borrow source (which contains rush skeletonweed, a new invader weed species) under both the No Action Alternative and the Proposed Action would not comply with the KNF noxious weed MOU with Lincoln County. The No Action Alternative would use the lacustrine and volcanic ash-derived soil materials from near the tailings impoundment to reclaim the mine and mill areas. However, another new invader species, meadow knapweed, is found in those materials. Use of these reclamation materials on NFSL under the No Action Alternative would not comply with the KNF noxious weed MOU with Lincoln County.

The Agency-Mitigated Alternative would better comply with the regulatory framework because it would not use the USFS borrow area containing rush skeletonweed and would limit the use of lacustrine and volcanic ash-derived soil material containing meadow knapweed to private lands.

ES.7.7 Wildlife

There are no differences between the three alternatives and no substantial impacts for the following wildlife species:

- Threatened or Endangered Species: Canada lynx, gray wolf
- Sensitive Species: bald eagle, black-backed woodpecker, Coeur d'Alene salamander, common loon, fisher, flammulated owl, harlequin duck, peregrine falcon, Townsend's big-eared bat, wolverine
- Management Indicator Species: elk, mountain goat, pileated woodpecker
- Migratory birds

There are substantial differences between the alternatives with respect to grizzly bear and western toad.

The No Action and Agency-Mitigated Alternatives would reclaim most roads, which would improve habitat conditions for grizzly bear. The Agency-Mitigated Alternative includes seasonal restrictions on road reclamation work that could further minimize effects on grizzly bear. The Proposed Action does

not include road reclamation, although because it would not build or open roads to motorized traffic it would maintain current road densities.

The No Action Alternative includes sweet clover (*Melilotus* spp.) in the seed mix which could create human-grizzly conflicts in areas where it is planted because it attracts grizzly bears. The No Action Alternative, if approved today, would not be in compliance with ESA because it creates human grizzly conflicts. Both the Proposed Action and the Agency-Mitigated Alternative would use native seed mixes for revegetation and neither alternative would use sweet clover.

The No Action Alternative and Proposed Action could adversely affect western toad individuals and breeding/metamorphosis habitat in the toe ponds at the tailings impoundment area during reclamation material excavation and by alterations to the toe ponds. Agency-Mitigated Alternative includes a variety of mitigation measures to avoid and minimize these potential impacts.

Table ES-1. Potentially Substantial Effects by Alternative

	No Action Alternative	**Proposed Action**	**Agency-Mitigated Alternative**
Fish	Alternative would result in potential water quality impacts from mine water discharge to Stanley Creek. Road reclamation would minimize potential sediment delivery to streams over the long-term.	Sediment delivery quantities to streams would continue because road reclamation would not occur; potential water quality and erosion impacts from potential breakage of tailings pipelines carrying mine water discharges.	Additional mitigation measures and monitoring would minimize potential for water quality violations (see ES.6.1 and ES.6.3). Road reclamation would minimize sediment delivery to steams over the long-term.
Geology	Alternative does not address subsidence.	Subsidence measures would not be adequate.	Subsidence effects would be mitigated.
Hydrology	Untreated mine water would be discharged to surface water and would violate water quality standards.	Alternative poses a high risk of short-term water quality violations because of the higher risk of accidental discharge of mine water from the tailings pipeline to Stanley or Lake creeks.	Additional mitigation measures and monitoring would minimize potential for water quality violations (see ES.6.3).

	No Action Alternative	Proposed Action	Agency-Mitigated Alternative
Reclamation Materials	Use of fine-grained soils that would not be stable on slopes over eight percent in the mine and mill area would result in erosion.	Alternative would not result in comparable utility on the reclaimed tailings impoundment.	Alternative would use the soil materials that were stockpiled prior to construction of the tailings impoundment and would include use of organic, wood-based amendments. Materials would be applied appropriately depending on slope and grain size (*e.g.* fine-grained materials on flatter areas, coarser grained materials on steeper slopes.)
Transportation	Alternative would reclaim and stabilize roads.	Alternative maintains the existing road system and related road maintenance costs.	Alternative would reclaim and stabilize roads. Road maintenance costs on NFSR 4626 would be further reduced compared to other alternatives.
Vegetation	Plant species mix proposed includes non-native species including sweet clover. Alternative would use the USFS borrow source which contains rush skeletonweed. The lacustrine and volcanic ash-derived soil materials from near the tailings impoundment would be used to reclaim the mine and mill areas, spreading meadow knapweed to these areas. Alternative would not comply with noxious weed and native species policies.	Alternative would use the USFS borrow source (which contains rush skeletonweed) and would not comply with noxious weed and native species policies.	The spread of noxious weeds would be minimized by restricting the use of the USFS borrow site and limiting use of lacustrine and volcanic ash-derived soils to the tailings impoundment area. Seed sources for native plant species would be from northwestern MT, if available at the time of reclamation. Alternative would comply with noxious weed and native species policies.

	No Action Alternative	Proposed Action	Agency-Mitigated Alternative
Wildlife	Alternative includes sweet clover in the seed mix which could create human-grizzly conflicts in areas where it is planted. The No Action Alternative, if approved today, would not be in compliance with ESA. Western toad habitat would be potentially affected by reclamation material excavation and alterations to the toe ponds.	Alternative would not reclaim roads and so would not result in an improvement in grizzly habitat parameters. Western toad habitat would be potentially affected by reclamation material excavation and alterations to the toe ponds.	Potential impacts to grizzly bear would be mitigated by requiring native plant in the revegetation mixes and road reclamation. Western toad habitat effects would be minimized through appropriate BMPs.

United States Department of Agriculture | **Forest Service** | **Kootenai National Forest** | **31374 U.S. Highway 2 Libby, MT 59923**

Montana Department of Environmental Quality | **PO Box 200901 Helena, MT 59620-0901**

File Code: 2810/1950
May 4, 2011

Dear Interested Party,

The Kootenai National Forest (KNF) and the Montana Department of Environmental Quality (DEQ) have completed the Troy Mine Revised Reclamation Plan Draft Environmental Impact Statement (EIS). The project proposes to reclaim disturbed lands associated with the Troy Mine, located about 15 miles south of Troy, Montana, near the Cabinet Mountains of northwestern Montana. Troy Mine, Inc. has submitted a revised reclamation plan for approval that updates the approved 1978 plan in anticipation of future mine reclamation. Either a Summary or the full Draft EIS is enclosed for your review and comment.

The Troy Mine Revised Reclamation Plan Draft EIS describes the land, people, and resources potentially affected by the proposed revised reclamation activities. The purpose of the proposed revision is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. Alternatives considered in detail include a No Action Alternative (the previously approved 1978 reclamation plan), the Proposed Action (Troy Mine, Inc.'s Revised Reclamation Plan), and an Agency-Mitigated Alternative (the Agencies' preferred alternative). The Draft EIS analyzes Troy Mine, Inc.'s revised plan as well as agency-proposed modifications (e.g., adit closure, mine water management, water treatment and monitoring, reclamation cover requirements, subsidence monitoring, debris disposal, and road closures). The major state and federal actions include approval of a reclamation plan and any necessary permits to implement the reclamation activities, including construction and long-term monitoring.

Your comments will be invaluable to the agencies as they prepare the Final EIS and Record of Decision (ROD). Written comments must be postmarked, e-mailed, faxed or otherwise submitted by the end of the 45th calendar day following the publication of the Notice of Availability (NOA) of the Draft EIS in the *Federal Register*, which will be on or about May 20, 2011. The date of publication and the end of the comment period, along with an electronic version of the Draft EIS will also be available on the internet at: http://www.fs.usda.gov/goto/kootenai/projects and http://deq.mt.gov/eis.mcpx.

Written comments should be submitted to either the KNF or the DEQ. Comments can be submitted via postal mail, e-mail, or fax and addressed to:

Bobbie Lacklen
Kootenai National Forest
31374 U.S. 2
Libby, MT 59923-3022
TroyMineReclamation@fs.fed.us

Emily Corsi
Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901
DEQTroyMine@mt.gov

Comments may be faxed to (406) 283-7709 (KNF) or 406-444-4386 (DEQ Director's Office), or hand-delivered to the KNF Supervisor's Office and DEQ Director's Office between the hours of 8:00 a.m. and 4:30 p.m. Hand delivered comments must be time and date imprinted by the respective agency by the close of business on the 45th calendar day following publication of the NOA in the *Federal Register*.

One public hearing is scheduled to provide a forum for public comment. The hearing will be June 8, 2011 at the Troy High School Auditorium, 116 East Missoula Avenue, Troy, MT at 7 pm. An open house will be held at 6 pm, before the hearing, where you may ask technical and procedural questions of agency personnel. Both written and oral comments may be submitted at the hearing.

As outlined in 36 CFR 215.13, only those who submit timely comments will be accepted by the Forest Service as appellants following the release of the Troy Mine Revised Reclamation Plan Final EIS and Record of Decision. Comments must be specific to the proposed activities and area being analyzed. Comments should include: (1) name, address, telephone number, and organization represented, if any; (2) title of the document on which the comment is being submitted; (3) specific facts and supporting reasons for the decision makers to consider; and (4) signatures.

All comments become part of the public record associated with this project, and are available for public review, along with the name(s) of the commenter(s). Comments submitted anonymously will be accepted and considered; however, those who submit anonymous comments will not have standing to appeal the subsequent decision under 36 CFR 215.12.

Thank you for taking time to be involved with the environmental review process for the Troy Mine Revised Reclamation Plan. For more information or to request a copy of the Draft EIS, please contact one of the project coordinators, Bobbie Lacklen or Emily Corsi.

Sincerely,

Paul Bradford, Forest Supervisor
Kootenai National Forest

Richard H. Opper, Director
Montana Department of Environmental Quality

enclosure

Appendix A
Scoping Report

Troy Mine Revised Reclamation Plan
Environmental Assessment

Scoping Report

March 10, 2008

Contents

Section 1 Introduction

Section 2 Background
2.1 Troy Mine History 2
2.2 Project Management Plan 4
2.3 Public Involvement Process 4

Section 3 Implementation of the Scoping Process
3.1 Press Release 5
3.2 Scoping Document 5
3.3 Open House and Public Meeting 6

Section 4 Results of the Scoping Process
4.1 Issues Raised During the Scoping Process 7
4.1.1 Water Quality 7
4.1.2 Cover Source Materials 8
4.1.3 Impoundment Stability 8
4.1.4 Buried Drums 8
4.1.5 Subsidence 8
4.1.6 Other 8
4.2 Issues Considered But Not Recommended For Further Evaluation 9
4.3 Issues to be Considered in the EA 10
Mine Water 10
Groundwater Protection 10
Long Term Prognosis/Monitoring 10
Water Treatment 11
Cover Source Materials 11
Impoundment Stability 11

Section 5 Identification of Data Gaps
5.1 Water Treatment Alternatives 12
5.2 Copper Attenuation Process 12
5.3 Surface Water Quality 13

Section 6 References

Appendices

Appendix A Press Release
Appendix B Scoping Document
Appendix C Mailing List for Open House/Public Meeting
Appendix D Newspaper Advertisements for Open House/Public Meeting
Appendix E Sign in Sheets for Open House/Public Meeting
Appendix F Written Comments Received During the Scoping Process

Section 1
Introduction

CDM was contracted by the Montana Department of Environmental Quality (DEQ) in October 2007 to begin the first phases of an Environmental Assessment (EA) for the proposed reclamation at the Troy Mine near Troy, Montana. The contract includes four task orders:

- Task Order 1 –Reclamation Plan Review and Public Scoping Activities
- Task Order 2 – Administrative Record and Project Management Plan
- Task Order 3 – Data Gap Analysis
- Task Order 4 – Alternatives Development, Initial Evaluations, and Environmental Assessment

Task Order 1 includes two subtasks: Review Permit and Proposed Reclamation Plan and Public Scoping and Public Input Activities. CDM has completed the first task order and is submitting this scoping report in accordance with the deliverables list provided in Task Order 1.

Public scoping is the first step in conducting an EA. It is a process for determining the scope of issues to be addressed and identifying the significant issues related to a proposed action. The scoping process helps in determining what will be reviewed in the EA and the level of analysis, in part, through the collection of written and verbal comments from the public. Scoping helps agencies identify environmental issues associated with the project and aids in the development of reasonable reclamation alternatives. It also allows effective public and stakeholder involvement prior to the submittal of the draft EA.

This report describes the results of the scoping activities conducted between October and December 2007 as part of the EA. It includes:

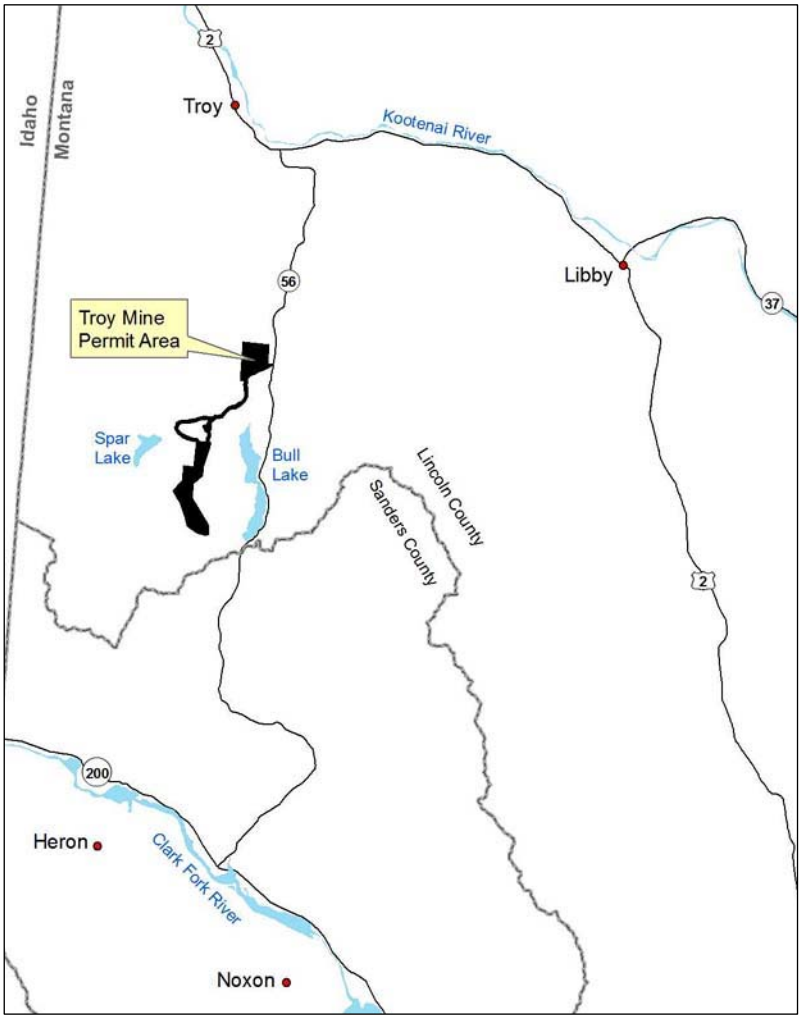
- Introduction
- Background
- Implementation of the Scoping Process
- Results of the Scoping Process
- Identification of Data Gaps

Section 2
Background

2.1 Troy Mine History

The Troy Mine is located in Lincoln County, Montana, about 15 miles south of Troy. The mine permit area covers 2,635 acres of public and private land off MT Highway 56 (see figure below). It consists of an underground mine, mill, and office facilities; tailings and water pipelines; power line; tailings impoundment; and associated support facilities.

The ASARCO, Inc. Troy Mine project was permitted in 1978 by the U.S. Forest Service (USFS) and State of Montana as a 20,000 ton-per-year underground copper/silver mine. The ore was and is mined using the "room-and-pillar method." ASARCO began full production in 1982 but put the mine on standby mode in 1993 due to depressed metal prices. During the shut-down period, ASARCO sold its interest to Sterling Mining Company, which became Revett Silver Company (Revett). Production resumed in 2005 under Genesis (a wholly owned subsidiary of Revett) and is projected to continue at least 5 years until the ore body is depleted.



The Troy Mine is now permitted and operated by Genesis. Genesis currently has posted a $10.5 million reclamation bond for the project. The reclamation bond is being updated to $12.9 million. Genesis submitted the Revised Reclamation Plan in March of 2006. The revised plan describes proposed reclamation elements for final closure of the Troy Mine following cessation of mining activities.

Over the course of mine operation, knowledge has been gained through studies, data collection, revegetation test plots, prior reclamation plan development and reviews, and bonding determinations. In addition, some conditions have changed since the 1979 planning

and permitting documents were prepared. One changed condition is the presence of toe ponds at the perimeter of the tailings facility dam. Another is the change in state water discharge standards which do not allow direct discharge of produced mine water into Stanley Creek. The Revised Reclamation Plan attempts to incorporate and address all of the above issues and changes.

The Revised Reclamation Plan addresses facility removal for many developmental and operational features including:

- Roads
- Waste rock dumps
- Mine portals
- Underground facilities
- Mill and plant site
- Soil borrow sites
- Power supply—transmission line, generators, fuel tanks, etc.
- Water supply and pump facilities
- Sewage treatment facility
- Pipelines
- Tailings impoundment
- Monitoring wells
- Fences

The Revised Reclamation Plan proposes to use concrete plugs in the service and conveyor adits. These plugs would be designed to avoid the possibility of large-scale mine discharge or overflow from one of the adits. Other water treatment options include piping the mine water discharge to the tailings decant ponds for direct groundwater discharge.

The Revised Reclamation Plan also contains reports and plans including:

- Mine Flooding Report
- Revegetation Status Report
- Assessment of Fate and Transport of Copper in Decant Pond Disposal System
- Soil Investigation Results
- Weed Control Plan
- Water Monitoring Plan
- Revegetation Plan
- Geotechnical Monitoring Plan
- Tailing Facility Stability Report
- Conceptual Portal Plug Study

In addition, a report has been prepared that discusses the cause of two surface subsidence events and potential future subsidence issues.

2.2 Project Management Plan

The project management plan serves as a guide for the Troy Mine Revised Reclamation Plan EA process. It establishes responsibilities, schedules, and procedures for the project team. It includes a description of the project team and potential cooperating agencies, contact information, project tasks, a task schedule, known data gaps, issues of concern, the public involvement strategy, a preliminary draft of the proposed action and alternatives, the format for the EA, and a description of how the Administrative Record will be compiled.

2.3 Public Involvement Process

Early attention to consensus building generally makes the project move more smoothly by ensuring that the public has an opportunity to voice their concerns and to be part of the overall decision making process. CDM and DEQ will gather public input using various components of the scoping process.

The public involvement program also includes the preparation of a scoping document to be distributed before the open house and the preparation of this scoping report. CDM will also assist DEQ in compiling important EA-related documents for an information repository. This will include fact sheets and newspaper articles, as well as copies of the draft and final EA.

Section 3
Implementation of the Scoping Process

The following scoping activities were completed between October and December 2007 as part of the scoping process for the Troy Mine Revised Reclamation Plan EA:

- Press Release
- Scoping Document
- Open House / Public Meeting

The scope of each of these elements and their implementation is discussed below. The issues identified during the scoping process are provided in Section 4.

3.1 Press Release

A press release was published by the DEQ on October 11, 2007. The press release provided notice of the scoping period for the Troy Mine Revised Reclamation Plan EA process. The press release is shown in Appendix A.

3.2 Scoping Document

A scoping document (Appendix B) was prepared and distributed prior to the open house and public meeting. The scoping document included the following topics:

- Opportunities for public involvement
- Troy Mine history
- Components of the Revised Reclamation Plan
- Initial issues of concern
- Overview of the EA process
- EA schedule and deliverables
- Sources of additional information

The scoping document was reviewed and approved by DEQ and USFS prior to being finalized. It was distributed by mail to approximately 88 individuals on the mailing list provided by DEQ. The mailing occurred on October 15, 2007. Approximately 20 individuals and 68 government organizations, elected officials, or private interest groups were included on the mailing list (Appendix C).

3.3 Open House and Public Meeting

The public meeting and open house were held at the Kootenai Senior Citizens Center in Troy, Montana on Tuesday, October 30, 2007. The public meeting began at 6:30 pm with a half-hour presentation. An open house followed the presentation and continued until 8:30 pm when the meeting was closed.

An advertisement was prepared by USFS for publication in four area newspapers: the *Western News* on October 24, 2007, the *Sanders County Ledger* on October 25, 2007, the *Daily Inter Lake* on October 21, 2007, and the *Bonner County Daily Bee* on October 24, 2007. These four ads are included in Appendix D.

The format for the public meeting was agreed upon with DEQ prior to the event. CDM started the meeting with a 20-minute presentation that introduced the EA team and discussed the scope of the EA, history of the mine, and potential remedial alternatives. Gwen Pozega of CDM led this presentation.

Seven tables, each representing a particular topic, were set up in a large meeting room. Each table was staffed by one or more CDM, AMEC, USFS, or DEQ employees. Two copies of the revised reclamation plan were available for review. Individual topic areas and their respective representatives were:

- MEPA/NEPA - Kathy Johnson (DEQ) and John Gubel (USFS)
- Engineering/Geotechnical – Charlie Freshman (DEQ) and Darrel Stordahl (CDM)
- Hydrogeology/Water Quality - Wayne Jepson (DEQ), Jim Castro (DEQ), Rebecca Ridenour (DEQ), John McKay (USFS), and Kent Whiting (CDM)
- Reclamation/Soils/Vegetation – Patrick Plantenberg (DEQ), Lisa Boettcher (DEQ), and Steve Prieve (USFS)
- Permit Amendment Process – Herb Rolfes (DEQ)
- Wildlife/Fisheries – Pat Mullen (AMEC) and John Carlson (USFS)
- Troy Mine/Genesis Inc.- Genesis Inc. Representative

Thirty-three people registered on the sign in sheet for the open house (Appendix E). Attendees were encouraged to move freely from table to table, depending upon their interests. During discussion with the technical representative at each table, notes of the discussions were recorded on a flip chart for use in summarizing the event.

Section 4
Results of the Scoping Process

The comments received during the scoping process have been summarized into major issues. Copies of the written comments are provided in Appendix F. This section presents the major issues and identifies those that will be carried forward for further evaluation in the EA. Issues that will not be carried forward were eliminated because of technical impracticability. Although issues may have been eliminated from further evaluation, they will still have an impact on the EA process because of the background information and community insight they provided.

4.1 Issues Raised During the Scoping Process

Issues raised during the scoping process are summarized by major topic area in Sections 4.1.1 through 4.1.6. The topic areas are:

- Water Quality
- Cover Source Materials
- Impoundment Stability
- Buried Drums
- Subsidence
- Other

4.1.1 Water Quality

Water quality issues and concerns identified during the scoping activities include:

- Mine Water –Will there be increased flows to the impoundment area? What are the potential impacts of increased flows on water quality, the toe ponds, etc? What is the level inside the mine that water would reach (at a "sustainable" rate) using portal plugs? Why not replicate the decant ponds at the mill site and remove the seven-plus miles of tailings pipelines?

- Groundwater Protection – How does the Reclamation Plan address long-term seepage/groundwater discharge to Lake Creek? Why is groundwater an issue at this time, after 20 years of water being diverted to the decant ponds? Sealing mine openings is not reasonable; may pose future threat of releasing contaminated water should structural failure occur. Toe ponds leak directly into Lake Creek. Discharges from the mine have begun to appear in the vicinity of Ross Creek. An MPDES permit should be required for discharge of mine water.

- Long Term Prognosis/Monitoring – What will copper concentrations be in the future? Will copper reach Lake Creek? If so, when? The monitoring proposed in the Revised Reclamation Plan is inadequate in every respect; monitoring "in perpetuity" is impossible.

- Water Treatment - Can mine water be treated in the service adit prior to discharge? Is there any treatment of discharged mine water? Several comments stated a preference for treatment water now rather than long-term (indefinitely). Perpetual discharge of polluted water is a poorly conceived idea.

4.1.2 Cover Source Materials

- The impacts would be lessened if the topsoil stockpiles at the toe ponds are not disturbed, but where would cover material come from?

- Comment to use topsoil stockpiles at toe ponds instead of disturbing a new area.

4.1.3 Impoundment Stability

- How will continued discharge of mine water affect the stability of the tailings impoundment?

- Stability of the tailings impoundment is tied to its dewatering; sinkholes and recent field reports indicate inherent instability features that should be investigated.

- Instability of the impoundment and failure of the dam may negatively impact operation of the Northern Lights dam; this should be assessed and mitigated.

4.1.4 Buried Drums

- Are the buried drums addressed in the revised Reclamation Plan?

- Will the buried drums be unearthed and sampled?

4.1.5 Subsidence

- How would hydrology be affected by future occurrences of subsidence?

- How will future occurrences of mining-related subsidence be addressed?

- A bond commensurate with the possibility of further incidents and their mitigation should be considered.

- Closure of the mine will result in a small underground lake; further faulting in the area may produce blowouts or rupture the mine plugs, causing discharges of polluted water to surface waters.

4.1.6 Other

Other issues and concerns identified during the scoping process that do not concern the other primary disciplines include:

- Request for Forest Service to require an Environmental Impact Statement, as an Environmental Assessment is not adequate to cover Genesis' proposal.

- A cash bond should be required to cover all obvious and potential problems that could be associated with reclamation and perpetual maintenance, including mandatory review at ten-year intervals.

- Request for copies of the Reclamation Plan to be placed at Heron Library, Noxon High School Library, and Libby Library.

- No reclamation other than tree planting should occur – the mine should be left open to be used as an educational resource and a tourist attraction.

- Comment stating concern regarding blowing dust from the tailings impoundment area.

- Releasing water down pipelines to tailings impoundment provides water needed for revegetation.

- Discharge of mine water to tailings impoundment would provide incentives for wise development and re-use of tailings area.

- The Northern Lights Dam at the mouth of Lake Creek traps sediment; it has been dredged twice, but no analysis of sediments has been conducted to determine extent of contamination from Troy Mine operations.

- The milling process uses iron, but occurrences of 'iron flock' have been attributed to natural processes; fate and transport of iron should be studied as carefully as copper.

- The amount of topsoil currently stockpiled is unsubstantiated, as some of the stockpile was used in creation of toe ponds, which hide violations of the Clean Water Act.

4.2 Issues Considered But Not Recommended For Further Evaluation

The scoping process has provided opportunities for the public to present concerns and issues to be considered during the EA process. Most of the technical issues raised will be carried forward for further consideration in the EA process. However, several issues were not recommended for further evaluation by consensus during the IDT meetings. These issues will be discussed and summarized in the EA, but no additional analysis is anticipated for these issues which are described below.

In December 2002 the Cabinet Resource Group (CRG) initiated a lawsuit against ASARCO and Sterling Mining Company (now Revett Silver Company) that alleged that barrels of hazardous waste were buried within the tailings impoundment during ASARCO's operation of the Troy Mine. CRG also claimed that barrels containing solvents and waste oil and grease were buried in the tailings impoundment. The allegations were never substantiated, and in July 2006, U.S. District Court Judge Donald Molloy dismissed the case without prejudice.

ASARCO has admitted to burying the drums but has also stated that the drums did not contain contaminants. The DEQ has reviewed water quality data and determined that CRG claims were not substantiated. The water quality analysis to be conducted for this EA will provide additional data to determine whether there is any merit to the claim of contamination in the buried drums.

Blowing dust from the impoundment area would only be a concern during operation of the mine. Once the mine has closed and ceases to place additional lifts of tailings in the impoundment, the area will be covered with topsoil and seeded with native plant species. The revegetated areas will be irrigated during the first growing season to ensure plant growth. Establishment of vegetation will control erosion and blowing dust.

The suggestion to leave the Troy Mine open as a tourist attraction does not meet the purpose and need for the reclamation project. Public health and safety, water quality concerns, and habitat for wildlife and threatened and endangered species would not be improved by leaving the Troy Mine open.

Subsidence has been addressed in previous technical reports. Previous occurrences of subsidence have been dealt with operationally, and a bond is in place for any future occurrences. The EA will discuss the potential environmental consequences of future occurrences, but the issue would not be included in the Reclamation Plan.

The purpose of the environmental assessment process is to determine whether significant impacts are likely to occur. The preparation of an EA for the Troy Mine Revised Reclamation Plan does not preclude the preparation of an Environmental Impact Statement (EIS). The EA will assist the agencies in identifying any potential impacts that should be considered and analyzed in more detail. Should significant impacts be identified during the EA process, an EIS will be prepared to assess the impacts, identify mitigation measures, and involve the public in resolution of adverse effects.

4.3 Issues to be Considered in the EA

Issues not dismissed for technical reasons will be addressed during the alternatives evaluation process in the EA. They are:

- Mine Water – Should hydraulic plugs be used to close adits? How much water will be held in the mine when it floods, and where will mine water drain to?

- Groundwater Protection – Will the copper attenuation process continue to function indefinitely ? Will groundwater be protected from elevated copper levels, and for how long? Will continued transmission of mine water through the tailings lines to the tailings impoundment/decant ponds cause any environmental impacts after the mine ceases operations?

- Long Term Water Quality Prognosis/Monitoring – what will copper concentrations be in the future? Will copper reach Lake Creek? If so, when? Will the toe ponds continue to drain

to Lake Creek? What are the effects to Ross Creek? How long can/should monitoring realistically be continued?

- Water Treatment - Can mine water be treated in the service adit prior to discharge? Is there any treatment of discharged mine water? Why not replicate the decant ponds at the mill site and remove the seven-plus miles of tailings pipelines? Will an MPDES permit be required and obtained?

- Cover Source Materials – Are the impacts of using the stockpiled topsoil greater than using another source of cover material?

- Impoundment stability - How will continued discharge of mine water affect the stability of the tailings impoundment? How will future placement of additional tailings lifts affect stability?

Section 5
Identification of Data Gaps

Most of the information needed to conduct the NEPA/MEPA evaluation is available from existing sources. The following information will be needed to analyze the issues and prepare the EA:

- An analysis of water treatment alternatives related to 1) mine water discharge through tailings pipelines and 2) hydraulic/non-hydraulic plugging of adits and mine flooding

- An analysis of the sustainability of the copper attenuation process

- Hydrology information, i.e., sampling data for Ross Creek and its tributaries

- A cultural resource survey for any additional borrow areas identified

5.1 Water Treatment Alternatives

Evaluation of the method of mine water discharge and its potential impacts to local hydrology and water quality will require additional studies to acquire the necessary data:

- Further study of alternative water treatment approaches, e.g., water might be treated prior to leaving the mine, allowing discharge not necessarily through the tailings pipelines; or water might be treated after exiting the mine in a series of constructed wetlands near the mill site.

- Analysis of hydraulic versus non-hydraulic plugs - Genesis initially proposed the use of hydraulic plugs in the service and conveyor adits to prevent discharge of adit water to the portal patio. This proposal has been dropped **in favor of non-hydraulic plug**s consisting of concrete and backfill from the portal patios. Water would be piped from the adit (through the plug) to the decant ponds for discharge. Non-hydraulic plugs would provide control of the flow rate of water discharging from the mine, would prevent access to the underground workings, and could potentially result in lower oxygen concentrations in the flooded mine and less oxidation of copper minerals (although reduction of oxygen concentration would be greater with hydraulic plugs).

5.2 Copper Attenuation Process

A phased technical study is proposed to evaluate the copper attenuation process. The attenuation of copper via adsorption within the upper portions of the decant pond is likely to continue for a very long time due to the low loading rate of copper onto the organic matter. The precipitation of copper minerals could continue indefinitely, provided that the geochemical conditions that allow the precipitation to occur are maintained. Should those conditions change and become less effective in the future, an additional attenuation mechanism within the aquifer may become important. An analysis will be conducted of the copper attenuation process and any additional mechanisms that can be used to prevent contamination of groundwater or Lake Creek.

5.3 Surface Water Quality

Surface water quality data will be used to evaluate the quality of water present in drainages. Additional data needs identified during the scoping process include:

- Water quality and flow rates of Ross Creek and its tributaries, which have not been routinely monitored under the operating permit, are needed to identify potential impacts from mining operations and assess mitigation measures, if necessary

- Storm water data for drainage are needed to assess impacts of mine features on quantity and quality of storm water and potential re-routing or catchment options

Data gap gathering activities will commence as the particular data are required and as the necessary funds to gather these data are available. DEQ will request water sampling data from Genesis, Inc. to expand upon the existing water quality database and to determine if additional water quality sampling data are needed.

Section 6
References

Genesis, Inc. 2005. Troy Mine Operating Permit #00093.

Genesis, Inc. 2006. Troy Mine Revised Reclamation Plan.

Appendix A
Press Release

REQUEST FOR COMMENT and NOTICE of PUBLIC MEETING
Genesis Incorporated Troy Mine Revised Reclamation Plan

USDA Forest Service, Kootenai National Forest

Three Rivers Ranger District, Troy Ranger Station
Lincoln County, Montana

Genesis, Inc. submitted a Troy Mine Revised Reclamation Plan which outlines their closure adit water management and modified reclamation proposal when the mine ceases operations in approximately six years, according to the latest estimate. The Plan describes their proposal including closure of facilities, revegetation, water management, and maintenance/monitoring. The Kootenai National Forest (KNF), and Montana Department of Environmental Quality (DEQ) are beginning the formal process of environmental analysis, and would like your input on the proposal. Your input is important to identify any concerns with the proposed activity.

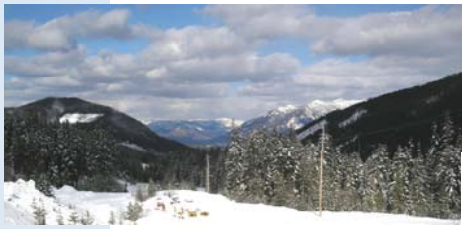
Copies of the Troy Mine Revised Reclamation Plan are available for review at the KNF Supervisors Office, 1101 Hwy 2 West, Libby, MT 59923, at the DEQ, Environmental Management Bureau, 1520 East 6th Avenue, Helena, MT 59620. Copies are also available for review at the public library in Troy, MT, and at the Three Rivers Ranger District, 1437 Hwy 2 West, Troy, MT., or on the KNF web page at the address shown below.

Comments concerning the proposed action must be postmarked by December 28, 2007, to be considered in the draft environmental document. The draft is expected by August, 2008, and the final by February, 2009. Send written comments concerning the Proposed Action to Paul Bradford, Forest Supervisor, Troy Mine Reclamation Project, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923. Send e-mail comments to: comments-northern-kootenai@fs.fed.us. All comments must contain name of commenter, postal service address, and date of comment. A copy on a computer generated CD should accompany all comments over one page in length.

For further information contact the Project Coordinators John McKay, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923, Phone (406) 283-7691, e-mail jmckay@fs.fed.us, or Kathy Johnson, DEQ, PO Box 200901, Helena, MT 59620, Phone (406) 444-1760, e-mail katjohnson@mt.gov or consult the Kootenai National Forest web page at http://www.fs.fed.us/r1/kootenai/resources/minerals/index.shtml.

An open house informational and scoping meeting will be held on Tuesday, October 30, 2007, at the Senior Citizens Center, Troy, MT, from 6:30 – 8:30 p.m.

Appendix B
Scoping Document



Troy Mine Revised Reclamation Plan Environmental Assessment

Kootenai National Forest and the Montana Department of Environmental Quality *October 2007*

Site Background

The Troy Mine is located in Lincoln County Montana, about 15 miles south of Troy. ASARCO, Inc. originally permitted the copper and silver mine in 1978, commencing full production in the fall of 1982. By 1993, ASARCO stopped production at the mine in the wake of low metals prices. Genesis, Inc. bought the mine during the shutdown period and production resumed in 2005.

In March 2006, Genesis, Inc. submitted their final revised reclamation plan which describes proposed reclamation elements for final mine closure. Closure is anticipated in five to six years, after the ore deposit runs out. The revised plan was needed as a result of new information from studies, data collection, revegetation test plots, prior reclamation plan development reviews, and bonding determinations. Changed conditions (e.g., the toe ponds at the perimeter of the tailings facility dikes) and new regulations (e.g., state water discharge standards that prohibit the direct discharge of produced mine water into Stanley Creek) were also a factor in the need for a revised plan.

DEQ and KNF are reviewing the revised reclamation plan and all of the associated information accumulated during the mine's nearly 30-year life. Through the EA process, they will analyze the impacts of implementing the reclamation plan and all of the developed alternatives.

The Troy Mine has submitted a revised plan for mine reclamation. As required by the ***Metal Mine Reclamation Act*** (MMRA), an ***Environmental Assessment*** (EA) must be prepared to ensure the actions proposed are protective of the environment.

This fact sheet provides a brief description of the mine, its history, and the proposed reclamation plan. It also discusses the purpose, scope, and schedule of the EA and describes how the public can provide general information about the project or specific comments on the plan. Sources for copies of the plan and additional information are also provided.

Open House and Public Meeting

The ***Kootenai National Forest*** (KNF) and the ***Montana Department of Environmental Quality*** (DEQ) are seeking public comments prior to preparing an EA for the Revised Reclamation Plan for the Troy Mine. Public input is important to identify any concerns with the proposed plan.

Tuesday, October 30, 2007
Senior Citizens Center in Troy
Open house - 6:30 to 7:30 pm
Public meeting - 7:30 to 8:30 pm

The open house is an opportunity for the public to chat one-on-one with technical staff about various areas (such as water quality or mine reclamation) and view maps, posters, etc. At the public meeting, DEQ and KNF will bring everyone up to date with what's going on. People with an interest in the mine are encouraged to attend these events.

DEQ will make reasonable accommodations for persons with disabilities who wish to participate in the open house. If you require accommodation, please contact Kathy Johnson at 406-444-1760.

Everyone is welcome!

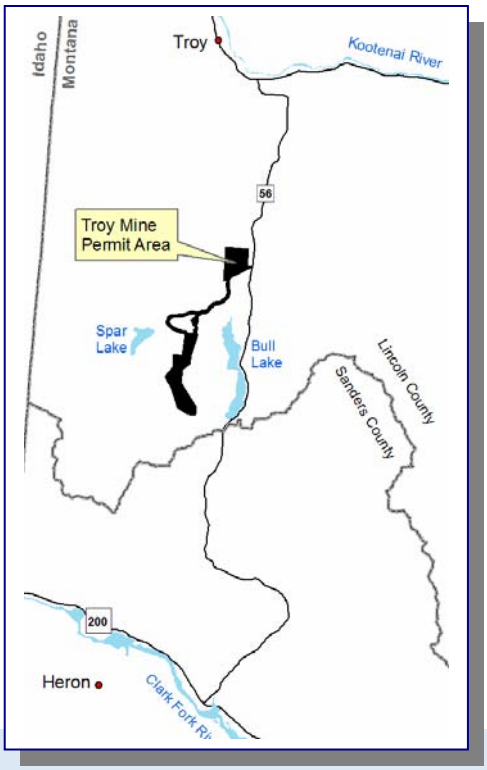
About the Troy Mine

The mine is located on 780 acres of public and private land south of Troy, Montana on US Highway 56 (see map). It consists of an underground mine, mill, and office facilities; tailings and water pipelines; power line; tailings impoundment; and associated support facilities (see pictures at right). The tailings facility and associated disturbances are on private land, and the tailings and water pipelines and the power line are on federal and private land.

Development of the underground copper/silver mine started in 1979 and production of ore concentrate started in 1981. During production, the mine produced approximately 8,500 tons/day of ore. In April 1993, ASARCO suspended mining and milling and placed the Troy Mine on care and maintenance status due to low metal prices. In November 2004, Genesis Inc. reinitiated mining which has focused on development of the East Ore Body portion of the mine.

From 1993 through 2004, the primary activities included:

- Care and maintenance of equipment and facilities
- Reclamation of portions of the tailing facility
- Evaluation of revegetation success
- Testing of methods for tailing reclamation
- Geotechnical monitoring of the tailing facility
- Monitoring of creeks and groundwater
- Initiation of fate and transport studies for mine water
- Preliminary assessment of tunnel-plugging methods
- Evaluation of water treatment methods
- Evaluation of mine flooding during pump shutdown period



What is an EA?

An EA is a detailed study that analyzes the environmental effects of a proposed action and its alternatives. It compares the impacts of the proposed action against those of “no action.” DEQ and KNF have committed to preparing an EA to determine the nature and extent of impacts to the environment that may occur with implementation of the proposed revised reclamation plan. An EA provides for a thorough investigation of the potential impacts of a proposed action and also delineates measures that may be implemented to lessen any identified impacts.

The EA has two potential outcomes. If significant impacts to the environment are identified that cannot be avoided or mitigated, an Environmental Impact Statement (EIS) will be prepared. If no significant impacts are identified, a ***Finding of No Significant Impact*** (FONSI) will be prepared that will state all of the mitigation measures identified, especially those required to make the recommended alternative environmentally acceptable.

Components of the Plan

The original reclamation plan was submitted in the mine permit application in 1978. The revised plan for reclamation submitted by Genesis, Inc. describes their proposals for closure of facilities, revegetation, water management, and maintenance/monitoring.

Modifications to the original reclamation plan include:

- Modification of the adit water management plan
- A reclamation cap for the tailings impoundment
- Identification of new soil borrow areas for the reclamation cap
- Modification of seed mixes
- Incorporation of wetlands and open ponds to be left at closure
- Incorporation of more expansive weed control and weed prevention measures
- Use of the decant ponds to capture storm water runoff from the impoundment
- Use of toe ponds to capture dike runoff and groundwater seepage

Initial Issues of Concern

DEQ and KNF have identified several potential issues of initial concern:

- Air quality – blowing dust from the tailings impoundment area
- Surface and groundwater quality – long-term treatment/disposal of discharge water and potential for groundwater contamination beneath the tailings impoundment
- Wetlands – the creation of wetlands at the tailings impoundment
- Subsidence – reclamation of any future mining-related subsidence
- Tailings impoundment stability
- Effects on fisheries and wildlife (including threatened, endangered, or sensitive species) – potential long-term impacts from water quality degradation and short-term from plan implementation
- Vegetation and noxious weeds
- Cover soil – quality, location, and available volume of sources
- Potential for buried contaminants in tailings impoundment

These issues, and any other substantive issues identified by the public or the agencies' consultants, will be addressed in the EA. **The public is encouraged to come to the open house to discuss issues or to provide comments in writing about the plan.**

The EA Process

- Conduct scoping activities to make stakeholders (the public and local, state, and federal agencies with an interest in the project) aware of the EA
- Research/analyze existing conditions in project area
- Review proposed alternative and, if needed, develop additional alternatives that more fully address the purpose
- Analyze impacts of the alternatives and develop mitigation measures to lessen or avoid them
- Prepare a draft EA and make available to the public and agencies for review and comment
- Hold a public hearing to solicit comment from stakeholders
- Review all comments and apply, where feasible and reasonable
- Provide responses to stakeholders and revise the EA as necessary to incorporate any needed changes
- If no significant impacts are identified, conclude the EA with a FONSI
- If significant impacts are identified that cannot be mitigated, prepare an EIS and a ***Record of Decision*** (ROD) to document impacts and the decisions made to minimize them

EA Schedule and Deliverables

The EA process began in October 2007 and is anticipated to take approximately 18 months to complete.

Scoping Report.....	**December 2007**
Draft EA.....	**April 2008**
Public Hearing.....	**September 2008**
Comment Period.....	**August-Sept. 2008**
Review of Comments.....	**Sept.-Nov. 2008**
Final EA.....	**February 2009**
FONSI	**March 2009**

This assumes the EA will be sufficient to analyze the environmental impacts, that no significant impacts will occur, and that an EIS will not be required.

Reclamation Plan Goals

- Re-establish wildlife habitat
- Protect groundwater quality and surface water quality in local creeks
- Protect air quality in surrounding areas
- Provide public access to Federal lands
- Protect public health and safety by removing potential hazards

Identity of back page picture: The ball mill from inside the Troy mine. Come to the meeting to find out more.

Do You Want to Learn More?

Copies of the Plan

Copies of the *Troy Mine Revised Reclamation Plan* are available for review at the KNF Supervisors Office, 1101 Highway 2 West, Libby, Montana and at the DEQ Environmental Management Bureau, 1520 East 6th Avenue, Helena, Montana. Copies are also available for review at the public library in Troy and at the Three Rivers Ranger District, 1437 Highway 2 West, Troy, Montana.

Questions or Comments

For further information contact the following Project Coordinators:

- **John McKay,** Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923, (406) 283-7691, jmckay@fs.fed.us
- **Kathy Johnson**, DEQ, PO Box 200901, Helena, MT 59620, (406) 444-1760, katjohnson@mt.gov

Information (including an electronic version of the plan) is also available on the KNF and DEQ websites:

- www.fs.fed.us/r1/kootenai/resources/minerals/index.shtml
- www.deq.mt.gov

How to Comment on the Reclamation Plan

Written comments concerning the proposed action must be postmarked by December 28, 2007, to be considered in the draft EA. Comments should be sent to Paul Bradford, Forest Supervisor, Troy Mine Reclamation Project, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923, or e-mailed to: **comments-northern-kootenai@fs.fed.us** with "**Troy Mine Revised Reclamation Plan**" in the subject line.

All comments must contain name of commenter, postal service address, and date of comment. A copy on a computer generated CD should accompany all written comments over one page in length.

Montana Department of Environmental Quality
PO Box 200901
Helena, MT 59620
Attn: Kathy Johnson

Return Service Requested

Can you identify this mystery mining picture?
(See inside for answer)

Appendix C
Mailing List for Open House/Public Meeting

Company	First Name	Last Name	Address	City	State	Zip
BUREAU OF MINES & GEOLOGY	ROBIN	McCULLOCH	1300 WEST PARK ST RM 200	BUTTE	MT	59701-8998
DAILY INTERLAKE	BILL	SPENCE	727 E IDAHO ST	KALISPELL	MT	59904
MONTANA DNRC	LIBBY UNIT		14096 HWY 37	LIBBY	MT	59923
NORTHWEST MINING ASSOCIATION		220		SPOKANE	WA	99201-0772
WETA	DON	ALLEN	2301 COLONIAL DR	HELENA	MT	59601
SHPO		DEADHEAD	HELENA			
EARTHWORKS	BONNIE	GESTRING	PO Box 8383	MISSOULA	MT	59807
BLM - DILLON FIELD OFFICE	BOB	GUNDERSON	PO BOX 9431	DILLON	MT	59725
BLM - LEWISTOWN FIELD OFFICE	SCOTT	HAIGHT	PO BOX 1160	LEWISTOWN	MT	59457-1160
MEIC	JIM	JENSEN	PO BOX 1184	HELENA	MT	59624
VALLEY COUNTY RD DEPT	RICK	SEILER	PO BOX 1024	GLASGOW	MT	59230
WETA	DON	SERBA	2301 COLONIAL DR STE 2A	HELENA	MT	59601
WETA	DON	SERBA	216 CENTENNIAL ST	MISSOULA	MT	59801
MONTANA HISTORICAL SOCIETY	STAN	WILMOTH, PhD	PO BOX 2001201	HELENA	MT	59620-1201
MONTANA MINING ASSOCIATION			PO BOX 5567	HELENA	MT	59604
MONTANA TECH Library	Document Dept		1300 W Park	BUTTE	MT	59701-8997
NWEST MINING ASSOCIATION			10 N POST SUITE 220	SPOKANE	WA	99201-0772
MONTANA MINING ASSOCIATION			PO BOX 5567	HELENA	MT	59604
GOVERNOR'S OFFICE	CAPT. BLDG RM 204		DEADHEAD			
BLM - LEWISTOWN FIELD OFFICE			PO BOX 1160	LEWISTOWN	MT	59457-1160
BLM-MALTA FIELD OFFICE			HC 65 BOX 5000	MALTA	MT	59538-0047
CHOTEAU COUNTY			PO BOX 459	FORT BENTON	MT	59442
CITY OF HARLOWTON			PO BOX 292	HARLOWTOWN	MT	59036
DNRC			PO BOX 1021	LEWISTOWN	MT	59457-1021
GALLATIN NATIONAL FOREST			PO BOX 130	BOZEMAN	MT	59771
HELENA NATIONAL FOREST			2880 SKYWAY DR	HELENA	MT	59601
L YELLOWSTONE IRR PROJECT			2327 LINCOLN AVE SE	SIDNEY	MT	59270
WHEATLAND COUNTY			PO BOX 1903	HARLOWTOWN	MT	59036
ENIRONMENTAL QUALITY COUNCIL	Legislative Environmental Policy Office		PO BOX 201704	HELENA	MT	59620-1704
	CHAS	VINCENT	5957 CHAMPION RD	LIBBY	MT	59923
	AUBYN	CURTISS	PO BOX 216	FORTINE	MT	59918-0216
	RALPH	HEINERT	PO BOX 577	LIBBY	MT	59923-0577
COUNTY COMMISSIONER LINCOLN	JOHN	KONZEN	512 CALIFORNIA AVE	LIBBY	MT	59923
COUNTY COMMISSIONER LINCOLN	MARIANNE	ROOSE	PO BOX 2012	EUREKA	MT	59917
COUNTY COMMISSIONER LINCOLN	RITA	WINDOM	512 CALIFORNIA AVE	LIBBY	MT	59923
COUNTY COMMISSIONER SANDERS	CAROL	BROOKER	PO BOX 794	PLAINS	MT	59589
COUNTY COMMISSIONER SANDERS	HAROLD	LAWS	PO BOX 745	THOMPSON FALLS	MT	59873
COUNTY COMMISSIONER SANDERS	JUSTIN	PATTON	129 PATTON RD	LONEPINE	MT	59848
US FISH AND WILDLIFE SERVICE			780 CRESTON HATCHERY RD	KALISPELL	MT	59901
WILDWEST INSTITUTE			PO BOX 7998	MISSOULA	MT	59807
ALLIANCE FOR THE WILD ROCKIES	LIZ	SEDLER	PO BOX 1203	SANDPOINT	ID	83864
CABINET BACK COUNTRY HORSEMEN	ROCKY	SCHAUER	PO BOX 949	LIBBY	MT	59923
CABINET BACK COUNTRY HORSEMEN	LEE	METZGAR	1001 E BROADWAY ST NO 2-206	MISSOULA	MT	59802
MONTANA WILDERNESS ASSOCIATION	CESAR	HERNANDEZ	643 FULKERSON LANE	POLSON	MT	59860
MONTANIANS FOR MULTIPLE USE	STEVE	FUNKE	578 1ST AVE NE	KALISPELL	MT	59901

Company	First Name	Last Name	Address	City	State	Zip
MT CHAPTER AMERICAN FISHERIES SOCIETY	ERIC	REILAND	PO BOX 5186	MISSOULA	MT	59806
MT DEPT OF NATURAL RESOURCES	JOHN	SHOTZBERGER	14096 US HWY 37	LIBBY	MT	59923
MT FISH WILDLIFE AND PARKS	JERRY	BROWN	475 FISH HATCHERY ROAD	LIBBY	MT	59923
UNITED STATES HOUSE OF REPRESENTATIVES	DENNIS	REHBERG	301 E BROADWAY, SUITE 2	MISSOULA	MT	59802
UNITED STATES SENATE	MAX	BAUCUS	8 THIRD STREET EAST	KALISPELL	MT	59901
UNITED STATES SENATE	JON	TESTER	1845 HWY 93 S SUITE 210	KALISPELL	MT	59901
MT STATE REPRESENTATIVE, DIST 13	PAT	INGRAHAM	PO BOX 1151	THOMPSON FALLS	MT	59873
MT STATE SENATOR, DIST 7	JIM	ELLIOT	100 TROUT CREEK RD	TROUT CREEK	MT	59874
ROCK CREEK ALLIANCE	RICK	STERN	210 HIGGINS, SUITE 206	MISSOULA	MT	59802
SOCIETY OF AMERICAN FORESTERS			PO BOX 345	LIBBY	MT	59923
LIBBY MAYOR	TONY	BERGET	PO BOX 1428	LIBBY	MT	59923
TROY MAYOR	JIM	HAMMONS	PO BOX 1030	TROY	MT	59935
US FISH AND WILDLIFE SERVICE	WAYNE	KASWORM	FARM TO MARKET RD	LIBBY	MT	59923
CLARK FORK COALISTION	MATT	CLIFFORD	PO BOX 7593	MISSOULA	MT	59807
	HANNAH	HERNANDEZ	71 FOUR CORNERS S	HERON	MT	59844
	JUDY	HUTCHINS	PO BOX 104	HERON	MT	59844
LINCOLN COUNTY COALITION	WAYNE	HIRST	209 MINERAL AVE	LIBBY	MT	59923
YAAK VALLEY FOREST COUNCIL	ROBIN	KING	155 RIVERVIEW DR	TROY	MT	59935
	STEVE	PRIEVE	PO BOX 213	TROY	MT	59935
ENVIRONMENTAL PROTECTION AGENCY	STEVE	POTTS	10 W 15TH STREET SUITE 3200	HELENA	MT	59626
ENVIRONMENTAL PROTECTION AGENCY	BILL	RILEY	1200 6TH AVE	SEATTLE	WA	98101
MONTANA TROUT UNLIMITED	TIM	LINEHAN	472 UPPER FORD ROAD	TROY	MT	59935
NATIONAL WILDLIFE FEDERATION	HANK	FISHER	3342 BUTLER VIEW LN	MISSOULA	MT	59806
SIERRA CLUB	JIM	CURTISS	1318 KHANABAD DR	MISSOULA	MT	59802
USFWS	MARK	WILSON	100 N PARK SUITE 320	HELENA	MT	59601
ARMY CORPS OF ENGINEERS	BOB	NEBEL	215 N 17TH ST	OMAHA	NE	68102-4978
	RAY	REMP	208 N COLORADO AVE	LIBBY	MT	59923
	DASIOS	FOTULA	PO BOX 723	TROY	MT	59935
MONTANA MOUNTAIN VALLEY, LLC			PO BOX 1626	EAGLE RIVER	WI	54521
	RAY	SAMPSON	8952 BULL LAKE RD	TROY	MT	59935
	RON	COTTON	1011 SHINING MTNS TRAIL	TROY	MT	59935
	STEVE	GIBSON	435712 STATE HWY 20	NEWPORT	WA	99156
	JOHN	NORRIS	PO BOX 456	MT BALDY	CA	91759
	ROBERT	JENKINS	1672 SPAR LAKE ROAD # RE	TROY	MT	59935
	DAVID	REID	PO BOX 257	TROY	MT	59935
	RICHARD	GREENE	1365 STAR GAZE CT	COLFAX	CA	95713
ATHENS INVESTMENTS, INC			201 W MAIN STREET STE 201	MISSOULA	MT	59802
	TOM	BAMFORD	PO BOX 971	TROY	MT	59935
	CAROLE	WRIGHT	9504 BULL LAKE RD	TROY	MT	59935
	NEIL	NEWTON	PO BOX 523	SEELEY LAKE	MT	59868
	DON	WEATHERBY	9564 BULL LAKE RD	TROY	MT	59935
	ALLAN	BACON	9566 BULL LAKE RD	TROY	MT	59935
NORTHWEST PROPERTIES, LLC			103 W LINCOLN BLVD	LIBBY	MT	59923

Appendix D

Newspaper Advertisements for Open House/Public Meeting

Western News

Libby, MT

USDA Forest Service, Kootenai National Forest
Three Rivers Ranger District, Troy Ranger Station
Lincoln County, Montana

The Kootenai National Forest (KNF) and Montana Department of Environmental Quality (DEQ) are beginning the formal process of environmental analysis, and would like your input on the proposal. Your input is important to identify any concerns with the proposed activity.

An open house informational and scoping meeting will be held on Tuesday, October 30, 2007, at the Senior Citizens Center, Troy, MT, from 6:30 - 8:30 p.m.

Comments concerning the proposed action must be postmarked by December 28, 2007, to be considered in the draft environmental document. The draft is expected by August 2008, and the final by February 2009. Send written comments concerning the Proposed Action to Paul Bradford, Forest Supervisor, Troy Mine Reclamation Project, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923. Send e-mail comments to: **comments-northern-kootenai@fs.fed.us.** All comments must contain name of commenter, postal service address, and date of comment. A copy on a computer generated CD should accompany all comments over one page in length.

Genesis, Inc. submitted a Troy Mine Revised Reclamation Plan, which outlines their closure adit water management and modified reclamation proposal when the mine ceases operations in approximately six years, according to the latest estimate. The Plan describes their proposal including closure of facilities, revegetation, water management, and maintenance/monitoring.

Copies of the Troy Mine Revised Reclamation Plan are available for review at the KNF Supervisor's Office, 1101 Hwy 2 West, Libby, MT 59923, at the DEQ, Environmental Management Bureau, 1520 East 6th Avenue, Helena, MT 59620. Copies are also available for review at the public library in Troy, MT, and at the Three Rivers Ranger District, 1437 Hwy 2 West, Troy, MT., or on the KNF web page at the address shown below.

For further information contact the Project Coordinators John McKay, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923, Phone (406) 283-7691, e-mail jmckay@fs.fed.us or Kathy Johnson, DEQ, PO Box 200901, Helena, MT 59620, Phone (406) 444-1760, e-mail katjohnson@mt.gov or consult the Kootenai National Forest web page at **http://www.fs.fed.us/r1/kootenai/resources/minerals/index.shtml.**

opt a Family Programs throughout Montana to
Giving Program. Fifty $500 Grants are available
ions. Please send a brief letter describing your
dopt A Family Program, P.O. Box 6000, Butte,
vember 9, 2007 for Christmas of 2007

Kootenai National Forest Service 10-24-07

County papers over the years

by Sandra Gubel

From an historical point of view, there have been several newspapers operating through the years in Sanders County--some with a fair amount of longevity.

In a brief stint, Publisher Adam Aulbach published 13 issues of the *Belknap Sun* in the period around 1884. Belknap at that time was the "getting on" point to depart on the train to the Coeur d'Alene gold fields. The temporary town that held some 6,000 people awaiting departure on the trains, soon diminished, and Aulbach himself eventually decided to climb on board awaiting a "golden" opportunity.

Nearby Thompson (only later named Thompson Falls), became the spot that people inhabited more in the days afterward--those who remained here, or returned after finding the life of the gold country not to their liking.

The *Western Montanian*, noted Lorraine Dufresne in her book *A Heritage Remembered*, sprung up in 1896, published in Thompson. Maurice Helterline, who painstakingly researched that publication and several others, gleaning births, deaths and marriages, noted he'd checked all issues of the Montanian during its publication years of 1894 to 1896. D.A. Hendricks was publisher of the paper, which came out each Saturday. Subscriptions were $2.50 per year.

Sanders County Signal was published in the Plains/Hot Springs area from 1906 to 1924. The Plainsman (in Plains) published in 1895 and 1896, and again from 1900 to 1992. The *Sanders County Democrat* was published in 1911 and 1912 from Plains, with C.C. Willis as publisher. The *Hot Springs Sentinel* was published from 1950 to 1960. There was also a newspaper called the *Hot Springs Citizen*.

Also publishing news were the newspapers *Camas Hot Springs Exchange* and *Camas Hot Springs Record*.

It is believed that the newspaper for whom Edith Colby worked (see additional historical article), the *Independent-Enterprise* was published for a period of time and was in operation before and during the time that the reporter stood trial for the shooting of Thompson businessman Atwood C. Thomas. Editor of that paper was J. Manire.

Of the newspapers that remain in business, the *Little*

REQUEST FOR COMMENT and NOTICE of PUBLIC MEETING

Genesis Incorporated Troy Mine Revised Reclamation Plan

USDA Forest Service, Kootenai National Forest
Three Rivers Ranger District, Troy Ranger Station
Lincoln County, Montana

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Published in the Sanders County Ledger October 25, 2007

NOTICE

Notice is hereby given th
conjunction with Town of

SHALL THE TOWN COU
ADDITIONAL 75 MILLS
ADDITIONAL FUNDING

The polls will be open
p.m., on election day for

Town of

DATED this 17th day of

Published in th

that a 237-member steering committee led by Hu approved the final candidate list for the Central Committee after two days of consultations with congress delegates. China Central Television showed Hu and other leaders raising their hands in approval.

the town of Musa Qala in Helmand province, sparking a battle that lasted several hours and involved the use of military aircraft, the coalition said in a statement. Nearly three dozen militants were killed.

The battle was the second in two days near Musa

months after British troops left the town following a contentious peace agreement that handed over security responsibilities to Afghan elders. Musa Qala has been in control of Taliban fighters ever since and is in the heart of the world's largest poppy-growing region.

Daily Inter Lake

10/21/07

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USDA Forest Service, Kootenai National Forest
Three Rivers Ranger District, Troy Ranger Station
Lincoln County, Montana

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For further information contact the Project Coordinators John McKay, Kootenai National Forest, 1101 U.S. Hwy 2 West, Libby, MT 59923, Phone (406) 283-7691, e-mail jmckay@fs.fed.us, or Kathy Johnson, DEQ, PO Box 200901, Helena, MT 59620, Phone (406) 444-1760, e-mail katjohnson@mt.gov or consult the Kootenai National Forest web page at http://www.fs.fed.us/r1/kootenai/resources/minerals/index.shtml.

Kootenai National Forest - Mail 1

GREAT FOOD • GREAT PAPER • D

and receive $10 off any meal at The Landing Restaurant

BONNER COUNTY DAILY BEE

10/24/07

THE LANDING

41 Lakeshore Drive, Sagle • Just across The Long Bridge • 265-2000

452888S-1023

REQUEST FOR COMMENT and NOTICE of PUBLIC MEETING

Genesis Incorporated Troy Mine Revised Reclamation Plan
USDA Forest Service, Kootenai National Forest
Three Rivers Ranger District, Troy Ranger Station
Lincoln County, Montana

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452287S-1024

Kootenai National Forest

Appendix E
Sign in Sheets for Open House/Public Meeting

PLEASE SIGN IN

Name: Kevin & Brenda Goe
Mailing Address: P.O. Box 24
City: Troy State: MT Zip Code: 59935
Phone: 295-7214 Email: —

Name: Doug Paker
Mailing Address: 667 E Beckwith
City: Missoula State: MT Zip Code: 59801
Phone: Email:

Name: Bruce Clark
Mailing Address: PO Box 479
City: Troy State: MT Zip Code: 59935
Phone: 295-4727 Email:

Name: STEVE LLOYD
Mailing Address: Box 874
City: Hot Springs State: MT Zip Code: 59845
Phone: 240-1349 Email:

Name: LINDA Newstrom
Mailing Address: PO BUX 524
City: Troy State: MT Zip Code: 59935
Phone: 406/295 5568 Email: x

Name: Donald W. Barney
Mailing Address: 155 Forest Ave
City: Libby State: MT Zip Code: 59923
Phone: (406) 293-7860 Email:

PLEASE SIGN IN

Name: Derek L. Feeback
Mailing Address: PO Box 1282
City: Libby State: MT Zip Code: 59923
Phone: 293-6151 Email: rx@backadit.com

Name: Paul Cook
Mailing Address: 68 Swanson Lodge Rd
City: Troy State: MT Zip Code: 59935
Phone: 295 9916 Email:

Name: Rep. Chas Vincent
Mailing Address: 5957 Champion Rd
City: Libby State: MT Zip Code: 59923
Phone: 293.1575 Email: cvvincent@hotmail.com

Name: Torin Hasz
Mailing Address: 1688 Iron Creek Rd
City: Troy State: MT Zip Code: 59935
Phone: ~~406~~ (406) 295-9877 Email: Torinhasz@yahoo.com

Name: Joshua Peterson
Mailing Address: Box 1150
City: Troy State: MT Zip Code: 59935
Phone: 295 6015 Email:

Name: James THill
Mailing Address: P.O. Box 250
City: TROY State: MT Zip Code: 59935
Phone: 295-9061 Email:

PLEASE SIGN IN

Name: Judy Hutchins
Mailing Address: P.O. Box 104
City: Heron State: MT Zip Code: 59844
Phone: 406-847-2717 Email: Jhutch7494@aol.com

Name: Jeff Franke
Mailing Address: 851 Lake Creek Road
City: Troy State: M.T. Zip Code: 59935
Phone: 406-295-5232 Email: frankej@troymine.com

Name: Lloyd Doney
Mailing Address: 40 Halo Ct. S.
City: Troy State: MT. Zip Code: 59935
Phone: 295-5882 Email: Doneyl@Troymine.com

Name: Janine Price
Mailing Address: PO Box 180
City: Troy State: MT Zip Code: 59935
Phone: 295-5248 Email:

Name: Carleen Jensen
Mailing Address: 53 Swanson Rdg Rd
City: Troy State: Mt. Zip Code: 59935
Phone: Email:

Name: Clint Jensen
Mailing Address: P.O. Box 71
City: Heron State: Mont Zip Code: 59844
Phone: 406-847-2127 Email:

PLEASE SIGN IN

Name: Donald B Davis
Mailing Address: 3945 Bull Lk Rd
City: Troy State: Mont Zip Code: 59935
Phone: 295-4910 Email:

Name: Joe Madaski
Mailing Address: P.O. Box 748
City: Troy State: MT. Zip Code: 59935
Phone: (406) 295-4191 Email:

Name: Allen Layer
Mailing Address: PO 284
City: Troy State: MT Zip Code: 59935
Phone: 406-295-9190 Email:

Name: Hannah Hernandez
Mailing Address: 71 Four Corners Rd
City: Heron State: MT Zip Code: 59844
Phone: Email: mtpaloma@hotmail.com

Name: Keith O'Blenes
Mailing Address: 74 Hamann Ave
City: Libby State: MT Zip Code: 59923
Phone: (406) 293-9832 Email:

Name: Darcy O'Blenes
Mailing Address: 74 Hamann Ave.
City: Libby State: Mt. Zip Code: 59923
Phone: 406-293-9832 Email:

PLEASE SIGN IN

Name: Aubyn Curtiss
Mailing Address: Box 212
City: Fortine State: MT Zip Code: 59918
Phone: 406-882-4448 Email: aubyna@interbel.net

Name: Debbie Lyman
Mailing Address: 34 Beaver Peak Rd
City: Heron State: MT Zip Code: 59844
Phone: 8472388 Email: lastlyman@blackfoot.net

Name: Ruby Miller
Mailing Address: PO Box 548
City: Troy State: MT Zip Code: 59935
Phone: 295-4255 Email: millerra@cdm.com

Name: Glenn Knodle
Mailing Address: 184 Elk Meadow Ln
City: Heron State: MT Zip Code: 59844
Phone: Email:

Name: Paul D Kukay
Mailing Address: 343 Warren Road
City: Libby State: MT Zip Code: 59923
Phone: 406-293-6989 Email: PKukay@hotmail.com

Name: Robert Winstron
Mailing Address: PO Box 775
City: Troy State: MT Zip Code: 59935
Phone: 406-295-5018 Email: info@troutfitters.com

PLEASE SIGN IN

Name: Colleen Hinds
Mailing Address: 21 Four Corners Rd S
City: Heron State: MT Zip Code: 59844
Phone: Email:

Name: Floyd Beck
Mailing Address: 813 Wisconsin Ave
City: Libby State: MT Zip Code: 59923
Phone: (406) 293-8681 Email:

Name:
Mailing Address:
City: State: Zip Code:
Phone: Email:

Name:
Mailing Address:
City: State: Zip Code:
Phone: Email:

Name:
Mailing Address:
City: State: Zip Code:
Phone: Email:

Name:
Mailing Address:
City: State: Zip Code:
Phone: Email:

Appendix F
Written Comments Received During the Scoping Process

PB

COMMENT ON TROY MINE RECLIMATION PROJECT
IN CARE OF PAUL BRADFORD FOREST SUPERVISOR
KOOTENAI N.F. 1101 US. HWY 2 WEST LIBBY MT - 59923

NOV 28 2007

Dear Sir: I beleive The Troy Mine Should NOT be Reclaimed, I beleive it Should be Kept As is Except For certain Landscapes which Could be Reclaimed With Tree Plants and grass Restoration. I beleive This Mine The only One of its Kind of Caveren And Pillar on Silver and Copper Minerals, Should be Used As A Education Facility For Children of Elementry Levels As well As Colleges, And Also Could be Used As A great Tourist Attraction Also,

I several Years Ago while Visiting A Open Copper Pit Mine which was NOT Operating AT This Time, had A Chance As A Tourist To Tour A underground Mine which was Also Idle, A Retired Miner who had worked There was The Tour guide who Explained The History Of The Mine, The Troy Mine Could Also be A great Tourist Attraction if Left Mostly As is. Thank you

Harvey H. Frederickson
120 Middle Thompson Lake Rd.
Libby MT 59923 Ph 293-4959

PB
McKay

321 Shaugnessy Rd
Libby, MT 59923
26 November 2007

Paul Bradford
Forest Supervisor
Troy Mine Reclamation Project
Kootenai NF
1101 US Hwy 2 W
Libby, MT 59923

NOV 2007
RECEIVED

Dear Mr. Bradford,

I am asking you to consider several issues of concern regarding the Troy Mine. These include:
air quality (especially blowing dust from tailings impoundment)
surface and groundwater quality-perpetual treatment of discharge water and potential groundwater contamination underneath the tailings
subsidence-reclamation of future mining related subsidence
tailing impoundment stability
effects n fisheries and wildlife
buried contaminants in the tailings impoundment (buried barrels)

Goals of a reclamation plan should include protecting the groundwater and surface water quality
protecting public health by removing potential hazards
protecting air quality and reestablishing wildlife habitat.

I urge you to consider these issues of impact to the environment. Thank you

sincerely,
Julie Waters-Barcomb

Paul Bradford, Forest Supervisor
Troy Mine Reclamation Project
Libby, MT 59923

12/26/07

RE: Troy mine Reclamation

Dear Mr. Bradford

The most important consideration should be a cash bond to cover all obvious and potential problems that could possibly be associated with reclamation and perpetual maintenance of that reclamation with inflation rates calculated in the initial bond amount. This could have a mandatory review at ten-year intervals to assess the needs for the future. This bonding requirement would be particularly appropriate for: 1) tailings ponds integrity including sub- permeability to ground water, dike leakage, toe pond integrity, and toxic materials from containers that become apparent at a later date; 2) treatment of mine water that may change in chemistry and volume at a later date; 3) subsidence that may occur in the future due to climate changes and geologic events.

The following concerns identified by the agencies should definitely be addressed and returned to the same or better standards that existed prior to the mine, in a natural self sustaining to perpetuity condition:

1. Air quality in a pristine forest condition through appropriate state-of-the-art restoration of all tailings impoundments.
2. Perpetual monitoring and, if necessary, treatment of ground water and surface water to a purity standard of unimpacted streams of the of the area.
3. Potential for subsidence should be eliminated through any mining technology necessary.
4. The stability and total integrity of all tailings ponds (toe ponds) should be established through testing, analyzing soil conditions and whatever process is necessary to guarantee that total integrity.
5. There should be no negative impacts to fisheries and/or wildlife in the entire area of mine activity, after reclamation.
6. Sub soils, cover soils of the depth and forest soils type, consistent with that forest community, should be established and natural vegetation – grasses, forbs, shrubs and trees of that community restored.
7. All buried containers (many have been located and to the satisfaction of the science, proven to exist), should be located and with any contaminants or other contaminating objects, removed from the tailings and/or any other site in the mine area. These materials or objects should be properly disposed of in accordance with toxic waste disposal.

In addition to the above specific concerns, the entire mine site area should be returned to its natural condition with removal of all objects and materials extrinsic to a natural condition with exception of only, those objects or conditions necessary for access and monitoring the site.

Thank you for the opportunity to participate in this scoping procedure.

Sincerely

Cal Ryder
PO Box 1628
Noxon, MT 59853-1628 406-847-2535 <calrene@blackfoot.net>

My Concerns About the Troy Mine Revised Reclamation Plan

Dear Mr. Bradford,

I wish to express some 'heartfelt thoughts' on this subject at this time of year. As folks ponder "peace on earth and goodwill towards all', the immediate welfare of our surroundings takes on special signifigance. I am requesting the Forest Service to live up to it's name and serve the forests of our nation by doing everything in it's power to make thorough, conscientous, and far reaching choices.

Within the strictures of the law, there are options you may select that can make a huge difference in the outcome of projects. I have no wish to detail 'all of my objections' to the proposed Reclamation Plan, other than to state a few obvious shortcomings in it's overall scope. I believe the monitoring is inadequate in every aspect. I believe the Revett-Troy proposals will require the least output by the company, without the future welfare of the land being of much consequence to them.

The history of this mine and the companies that have operated it does not inspire confidence. After watching this operation for over 25 years, I am left with a bad taste concerning the honesty and transparency of it's actions.

I wish to have the Forest Service require an Environmental Impact Statement for the reclamation plan. I do not believe an Environmental Assessment will be adequate to cover their proposal. When one refers to "in perpetuity", I wonder if that term is understood by the speaker/writer. It means 'FOREVER' and that is a difficult concept to grasp. Monitoring leakages, dust, vegetation, erosion, subsidence etc. " in perpetuity" is impossible.

It is of critical importance to have the Reclamation Plan be held to the highest standards. There is no reason to allow for minimum oversight when the welfare of the land is being decided. I ask that you consider my words. Thank you.

Wishing you a Happy New Year,

Debbie Lyman

Debbie Lyman
34 Beaver Peak Road
Heron, MT 59844
December 26, 2007

lastlyman
<lastlyman@blackfoot.net>

12/26/2007 04:24 PM

To: Paul Bradford <comments-northern-kootenai@fs.fed.us>
cc:
Subject: Troy Mine Revised Reclamation Plan

Concerns About the Troy Mine Revised Reclamation Plan

Dear Mr. Bradford,
I will be brief. There is no need to enumerate all the faults and shortcomings in the Revett 'revised reclamation plan'. I will focus on one subject that lies at the core of this 'reclamation'. Water and watersheds are soon to be recognized as the single most important element of our forests. How water is affected will be the primary concern in all land use (and abuse) decision making. We will be spending billions on water conservation and reclamation of damaged watersheds. The idea of perpetual discharge of polluted water will be considered barbaric and stupid. A global paradigm shift, driven by climate change, will make the strategy of disposing of any waste or toxic materials into a watershed a truly criminal act. Clean water will be more valuable than the resources that have been extracted using wasteful and polluting methods. I will remind you that good money is being made mining the tailings piles left over from mining activities abandoned a century ago. Those who look back on our mining practices and our disregard for fresh, clean water will wonder at the incredible waste, the inefficiency and the greed that caused the mess that they will have to clean up.
Please do the right thing and hold Revett to the highest standards for reclamation of their Troy mine. A full EIS. Revett should be held to the highest standard.
Sincerely,
David R. Lyman
34 Beaver Peak Road
Heron, MT 59844
Dec. 26, 2007

Rec'd 11-9-07

Montana Department of
ENVIRONMENTAL QUALITY

Comment Sheet for the Troy Mine Revised Reclamation Plan

The United States Forest Service – Kootenai National Forest (KNF) and the Montana Department of Environmental Quality (DEQ) would appreciate receiving your thoughts and concerns on the Troy Mine Revised Reclamation Plan proposed by Genesis, Inc. An environmental document will be prepared to evaluate the impacts of the revised reclamation plan as well as the impacts of following the No Action alternative. There are several ways to submit your comments on the revised reclamation plan: 1) leave the comment sheet with a study team member at the public meeting; 2) mail your comments to the address shown on the back of this page; or 3) email your comments to comments_northern_kootenai@fs.fed.us – *please include* "Troy Mine Revised Reclamation Plan" *in the subject line.* All comments must contain name of commenter, postal service address, and date of comment. We would appreciate receiving your comments before **December 28, 2007**. Thank you.

CURRENT PLAN FOR DISCHARGING MINE WATER ONTO TAILING EMPOUNDMENT IS THE MOST LOGICAL PROPOSAL FOR FOLLOWING REASONS:

1) SEALING MINE OPENINGS NOT REASONABLY FEASIBILITY & POSES A FUTURE THREAT OF RELEASING LARGE VOLUMES OF WATER SHOULD THERE BE A STRUCTURAL FAILURE.

2) WATER RELEASE DOWN EXISTING PIPELINES MEETS MT. WATER QUALITY STANDARDS AND IS VITAL TO FACILITATING THE REVEGETATION PROCESS... WHERE WOULD THE WATER COME FROM FOR MAINTAINING GROWTH IF NOT FROM THIS MOST AVAILABLE SOURCE? WHY DEPLETE THE WATER TABLE WHEN NOT NECESSARY.

3) LOOKING INTO THE FUTURE – THIS AVAILABLE RESOURCE WOULD PROVIDE INCENTIVES FOR WISE DEVELOPMENT AND USE OF TAILING AREA.

Name: JANINE PRICE

Mailing Address: PO BOX 180

City: TROY State: MT Zip Code: 59935

Phone: Email:

The Cabinet Resource Group

Dec. 27, 2008

Cathy Johnson
Montana DEQ
P.O.B. 200901
Helena, MT 59620-0901

S.O. Paul Bradford
Kootenai National Forest
1101 Highway 2 West
Libby, MT 59923

Dear Cathy Johnson and Paul Bradford,

Attached are the comments of the Cabinet Resource Group concerning scoping for the Troy Unit Revised Reclamation Plan (TRRP). Hard-copy of these comments will be accompanied by approximately 25 pages of supporting documents which are referenced as attachments in the body of CRG's comments. The three attachments (1,2, 3) reference documents in CRG possession, provided by Asarco regarding the Troy Mine CERCLA Lawsuit. A portion of them dealing with field investigation reports and communications between MT/DHES are (or should be) in the possession of DEQ. CRG will provide Bates # copies of said documents which DEQ/KNF may not have upon written request of the agencies. CRG personnel are available for discussion with the agencies and contractor chosen to write the NEPA / MEPA document these comments pertain to.

CRG would like to remind the agencies responsible for this document that DEQ publicly determined the TRRP amounted to a major amendment (Western News 2/28, 3/7, & 3/14/01) under the MMRA Sec. 82-4-342, which requires an EIS. CRG comments raise issues that would be insufficiently addressed in the context of an EA. On behalf of CRG's 175- members, we remind the agencies of their responsibilities under the law and respectfully request that an EIS be conducted for the TRRP.

Thank you.

Cesar Hernandez
Board Member CRG

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CRG, Troy Mine Revised Reclamation Plan EA Scoping Comments

1. Topsoil
2. Stability
3. Long Term H2O management plan
4. Barrels
5. MPDES
6. NL Troy Dam and sediment analysis
7. Subsidence
8. Other Discharges
9. Reclamation Bond
10. Catastrophic failure bond

1. (TOPSOIL) The existing Troy Mine Reclamation Plan requires the placement of 18 inches of stockpiled topsoil to cover the tailings impoundment surface upon completion of mining. The Revett / Genesis Troy Revised Reclamation Plan (TRRP) proposes the placement of (18") inches of borrowed subsoil and retention of stockpiled topsoil for toe ponds. This revision is prefaced by the claim that years of experimenting indicate that borrowed subsoil is a better cover medium. Unsaid and unsubstantiated are measurements of the currently existing topsoil stockpile and the true purpose of leaving the stockpiled topsoil in place. For numerous years (especially during operation) the phreatic water level in the tailings impoundment has exceeded the height of the starter dam. This situation was warned against at the earliest inception of the Troy Project as posing the possibility of catastrophic failure for the tailings impoundment. This hazard has been mitigated by the presence of nearly 1,000,000 cubic yards of topsoil at the toe of the tailings impoundment.

Significant amounts of the stockpiled topsoil have also been incorporated into the currently existing toe ponds that were not originally permitted with the facility. These toe ponds contain water that leaks from the tailings impoundment. Removing the toe ponds would expose conditions at the Troy Mine tailings impoundment that violate the Clean Water Act. The illegal toe ponds cover the fact the tailings impoundment was not constructed as permitted (with an internal drainage system). Such a system would have required an MPDES permit, containing permit requirements Asarco realized they would be incapable of meeting.

The toe ponds leak directly into Lake Creek despite the best efforts of the mining company and State regulators to avoid this inconvenient truth and despite their best band-aid efforts to hide this discrepancy. Both entities rely on dilution of the discharge as the solution to this problem.

2. (STABILITY) The stability of the Troy Mine tailings impoundment is tied to its dewatering. The current reclamation plan would move towards accomplishing this objective. The TRRP proposes to perpetually deliver mine water to the tailings impoundment as a method of treating mine water that does not meet surface water criteria. This proposal is little more than a financial decision of the mine owners to avoid more costly treatment options and fails to take into

account the long-term stability requirements of the tailings impoundment. The Reichsmuth (1/31/84) Report was denigrated and dismissed by Asarco and the regulatory agencies. However, sinkholes that appeared in 1988 and 91 as well as piping and recent (March 23 and April 14, 2007) field reports indicate instability features inherent in the facility. These features need to be vigorously and independently investigated.

3a. (H2O MANAGEMENT) Long-term water management of discharges from the mine and related facilities is the most important outstanding reclamation feature. Diffuse discharges from the mine itself towards Ross Creek have begun to show up. Ross Creek is the major tributary feeding Bull Lake. Mapping, monitoring and either eliminating or remediating these discharges are a long-term challenge that needs to be thoroughly addressed.

Discharges from the tailings impoundment are equally important because of its proximity to Lake Creek and for reasons outlined at #2 above. Another issue that must be addressed is that of buried material within the tailings impoundment. Attached is documentation indicating the possibility if not probability that hazardous materials (industrial solvents) were disposed of in the tailings impoundment. The attachments contain information gleaned from discovery documents provided by Asarco regarding a CERCLA lawsuit initiated by the Cabinet Resource Group, which was eventually dismissed without prejudice when Asarco went into bankruptcy. The bills of lading indicate that copious quantities (thousands of gallons) of industrial solvents were used at the facility from 1980-90, while a paper trail of their disposal (as required by EPA) is completely lacking. Documentation and the accounts of some former employees at the facility indicate that illegal and regular dumping of the material occurred under cover of darkness at the tailings impoundment. While Asarco initially denied any dumping of material at the facility, subsequent geophysical investigations located several anomalies consistent with the allegations that barrels are buried in the tailings impoundment. Asarco eventually admitted to burying barrels, but insists the material inside is benign flocculant. The adages; "fool me once shame on you, fool me twice shame on me" and "trust but verify" should prominently guide the actions of regulatory agencies here.

Just as it has taken over 25 years for subsidence at the mine to demonstrate itself a viable issue, so to the issue of buried barrels may take similar time. Buried barrels will deteriorate over time as they rust. The release of hazardous materials is a critica issue that DEQ cannot overlook. It's importance increases as development on private lands surrounding the tailings impoundment increases. Prudence dictates caution, as long-term public health concerns may well have to be dealt with long after the mine has closed, and the ability to hold its operators liable possible. The State of Montana and its Department of Environmental Quality need only look as far as Libby, MT and its Tremolite asbestos crisis, that was ignored for decades to see the effects of what burying its head in the sand over an issue can produce.

3b. (ATTENUATION) The RRP Fate and Transport study makes a great deal concerning the attenuation of copper : Pg. 24 *"all data collected to date indicates that copper is very immobile in the groundwater system surrounding the decant pond. Copper in mine water that is disposed in the decant pond becomes primarily bound in shallow soils/sediment in the*

bottom of the decant pond and very little copper is transported beyond a few tens or hundreds of feet in the groundwater system." Continued deposition of mine water to the tailings impoundment for treatment purposes would require long-term maintenance of at least one, if not all three, of the pipelines that service the tailings impoundment. Similarly if such is the case, then why aren't the tailings impoundment decant ponds replicated at the mine mill site, which would not require the maintenance of the more than seven miles of buried pipeline from mine to tailings impoundment? See F&T Study pages 30-31 for more information.

4a. (BARRELS) On March 19, 1996 Tom Reid (DEQ) received a Citizen Complaint from former Asarco Troy Mine employee Jim Meyer regarding a number of concerns that took place over the course of his employment (DEQ/ WQD Individual Activity Report 3/19/96). Mr. Meyers was employed at the Troy unit in excess of 10 years. Among his concerns was an allegation that Asarco routinely disposed of 55 gallon barrels (some containing hazardous wastes) in the tailings impoundment. The disposal of barrels under cover of darkness was corroborated by other Asarco employees. A map of the depositions accompanies the Individual Activity Report of 3/19/96. The Citizen Complaint was turned over to DEQ's Waste Management Division –Hard Rock Bureau; which did nothing.

The Cabinet Resource Group filed a CERCLA Law Suit against Asarco on 12/03. Subsequent geophysical investigations by Eco-Tech Geophysical (Missoula) as a part of discovery in the lawsuit identified several anomalies consistent with buried barrels. Asarco initially denied the allegations but admitted a year later that 17 barrels had been disposed of in the tailings impoundment. Asarco claimed the content of the barrels as benign flocculant. Physical copies of the Eco-Tech report and a plan to excavate the anomalies were turned over to Montana DEQ. DEQ was supposed to evaluate the proposed excavation plan and make a determination as to its feasibility and permitting. It did nothing! Asarco's eventual Bankruptcy filing caused the CERCLA case to be dismissed without prejudice. The issue of the buried barrels remains a liability that DEQ and the State of Montana ignore at their peril.

4b. (ATTACHMENTS) As a result of its CERCLA Lawsuit the Cabinet Resource Group was provided some 3000 pages of discovery documents. Those documents consisted of Bills of Lading and Purchase Orders as well as numerous other documents relating to the use and disposal of all industrial fuels and lubricants capable of generating hazardous waste. CRG broke these documents into three categories.

1) An inventory of all chemical and lubricant materials that were delivered to the mine in 55 gallon barrels.
2) An inventory of industrial solvents use.
3. A list of solvents and other documents possibly indicating their disposition.

From these documents it has been determined that during the 1st decade of Troy Mine operation Asarco relied on local mine personnel to dispose of all mine wastes. Beginning in 1991 (Dave Young tenure) Asarco employed the services of Safety-Kleen to handle the disposal of the mines lubricant waste stream capable of generating hazardous waste.
A synopsis of these documents is provided and some definitive conclusions can be reached.

a. The Troy mine used generous amounts of lubricants / solvents that contained hazardous substances (1.1.1. Trichlorethylene, 1.1.1 Trichloroethane / Bates # 5446, 5341-43, etc.).
b. Asarco filed for and received from the State of Montana (DHES / Hazardous Waste Bureau) a Hazardous Waste Generator Permit.
c. MT/DHES conducted some field inspections concerning use and handling practices of Troy mine generated haz-wastes (Bates # 5263-5410, 5309, 5330-31, etc). Concerns were raised in the field investigation reports regarding the disposal of hazardous materials.
d. Approximate use of material amounts containing hazardous wastes can be determined (Bates # 5446, 5330-31, 5344-45, etc.).
e. Only one Hazardous Waste Shipment Manifest (dated 2/18/93, Bates #5263-5410) was produced as a result of discovery.
f. Documents (Bates # 5297, 5317, 5328, etc.) providing clues that hazardous wastes were disposed of in manner and location violating permit and law.

Actual copies (Bates reg.) of these documents are in possession of CRG and are available for inspection by regulatory agencies. They are also part of the public record in the CERCLA case that was filed.

5. (MPDES) The Troy Mine will discharge into perpetuity. The quantity and quality of that discharge is a responsibility of the operators and a duty they are charged to manage through the MPDES / NPDES process. The regulatory agencies have been entirely deficient in this respect and are only now beginning to acknowledge and move in the direction that the facilities of the mine should have had one.

6. (NORTHERN LIGHTS TROY DAM) The Troy Mine and tailings impoundment has been a source of various discharges since its inception. From tailings line ruptures, storage pad snowplowing, through airborne particulate and piping from the tails impoundment, material from its operations have found their way into the ecosphere. The NL dam at the mouth of Lake Creek acts as a natural sediment trap in the watershed and contains a diary of accumulations in its sediments. The NL dam has been dredged twice since the inception of the Troy Mine yet no analysis of its sediments has been conducted. This is an issue that needs to be addressed. The issue of a catastrophic failure of the Troy mine tailings impoundment on the operation of the NL dam is also an issue that has been overlooked or dismissed.

7. (SUBSIDENCE) Two incidents (2004, 2005) of subsidence reaching the surface at the Troy mine should be regarded as canaries of the coal mine. Several incidents of rock-fall within the mine, one of which recently (2007) resulted in the death of a miner are indicative of the existing poor rock conditions within the mine. Spalling of support pillars is another indicator that stability within the mine may not be what is alleged and needs to be independently assessed. This is critically important given the possibility that removal of some of support pillars is being considered by Revett. Such a situation in a coal mine in Utah resulted in the death of at least six miners and three rescue personnel. Once the mine is closed there will be little opportunity to assess conditions within the mine. A bond commensurate with the possibility of further subsidence incidents and their mitigation for purposes of public safety needs to be considered.

This may be critically important as closure of the mine will result in a small lake forming underground. Rock fall or faulting in the area of the lake may produce pressures that blowout or rupture mine plugs. Subsidence or rock-fall within the mine may also be incidental to the creation of discreet hydrologic discharges to surface waters of the state. A plan and bonding sufficient to cover these possibilities needs to be considered.

8. (DISCHARGES) The issue of iron flock emanating throughout the bluffs between the tailings impoundment and Lake Creek has been blown off as "naturally occurring" throughout the drainage. It is well known the milling process at the Troy Mine utilizes tens of thousands of tons of iron / manganese grind balls. The RRP Fate and Transport Study discusses the use of x-ray spectra and electron microscope technology in the identification of copper-bearing phases important to attenuation. Repeated requests have been made to the regulatory agencies regarding the identification of the iron flock leaching from the Troy tailings impoundment. Identifying the source of the iron flock as native material or coming from the milling process is a relevant issue here. Elevated levels of nitrates, potassium xanthate and some copper have been identified outside of the tailings impoundment adjacent to Lake Creek. It is only reasonable to assume the probability this iron flock comes from the mine milling process. The only way such a definitive identification is possible is if it is investigated as thoroughly as the fate of the copper in the F&T Study.

9. (RECLAMATION BOND) The purpose of a Reclamation Bond is to dismantle the mine facilities after mining has ended and to protect the environment and public from the costs of problems associated with the mining activities. Potential problems that are not addressed and / or thoroughly investigated become public problems when they are dismissed and very serious problems after-the-fact if they have not been bonded for (remember Zortman-Landusky for reference). When viable evidence is provided that an issue should be of concern, it is the public duty and responsibility of the regulatory agencies (in this case DEQ / USFS) to objectively look at the issue and demand viable answers from the entities they are entrusted by the public to issue permits to.

For seven years regulatory agencies (DEQ and the KNF / USFS) have dallied in requiring establishment of a viable long-term Reclamation Bond for the Troy Project Mine.

10. (CATASTROPHIC FAILURE BOND) The Troy Unit Revised Reclamation Plan (Dec. 2000) prepared for Genesis Inc. contains the meeting notes of 10/12/2000 in Appendix I. Under "General Issues" is the quotation: "Forest Service needs a letter of intent to reopen. Their issues are not as problematic as DEQ, since DEQ will eventually **own** the mine and the tailings." These notes were taken by Len Murray of Klohn Crippen Co. a member of the Louis Berger Group. It can be assumed that Mr. Murray is a person of competence and that he accurately recorded the conversations of the meeting. At least there are no public documents contesting or requesting changes to that statement. The reference he records regarding "eventual ownership of the mine and tailings," is in all probability a reference to the fact that Montana DEQ will eventually own final responsibility and liability through its permitting authority for what becomes of permit #00093 once reclamation has occurred.

Notes: from TRRP

1. (Pg. 3-6) • Impoundment site topsoil stockpiles totaling approximately 560,000 cubic yards of salvaged topsoil located on about 44 acres along the western perimeter of the impoundment dike and acting as a dike containing the toe ponds.

2. (Pg. 4-16) Tailing facility cover-soil volume calculations are included in Table 4-1. Approximately 766,600 cubic yards of cover-soil materials will be required for tailing facility reclamation.

3. (Pg. 7-4) Evidence from mine operations indicates that the SOB and EOB have greater potential to dissipate water than the NOB.

4. (Pg. 7-6) Although the static groundwater levels will fluctuate seasonally, as experienced during previous shutdown of the mine, the water level in the mine is expected to reach equilibrium at approximately the 4248 elevation in the SOB and at the 4225 elevation in the NOB and EOB as shown on Exhibit D. The NOB mine pool will flow to the EOB when it reaches the 4186 elevation.

5. (Pg. 13 Fate & Transport Study) Some soil/sediment samples (DP-1 3 3/4 " and DP-1 4") are enriched to the extent that they contain nearly twice the copper content as ore from the Troy mine. Total copper concentrations in decant pond sediments suggest that copper is attenuated in surficial soil/sediments in the decant pond.

Attch. (1)

Troy Mine Barrel Inventory

Invoice #	Bates #	# Barrel dep.	#Barrel dep. rtrn.
1979			
6552	011592	4	
1980			
25495	011456	3	
25861	011492	10	
25588	011497	4	
25589	011498	2	
25586	011503	2	
25764	011505	4	
26578	011509	5	
26437	011510	5	
26412	011512	4	
26411	011513	4	
3570	011514		4
3577	011515		1
26382	011524	4	
3416	011528		6
26349	011529	10	
3806	011530		7*
3384	011536		4
26329	011538	10**	
26331	011539	10	
3352	011543		5
26277	011544	2	
2160	011546		9
25745	011547	5	
25750	011548	5	
25662	011552	5	
25659	011553	5	
25631	011554	5	
	011561	5***	
25981	011582	2	
25904	011565	2	
25905	011568	10	
2320	011570		8****
	011570		1****
2260	011571		1
7752	011575	10*****	
25841	011576	4	
Totals		131	46

* Page appears to have 2 barrel return invoices one on top of other. Cannot make out invoice or bates #, but appears to show 10 barrel return. ** Same superimposition as previous notation (*) only for 10 barrel deposit. *** Same superimposition as previous. Same superimposition as previous explanation. ***** Only notation of junk barrels ($2.00 apiece).

1981			
26601	011348	10	
2103	011349		?*
0189	011350	12	8
0169	011354	1	
0167	011357		9
3702	011359		3
3652	011360		6
928	011361	3	3
937	011363	5	
0247	011364	5	5
0246	011365	5	5
506	011379	2	
893	011381**		
0295	011386	10	5
0299	011387	10	1
747	011389	10	18
0266	011397	10	5
1095	011398	10	21
illegible	011402	5	1
1059	011403	5	1
041	011407	6	
075	011408	10	
074	011408	7	
076	011409		9
8669	011410	6	
8669	011411	100***	
071	011418	10	
063	011421		6
illegible	011428		2
082	011440	10	
6967	011441		8
084	011443	4	
083	011444	6	
080	011448	10	
Totals		252	116

?*Illegible.

** First invoice (dated 7/20/81) that mentions "barrel exchange." Lists 2 barrels but does not indicate in or out.
*** Largest known barrel deposit.

1982			
1589	011201	2	
115	011206		10
111	011206		8
096	011207		11
108	011207	10	
098	011209	6	
093	011209	10	
094	011210	10	
099	011210	3	
100	011214	12	
128	011218	1	
143	011219	2	
142	011219	2	
141	011220	2	
116	011220	8	
117	011221	10	
122	011221	10	
124	011223	10	
121	011223	2	
119	011224	4	
132	011224		10
103	011225	6	
129	011225		7
123	011226		5
125	011227	6	
137	011229		10
140	011229		9
135	011230		10
133	011231	10	
134	011231	10	
138	011232	3	
151	011236	10	
155	011237	3	
205	011239	1	
201	011239	4	
206	011240	6	
175	011241		9
170	011241		10
163	011245		10
150	011245		2
179	011246		11

157	011246		10
221	011249		10
227	011253		8
136	011254	10	
139	011255	7	
146	011255	4	
214	011256	10	
212	011257	10	
148	011258	10	
228	011259	10	
145	011260	7	
218	011262	10	
223	011263	6	
189	011264		5
229	011264		10
235	011265		11
232	011267	10	
161	011274	10	
164	011275	6	
169	011276	4	
174	011278	10	
193	011279		10
167	011279	2	
216	011286		11
197	011287	10	
207	011287	1	
211	011290		11
182	011291	1	
178	011291	10	
181	011292	11	
199	011293		10
196	011293		6
185	011295		7
204	011295		11
188	011296		6
236	011297	9	
242	011298	8	
243	011299		6
2195	011307	4	
246	011313	11	
Illelgible	011320	10	
253	011323		10
250	011325	10	
252	011330	9	
532153	011346	15	
Totals		407	267

1983

532188	011065	2	
532197	011066	10	
532189	011067	7	
532216	011080	2	
532212	011083	1	
503331	011084	1	
00000	011093	7	
503401	011104	2	
503402	011114	12	
503336	011117	5	
192	011128	1	
6974	011129		8
50340*	011133	3	
50340*	011134	5	
50339	011140	9	
01302	011159	3	
503412	011189	20	
503409	011190	2	
Totals		99	8

* Two Texaco invoices same number w/different # of barrel deposits?

1984

013012	010950	2	
5300	010964		3
503547	010981	20	
078277	011006	22	
6157	011060	5	
Totals		49	3

1985

6702	010721	4
078278	010723	10
078268	010724	10
11-05-?	010728	20
078276	010729	10
075875	010806	2
Total		56

1986

Note: This is the year that most invoices are missing. Instead there is a Purchase Order (continued) that is a type of synopsis of total products used.
From this synopsis it can be calculated that 71 / 120lb. grease drums were received, as well as 14 / 400 lb. grease drums for a total of 85 drums. Another 20 drums of transmission fluid, 45 drums of gear lubricant, 10 drums of EP-2 grease and another 40 drums of EP-220 oil were received. Altogether this amounts to **285 drums.**

Note: After 1986 barrel deposits and or returns appear to disappear from petroleum product invoices.

OF SPECIAL NOTE: Petroleum products were not the only thing that came in 55 gallon drums. If you look at the Troy discovery documents listing that I sent much earlier you find the following.
10. 5196-5222 Purchase Order sheets 300,000 lbs. Potassium Amyl Xanthate, pellet form packed 341 lbs. in 55 gal. drums. 7/91-12/93. **Sheet # 5207, item #4 discusses $20.00 drum deposit.** Sheet # 5217 itemizes sale of scrap metal from tailings area @ $25 / ton. Other scrap iron sales on other sheets.

The Potassium Amyl Xanthate (a frother) used at the mill came in approximately 870 barrels.

Some barrel deposit invoices (few in number & quantity) then begin to show up in 1990.

* 1981 - 86 — 554 BARRELS UNACCOUNTED FOR.

Attch (2)

Troy Story solvents use discovery doc. findings 7/9/04

Date / Year	Purchase Invoice	Legal file # (BATES)	Quantity
1979			
11/12/79	6006	011590	110 gal.
8-17-79	4157	011608	57 gal.
Total			167 gal.
1980*			
1-04-80	7308	011471	55 gal.
1-05-80	5109	011475	110 gal.
2-28-80	6955	011500	110 gal.
12-15-80	004	011511	220 gal.
6-10-80	7988	011558	110 gal.
6-05-80	7970	011559	110 gal.
5-19-80	7903	011563	220 gal.
Total			935 gal.

* Extensive and detailed itemization of barrel deposits and returns. #7752 / 011575 even lists "10 whole junk barrels."

1981*			
7-28-81	037	011374	110 gal.
6-24-81	023	011383	220 gal.
9-10-81	053	011422	220 gal.
9-15-81	8001	011424	220 gal.
Total			770 gal.

* Extensive and detailed itemization of barrel deposits and returns. #8669 / 011411 for 100 drums. Deposit of $2000
** Jan.-May and Oct.-Dec. invoices appear to be missing.

1982*			
1-21-82	142	011219	110 gal.**
3-03-82	1694	011254	220 gal.
5-03-82	201	011239	220 gal.
3-11-82	146	011255	110 gal.
6-07-82	223	011263	330 gal.
3-22-82	164	011275	330 gal.
Total			1310 gal.

* Indications barrels being returned for credit. See invoices 111 & 115 and others.

Invoice #098 / 12-31-82 indicates solvent barrel return for credit.
** Amoco Stoddard solvent.
Note: Period month invoices July – Dec. appear to be missing

1983*

1-07-83	3154	011074	500 gal.
6-08-83	3794	011124	142 gal.
7-06-83	3912	011150	1056 gal.
11-02-83	4704	011164	525 gal.
Total			2223 gal.

* Invoice 6974 only invoice showing / indicating barrel (8) return for deposit.
Note: Believe some invoices for period months Feb.- May and Aug. – Oct. missing.

1984*
* Approximately ½ invoices for 1984 photocopied at 200% causing it to be mostly impossible to tell what the product purchase is. Legible ones listed below.

2-01-84	4872	010919	210 gal.
3-08-84	5014	010943	478 gal.
7-09-84	5574	010993	474 gal.
10-05-84	6241	011018	520 gal.
11-20-84**	6544	011036	300 gal.
Total			1982 gal.

** Only invoice with (Hyd.) behind Solvent. Reference should be checked.
Note: Believe some invoices for time April – June may be missing.

1985*
* Approximately ½ invoices for 1985 photocopied at 200% causing it to be mostly impossible to tell what the product purchase is. Legible ones listed below.

7-01-85	7545	010818	300 gal.
8-06-85	7732	010819	480 gal
10-02-85	7995	010845	623 gal.
11-08-85	8165	010869	418 gal.
12-05-85	9692	010902	410 gal.
Total			2231 gal.

1986

***1986 file unlike others years had only 25 invoices. However, in the 1987 file one sheet was found that appeared to be a 1986 purchase order / all materials only solvent listed below.**

7-22-86	**26H-0488B**	**010513**	**3600 gal.**
Total			**3600 gal.**

1987

1-29-87	11158	010378	720 gal.
3-30-87	11479	010448	625 gal.
4-21-87	11557	010442	175 gal.
8-03-87	12216	010607	500 gal.
10-13-87	12741	010551	500 gal.
11-18-87	13130	010620	123 gal.
11-30-87	13215	010628	377 gal.
Total			3020 gal.

1988*

2-08-88	13775	008646	500 gal.
3-30-88	S206114	010187	540 gal.
5-02-88	S258856	010167	500 gal.
9-02-88	S3445830	0102433	400 gal.
11-4-88	S347078	010348	470 gal.
12-6-88	S34314?	010332	400 gal.
Total			2810 gal.

* May be missing some invoices period Jan. – Feb. & June – July.

1989

1-30-89	S347679	008692	380 gal.
3-02-89	S347951	008784	520 gal.
6-02-89	S346541	008862	500 gal.
7-10-89	15683	008909	15 cases*
7-24-89	S348901	008923	500 gal.
10-04-89	S34883	008983	500 gal.
Total			2400 gal.

* Only invoice on solvents by the case and with the designation that solvent is bio-degradable.

Note: Plenty of used oil return invoices.

1990			
2-12-90	S45906?	009077	500 gal.
5-03-90	S459236	009135	500 gal.
3-29-90	S458589	009158	410 gal.
7-24-90	S459372	009224	497 gal.
9-24-90	S460182	009344	500 gal.
11-14-90	L002438	009361	516 gal.*
12-28-90	126079	009858	**
Total			2923 gal.

*Notation on invoice reads:"Returned solvent to bulk plant."
Note: 1) Some drum return deposits and exchanges noticed.
2) Legal file # 009323 – 331 Safety-Kleen setup and product delivery sheets for all divisions of mine ops. (drill, main, ballmill, gas, lube room, secondary crusher). None of these noted in previous years, believe it indicates beginning use of Safety-Kleen services.
** Can not determine gal. or lbs. by sheet.

1991			
12-31-91	7566581	009516	1258 lbs.
1-25-91	449546	009836	1249 lbs.
2-09-91	797286	009903	946 lbs.
3-19-91	142929	009912	946 lbs.
3-21-91	L002805	009920	55 gal.**
4-18-91	490337	009894	946 lbs.
5-15-91	832912	009941	946 lbs.
6-13-91	182273	010068	1032 lbs.
?-17-91	532192	009928	1077 lbs. ***
8-13-91	974743	010054	1261 lbs.
9-11-91	324667	010033	1032 lbs.
10-10-91	78585	010010	1249 lbs.
11-05-91	032781	010124	1175 lbs.
12-03-91	388075	010091	1077 lbs.
Total			14,194 lbs.

* Can not determine amount of gal. to Safety-Kleen
**Not a Safety-Kleen ticket. City Service / Libby, MT.
*** Safety-Kleen ticket copy reprint offset. Paid Jul. 22, probably July ticket.

1992

1-29-92	101127	009570	1163 lbs.
1-29-92	101126	009571	72 lbs.
2-26-92	457973	009582	1077 lbs.
3-25-92	813-250	009598	991 lbs.
4-22-92	225898	009619	991 lbs.
4-22-92	225897	009620	72 lbs.
5-20-92	588356	009637	344 lbs.
5-20-92	M28869	009638	688 lbs.
6-17-92	953027	009675	1118 lbs.
7-15-92	317948	009729	1118 lbs.
7-15-92	317947	009730	72 lbs.
8-13-92	682651	009728	1290 lbs.
9-09-92	046194	009711	1118 lbs.
10-07-92	412064	009774	72 lbs.
10-07-92	412065	009775	1290 lbs.
11-02-92	777754	009806	1290 lbs.
12-02-92	142812	009784	1290 lbs.
Total			14,194 lbs.

*Note: 1 gal. Safety Kleen = 6.8 lb. Costs ran about $1.00 / lb.
* Safety-Kleen appears to be solvents from clean-up terminals???
Note: In reviewing these purchase orders it appears that during the use of Safety-Kleen services no solvents from other sources are being purchased or show up in records. However, the services of Safety-Kleen appear to be rather expensive compared to earlier purchase and use of solvents at mine.

1993

1-27-93	807586	009687	230 gal.*
3-24-93	46813	009480	192 gal.*
2-24-93	139239	009494	193 gal.*
Total			385 gal.

1997

4-23-97	1451	009449	1 drum* 6 drums**

* sorbents???? ** tank bottoms

1999			
9-28-99	934009	009440	30 gal.
2-18-99	841659	009441	30 gal.
Total			60 gal.

2000			
12-22-00	00014866701	009404	30 gal.
8-31-00	00013676781	009410	30 gal.*
5-16-00	00012496466	009412	30 gal.*
1-27-00	0011292014	009415	30 gal.
Total			120 gal.

* Safety-Kleen also attached appears to be waste disposal form for Petroleum Naptha.????

2001			
4-16-01	0017097842	009422	30 gal.*
8-06-01	0018239091	009419	30 gal *.
Total			60 gal.

* Safety-Kleen also attached appears to be waste disposal form for Petroleum Naptha.????

2002			
10-02-02	0021711374	009395	30 gal.
6-08-02	0020893939	009399	30 gal.*
Total			60 gal.

* Safety-Kleen also attached appears to be waste disposal form for Petroleum Naptha.????

2003			
12-19-03	0025003097	009383	30 gal.*
8-29-03	0024182332	009390	30 gal.
01-21-03	0022567153	009391	30 gal.
5-13-03	0023376874	009392	30 gal.
Total			120 gal.

NOTES:

1. From 1979 – 82 there are detailed and extensive records of deposits for barrels and returns of barrels for deposits. This radically changes from 1983 on when only one (1) barrel deposit is noted. After 1983 there are no invoices or documentation that indicate deposits are being placed on barrels or barrels are being returned for deposit.

2. Use of solvents doubles around 1982, doubles again in 1983 and appears to peak and level out in 1986-7 at perhaps 3000 gallons.

3.Safety-Kleen corporation comes on the scene about Dec. 1990, prior to this date invoices appear to indicate Asarco is handling purchase, use and disposal of solvents at Troy mine.

Attch. (3)

Troy Lawsuit Discovery Papers Report

BATES Doc. # Subject Remarks

1. 5000-5002 Requisition sheets Only 3 sheets (chemicals) might be useful to see all of them.

2. 5003-5029 Purchase Order sheets Some from 1988 – 91

3. 5030-5058 Purchase Order sheets Safety-Kleen Corp. for purchase and servicing of (3) solvent units used in cleaning mechanic shop parts. 1990-93. Monthly procedure that cost between $800-1500.

4. 5059-5061 Purchase Order sheets Appears to be for lab equipment etc.

5. 5063-5109 Purchase Order sheets Diesel, hydraulic oils, antifreeze and grease, 7/90 –7/91. P.O.S. #5096 for 1-55 Gal. Barrel of safety solvent, no I.D of what type.

6. 5110-5113 Purchase Order sheets Dowfroth 2500 & Orzana 4/90 – 1/91.

7. 5114-5120 Purchase Order sheets Drill grease 7/90 – 5/91

8. 5121-5173 Purchase Order sheets Diesel fuel, oil, transmission fluid and other lubricants. Lubricant comes in 120 lb. barrels.

9.5174-5195 Requisition sheets Antifreeze, diesel, motor oil and used oil pickup. Assorted dates 1993-97. None from before shutdown in 1993.

10. 5196-5222 Purchase Order sheets 300,000 lbs. Potassium Amyl Xanthate, pellet form packed 341 lbs. in 55 gal. drums. 7/91-12/93. **Sheet # 5207, item #4 discusses $20.00 drum deposit.** Sheet # 5217 itemizes sale of scrap metal from tailings area @ $25 / ton. Other scrap iron sales on other sheets.

10.1 5213-14 Purchase Order dated 1/5/92 Safety-Kleen concerning mineral spirits solvents and maintaining 12 machine site wash tanks. Service: solvent replacement, removal, cleaning tanks, waste removal.

11. 5223-5228 Halogenated solvent registration, # 1118 MT Dept. Health & Environmental Services. Registration / reporting form signed by Terry Erskine 10/3/89. Doug Lorentzen listed as Maintenance Supervisor to whom questions may be directed concerning solvent use at facility. **Indicates use of at least 440 gallons per year of halogenated solvents,** w/discharge to drywell, septic tank, lagoon or other industrial sewer.

Note: MDEQ publication "The Small Business Handbook for Managing Hazardous Waste (2/02) on page 9 states: "Small generators may not dispose of hazardous wastes on their property ***without*** *a permit issued by the MDEQ."*

12.5229-5262 Of note: #5244 Letter 11/14/96 about 500 lbs. used grease stored at mill from 4/93 shutdown. Disposed of on 3/94.

#5247, **Material Safety Data Sheet about Surtac Plus (Trichlorethylene), CAS 799-01-6, black paste with solvent odor.** *This wording precisely validates Jim Meyer's description of the contents he claims was in barrels buried at the Troy tailings impoundment.*

13. 5263-5410 Of note : #5295 Field Investigation Report 2/18/93 about Hazaardous Waste Manifest for shipment of 2,225 lbs. of D001/D008 wastes shipped to Romic Chemical Co., Palo Alto, CA. **Shipment of special solvent used to clean ball mill.**

#5297 Memorandum 2/19/93 Re: inspection by Bob Reinke, Solid & Hazardous Waste Bureau. Item. # 4 concerning underground storage of barrels.

#5307 Letter 9/12/91 from DHES to L. Erickson / Asarco about requirement of large and small hazardous waste generators to maintain log books or similar documentation. ***Want to make sure we ask for this log-book.***

#5309 Field Investigation Report, daated 10-28-91, Robt. Reinke. Of note: Discussion on floor drains in last para. Last paragraph, incomplete sentence, " Floor drains do not???????? Following page is missing.

#5317 Memo to file from L.A. Erickson (Unit Manager) dated 8/23/90 concerning inspection by Robert Reinke (MDEQ). **(B) "Solvent tanks / disposal in 55 gal. barrels."**

#5317 Memo to File from L..A Erickson, R.e. Montana Solid & Hazardous Waste Bureau concerning Robt. Reinke inspection of 8-22-90. Item (I)(B) "Solvent tanks / disposal into 55 gal. barrels ? Moore Oil hauls away?. Jan. – Aug. used 1600 gal. 2500 gal./ yr.(1990)."

#5328 Letter from Robert Reinke (DHES) 10/1/90 to L. Erickson. 1. Asarco Troy generating @12,940 lbs. of stoddard solvent per year. Asarco must justify haz-waste exemption or submit notification as small generator. 2. Asarco four drum of stoddard solvent sent to Moore Oil of Libby that qualified as hazardous waste. Moore Oil not allowed to handle such material. "Stoddard solvent is a hazardous waste." ***What was eventual disposition of 4 barrels of stoddard?***

#5330-31 Field Investigation Report (R. Reinke / DHES) 8/22/90 discussing waste practices. Mine generates 2000 gal. stoddard product per year. **6 / 55 gal. barrels (used for stoddard) stored behind shop. Lee McKinney explanation of waste management for assay lab.** Spent acids discharged to float machine.

#5341-43 Solvent consumption sheets. Great explanation: "Trichlorethane – Chlorethane sp. gr.=1.320, consumption: 440 gal. in 1987 = 37 gal. / mo.= 404 lb./mo. Disposal; evaporates; "? sludge goes into sewage treatment facility then to?"

#5344-45 Document dated 7/6/88. Reagents used at Troy Unit regarding Toxic Substances Control Act. #7. Chlorothane (1,1,1, **Trichlorethylene, usage: 450 gallons / yr.** #8 Varasol, solvent / degreaser, usage: 3600 gal. / yr. #9 Stench (Ethanol trichchloroflourmethane, usage 22 lbs. / yr.

#5346 Letter Asarco 7/19/79 Toxic Substances Control Act sheet for various NW mining divisions of Asarco. Couer Unit usage of 1600 lbs. sodium cyanide / yr., Galena Unit 2250 lbs. sodium cyanide / yr., Leadville Unit 10,000 lbs. sodium cyanide / yr.

 # 5350 Material Safety Data Sheet from Dow Chemical concerning Chlorethene VG ® Solvent. Warnings: "Keep out of water supplies. Dumping into sewers, on the ground, or into any body of water is strongly discouraged, and may be illegal."

14. 5411-5634
#5411 Memorandum 7/9/97 Joe Luchini / Asarco; concerning Hazardous Waste disposal at Libby landfill and disposal of vehicle oil filters. Not to be done in one large amount at one time. *Which begs the question of how they were being disposed of at the mine while it was in operation?*

#5414-32 Small Generator Annual Haz-waste Report Form to MDHES for 1993. #5415 speaks to Safety-Kleen issue and Petroleum Naptha waste.
#5431 Part Two (waste description sheet) of 1993 haz-waste Report Form to MDHES. Other chemicals, Trichloroethylene, Toulene, Sodium Hydroxide. Trichloroethylene waste amount generated 155 lbs. (8 lbs. / gal.) and amount shipped off-site, 155 lbs. does not square with (Item 13, #5344-45 which indicates 450 gallons of Trichloroethylene usage annually. *Explanation and reconciling needed!*

#5433-46 Small Generator Annual Haz-waste Report Form to MDHES for 1992.

#5434 Waste description sheet: Waste Petroleum Naptha Combustible Liquid amount generated 14,886 and amount shipped Off-site 14,886 is considerable and worthy of note!
#5446 Part Two (waste description sheet) reporting on Tetrachloroethylene, Toulene, Sodium Hydroxide. **Tetrachloroethylene waste amount generated 155 lbs. (8 lbs. / gal.) and amount shipped off-site, 155 lbs. does not square with (Item 13, #5344-45 which indicates 440 gallons of Trichloroethylene usage annually**. *Explanation and reconciling needed!*

#5470-84 Small Generator Annual Haz-waste Report Form to MDHES for 1991.

#5472 Waste description sheet: Waste Petroleum Naptha Combustible Liquid, 14796.

No other haz-waste reported, No Part Two waste description sheet for Trichloroethylene, Toulene, Sodium Hydroxide. Hard to believe use of such chemicals at mine would have changed so radically. Explanation and reconciling needed

#5485-93 Small Generator Annual Haz-waste Report Form to MDHES for 1990.

#5487 Waste description sheet. Waste Petroleum Naptha Combustible Liquid, 5209. *No other haz-waste reported, No Part Two waste description sheet for Trichloroethylene, Toulene, Sodium Hydroxide. Hard to believe use of such at mine would have changed so radically. Explanation and reconciling needed*

#5545- Invoice & Report for Professional Services / Maxim Technologies. "Chemical analysis of soil for Benzene and TCLP Metals. ***Invoice is addressed Ken. O'Toole, Northern Lights, Inc., P.O.B. 310, Sandpoint, ID 83864.*** Appears to be related to work done at Troy mine.

#5576-5634 Asarco letter dated 7/3/96 Environmental Practices Survey for the IRRC Environmental Profile on Asarco's Troy Unit. "A possible omission to the supporting detail for the IRRC profile is an environmental lawsuit filed against the Asarco Troy Unit (EPA ID. No. MTDO96199989). The accusation states water is being discharged from the tailings impoundment area without an MPDES permit."

#5583 Para. 6. Discussion on severe water pollution at Squirrel & Kerber Creek Mine near Bonanza, CO. "The wastewater, which resulted from the mine contamination, contains 75 times the safe level of iron, and may cost up to $10 million to cleanup.(RMN7/26/94)

#5619 40CFR Ch.1 (7-1-91 Edition) Subpart D – Record-keeping and Reporting 262.44 (a) A generator must keep a copy of each manifest signed in accordance with 262.23(a) for three years or until he receives a signed copy from the designated facility which received the waste.

15. 5663-5754
#5663-66 Asarco letter 3/17/82 Dean Knight to R.Thorvilson DHES to the effect that "Asarco's Troy Unit is a mining operation excluded from regulation by the Bevill Amendment." Clarification of Status form. X on "The following temporary exemptions of ARM 16.44.304 (and 40CFR 261.4) remove the need for hazardous waste management facility status for my business."

#5667-8 Asarco letter 8/12/80 Jack Bingham to EPA Region VIII. Notification of Hazardous Waste Facility, Troy Unit, Asarco, Inc.

#5742-49 Asarco letter to All Plant Managers dated 7/30/80 concerning Chemical Substance Inventory program initiation. #5744-49 are an example of all substances

/materials used by Wallace Office. *Troy mine would / should have one of these and we should ask for it. Lists all substances and suppliers..*

16. 5755-5867 Safety-Kleen Corp. service & delivery sheets 7/99 through 12/90.

17. 5868-6008
#5922 Attention Jack Tuholske: American Cyanamid Invoice (6/29/84) for 13 tons Aluminum Sulfate. Important for Rock Creek MPDES permit that dropped Aluminum monitoring criteria.

#5924 City Service Co. / Libby, MT. Invoice for bulk solvent @ 474 gallons.

#5944 Attention Jack Tuholske: Univar Co. Invoice (8/6/84) for 4000 lb Aluminum sulfate Gran. Same as 5922.

#5954 City Service Co. / Libby, MT. Invoice (10/9/84) for 4 barrels Unoba A2 grease. I believe this is one of the lithium greases used.

#5957 City Service Co. / Libby, MT. Invoice (10/5/84) 520 lbs. or gal. Solvent Rel.

#5969 City Service Co. / Libby, MT. Invoice (11/20/84) 300 lbs. or gal. bulk Solvent (Hyd).

#5993 City Service Co. / Libby, MT. Invoice (12/21/84) Gear lube 2,460 lbs.

#5995 Attention Jack Tuholske: Van Waters & Rogers / Univar. Invoice (12/21/84) 912 - 50 lb. bags of Aluminum Sulfate. Same as #5922

#6002 Attention Jack Tuholske: Van Waters & Rogers / Univar Invoice (10/31/84) 25-100 lb. bags of Aluminum Sulfate Gran. Same as #5922.

#6005 Nalco Chemical Co. Invoice (10/25/84) 7-55 gal. barrels Nalco 3DD758 Liquid D8D. ***Only Invoice found signed for by Lee McKinney.***

18. 6009-6129
#6048 Asarco memo concerning EPA inspection by Charles Frank Stagsdell of 5/14/81 Stan Stoker (electrical foreman) to Jack Bingham concerning EPA inspection of electrical equipment that may contain PCB's. *Interesting persecution complex letter for the times.*

#6116-8 Hazardous Waste Manifest 8/19/94 transport of PCB's from Troy mine, App. 260 gallons and 5 transformer carcasses.

#6124-29 Six forms of some sort indicating testing of PCB contaminated transformers. Notation at bottom of each: "Letter from Continental No PCB's 9-18-80. Tested 4/25/86 56-360 PPM Contaminated." *Note #6124-29 indicates 6 contaminated transformers and #6116-8 is invoice for removal of 5 carcasses.*

19. 6130-6362
#6130-38 Asarco PCB distribution list. #6138 (4) "Drained and decontaminated carcasses from PCB transformers and soil, rags and other debris (at any conc. PCB's) can be landfilled. *Does this include landfilled within a tailings impoundment?*

#6157 Asarco letter 6/20/95 D. Young – Mike Balboni (USFS) concerning 5 PCB transformers at Troy mine.

#6189 Bid from Continental Transformer Services Inc.(5/20/94) to remove PCB contaminated transformers. Retrofill / $23,370. Disposal / $18,065.00.

#6191 Transformer status & location sheet.

#6205-6 Asarco letter 6/9/94 New bids to remove PCB contaminated transformers. Half as expensive.

#6282 Low concentration PCB spill clean-up certification. *Clean-up done with Triclorethane.*

#6283 EPA Inspection report 7/25/90 on leaking transformers. Sheet indicates seven (7) leaking transformers. *See #6116-8 and #6124-9 for discrepancies.*

#6295 Manifest Number 510068. PCB debris drum content from Coeur, Galena and Troy operations.

#6297 Letter (6/6/91) from Ensco to Asarco about PCB debris pick-up and cost / 1-55 gal. bbl. $1200.

#6302 Asarco Letter 7/27/90 to EPA concerning low-concentration PCB oil stain on two transformer & clean-up.

20. #6363-6414 NA

21. 6415-6844 #6443-4 Industrial Hygiene & Toxicology Data Sheet. Trade name: Super Permalube Grease, important components: **Lithium thickener.**

#6445-6 Industrial Hygiene & Toxicology Data Sheet. Trade name: Amoco Lithium Multi-Purpose Grease, important components: **Lithium thickener.**

#6513-16 Copper concentrate: attention to Jim Meyer's symptoms.

#6544 J.T. Baker Chemical Co. / Barium nitrate / oxidizing agent. Material Safety Data Sheet, Attention: Summit Envirosolutions.

#6552-55 J.T. Baker Chemical Co. / Barium Chloride, Dihydrate. Material Safety Data

Sheet, Attention: Summit Envirosolutions.

#6640-43 J.T. Baker Chemical Co. / Sodium Cyanide, Material Safety Data Sheet.

#6672-74 Cyanamid / Material Safety Data sheet: Superfloc 355 Flocculant. Waste Disposal: "Disposal must be made in accordance with applicable government regulations."

22. 6853-7186 #6853 Material Safety Data Sheet. Product name: Chlorothene ® SM Solvent.

#6942 Material Safety Data Sheet. Product name: EutecTrode 2101. Ingredients: **Lithium Chloride 1-5%.**

#6960-1 Material Safety Data Sheet. Chemical name; Sodium Thiocyante. Trade name: Sodium Sulfocyante.

#7025-26 Fiske Brothers Refining Co. / Material Safety Data Sheet. Product name: Lubriplate Gear Shield. Formula: **Lithium soap**, mineral oil, and additives.

23. 7187-7717
#7244-45 Material Safety Data Sheet. Product name: Hi-Tri ® Solvent / Ingredient: **Trichloroethylene.**

#7247-8 Material Safety Data Sheet. Product name: Cool It. Formula: **1,1,1, Trichloroethane.**

#7330-33 Material Safety Data Sheet. Product name: **Sodium Hydroxide**. Waste disposal method: PPG recommends disposal of neutralized material in an approved hazardous waste management facility.

#7410-11 Transco NW. Inc. Product name: SC2000 / rubber adhesive. Formula: rubber compound kept liquid with **trichloroethylene.**

#7414 Shell Oil Co. Material Safety Data Sheet., Product name: Shell Alvanla ® Grease 2. Hazardous ingredients: **Lithium soaps.**

#7455-58 Thermacote Welco Co., Material Safety Data Sheet, Product name: Welco 1620 Anti-Spatter, Hazardous mixtures: *Specifically, **Trichlorothane III.**

#7459-61 Technichem Corp., Material Safety Data Sheet (MSDS), Product name: Heavy Duty Hot Tank Powder, Hazardous mixures: **Sodium Hydroxide 70-90%, Sodium Metasilicate 10-20%.**

#7464 Thatcher Chemical Company, Material Safety Data Sheet, Product: Aluminum Sulfate Solution. Attention: Jack Tuholske, RCM MPDES permit.

#7470-73 Tip-Top Stahlgruber, MSDS, Product name: SC-2000 Cement, **Chemical Characteristic: Trichlorethylene.**

#7485-87 Texaco Inc. MSDS, Product name: 01922 Molytex EP 2, **Chemical / Common Name: Lithium 12-hydroxystearate.**

#7491-93 Texaco Inc., MSDS, Product name: 921 Multifax EP1, **Components: Lithium Hydroxide CAS# (1310-65-2) 0.8%.**

#7494-97 Texaco Inc., MSDS, Product name: 995 Multifax EP2, **Components: Lithium hydroxide 4-10.99% CAS # (1310-65-2)**

#7498 Texaco Inc. **Dear Customer letter 2/10/87 to Asarco, P.O.B. 868, Troy, MT 59935** "Enclosed are Industrial Hygiene, Toxicology, and Material Safety Data Sheets for Texaco products you recently purchased."

#7515-17 Texaco Inc., MSDS, Product name: 01970 Crater 2X Fluid / Gear lubricant, Precautionary label: **Contains 1,1,1,-Trichloroethane.**

#7518-20 Texaco Inc., MSDS, Product name: 1970 Crater 2X Fluid / Asphaltic lubricant, **Composition: 1,1,1, Trichloroethane 18.5%.**

#7521-23 Texaco Inc. MSDS, Product name: 958 Marfax Multi-purpose 2 (grease), **Composition: Lithium Hydroxide 0.78%** CAS#(1310-65-2)

#7524-26 Texaco Inc. MSDS, Product name: 901 Multifax EP 0 (grease), **Composition: Lithium Hydroxide 0.6%** CAS#(1310-65-2)

#7561-63 Texaco Inc. MSDS, Product name: 00958 Marfax Multi Purpose 2 (grease), **Chemical / Common Name: Lithium 12-hydrosstearate 4-10.99%**

#7589-91 Texaco Inc. MSDS, Product name: 1939 Premiiium RB Grease, **Composition: Lithium 12-hydroxystearte 15-20%.**

#7668-71 Vulcan Chemicals MSDS, Product name**: Trichloroethylene 100%**

#7688-90 The Whitmore Manufactoring Co. MSDS, **Product name: Surtac Plus / black paste w/solvent odor, Trichlorwthylene, CAS (79-01-6)**

24. 7718-39 NA

25. 7740-7771
#7746 Used grease and oil pickup sheet 1/9/1991- 11/5/94. Other miscellaneous similar sheets. No data sheets prior to 1991.

26. 7772-7803 Water Pollution Prevention, Spill Prevention and Countermeasure Plan (SPCC) for Asarco Troy Unit.

#7773 Memorandum Brian Hansen (MFG) to Dave Young (Asarco) " I have reviewed SPCC plan..... *The plan indicates that gasoline, diesel fuel, oil, used oil, cleaning solvent and calcium hypochlorite are used on site. I was only able to find discussions on how the diesel fuel and used oil are handled and stored. It would be helpful to briefly discuss how the other substances are handled and stored. * The sections on Inspections and Records and Personnel, training and spill prevention procedures [corresponding to 40 CFR Part 112.7(e)(8)(i) and (e)(10)(iii), page 5 of the plan] should note that records are kept concerning the inspections and training."
It might be beneficial to ask for these documents (Inspections & Records) and maybe even Personnel!

27. 7804-7874 Reagent Consumption Use, Grinding Media and Power Use 1984-1993. Notes for Jack Tuholske: Aluminum Sulfate use begun in milling process in Dec. **1984.** During a period of 7 months in **1985** Aluminum Sulfate use averaged 9 ton per month. Also grind ball size & use varies considerably. ALL indications of some experimentation. July of **1986** work with Aluminum for water clarity completed. Still experimenting w/ milling process. Frother mix replacement.

Last three months of **1987** experimentation w/grinding medium (ball size).

1988, 89 & 90 Reagent Consumption Use, Grinding Media and Power Use **MISSING**???
See e-mail of 2/5/04 to Jim Kuipers, cc: Bechtold & Rossbach.

1991 Lot of play in the flocculant field.

1992 Not a lot to tell.

1993 Only 3 months of real operation.

28. 7875-7887 Flotation tailing report sheets. ????

29. 7888-7907 Distribution letter concerning Federal Rail Administration / DOT inquiries as to Asarco shipments of Hazardous Waste via rail, primarily heavy metals and contamination.

30. 7908-8636 Filler junk. NA

Recommendations for FURTHER DISCOVERY REQUEST and other questions.

A. See # 9. Should ask for "Requisition sheets" for all oils, grease and lubricants from 1981-93.

B. See #10. Purchase of Potassium Amyl Xanthate. Quantity use confirmed by Reagent Consumption Use sheets indicate at least 900+ / 55gal. barrels came into plant with this product alone. If there was a $20 barrel deposit as indicated then Asarco was ponying up $18,000 in deposit money per year on this reagent alone. This is enough deposit money to want to recover. There would have to be some methodology for tracking the return of all these barrels to recover the deposit. **DISCOVERY.**

C. See #11. Question; are the halogenated solvents described Trichloroethylene?

D. See #13 / **5307** Hazardous Waste logbook described in this document. Request copy through **DISCOVERY.**

E. See #13 /#5330-31 Field Investigation Report (R. Reinke / DHES) 8/22/90 discussing waste practices. Mine generates 2000 gal. stoddard product per year. **Lee McKinney explanation of waste management for assay lab.** Spent acids discharged to float machine. *This possibly corroborates some of Greg's testimony about lab waste reporting to tailings impoundment via tails thickener.*

#5341-43 Solvent consumption sheets. Great explanation: "Trichlorethane – Chlorethane sp. gr.=1.320, consumption: 440 gal. in 1987 = 37 gal. / mo.= 404 lb./mo. Disposal; evaporates; ? sludge goes into sewage treatment facility then to?"
See 11 above.

F. See #14 / **#5431 Part Two (waste description sheet) of 1993 haz-waste Report Form to MDHES. Other chemicals, Trichloroethylene, Toulene, Sodium Hydroxide. Trichloroethylene waste amount generated 155 lbs. (8 lbs. / gal.) and amount shipped off-site, 155 lbs. does not square with (Item 13, #5344-45 which indicates 450 gallons of Trichloroethylene usage annually**. *Explanation and reconciling needed!* **DISCOVERY.**

G. See #14 /#5470-84 Small Generator Annual Haz-waste Report Form to MDHES for 1991.
#5472 Waste description sheet: Waste Petroleum Naptha Combustible Liquid, 14796.
No other haz-waste reported, No Part Two waste description sheet for Trichloroethylene, Toulene, Sodium Hydroxide. Hard to believe use of such chemicals at mine would have changed so radically. Explanation and reconciling needed

#5485-93 Small Generator Annual Haz-waste Report Form to MDHES for 1990.
#5487 Waste description sheet. Waste Petroleum Naptha Combustible Liquid, 5209.
No other haz-waste reported, No Part Two waste description sheet for Trichloroethylene, Toulene, Sodium Hydroxide. Hard to believe use of such at mine would have changed so radically. Explanation and reconciling needed

DISCOVERY : We want to know if Trichloroethylene was purchased and used in these years. Relate to A & D above that might answer this question. If it was purchased and

used as in previous years then at least 155 gallons should show up as having gone to hazardous waste site as per F above.

H. See #15 / #5742-49 Asarco letter to All Plant Managers dated 7/30/80 concerning Chemical Substance Inventory program initiation. #5744-49 is an example of all substances /materials used by Wallace Office. *Troy mine would / should have one of these and we should ask for it. Lists all substances and suppliers.* **DISCOVERY**

I. See #18 / #6124-29 Six forms of some sort indicating testing of PCB contaminated transformers.
Notation at bottom of each: "Letter from Continental No PCB's 9-18-80. Tested 4/25/86 56-360 PPM Contaminated." *Note #6124-29 indicates 6 contaminated transformers and #6116-8 is invoice for removal of 5 carcasses. This could relate to unsolicited EPA brochure sent to CRG from EPA Region VIII, Denver.*

J. See #25 / **25**. 7740-7771
#7746 Used grease and oil pickup sheet 1/9/1991- 11/5/94. Other miscellaneous similar sheets. No data sheets prior to 1991.

Relate back to # 13 / #5328 Letter from DHES 10/1/90 to L. Erickson / Asarco four drums of stoddard solvent sent to Moore Oil of Libby that qualified as hazardous waste. Moore Oil not allowed to handle such material. *Possibility that Moore Oil of Libby was regularly picking up stuff they shouldn't have been.*

Appendix B
Mine Water Balance Analysis

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Memorandum

To: *Emily Corsi, Herb Rolfes, DEQ*

From: *Bill Bucher, Kim Chase - CDM*

Date: *April 12, 2010*

Subject: *Mine Water Balance Analysis - Troy Mine*

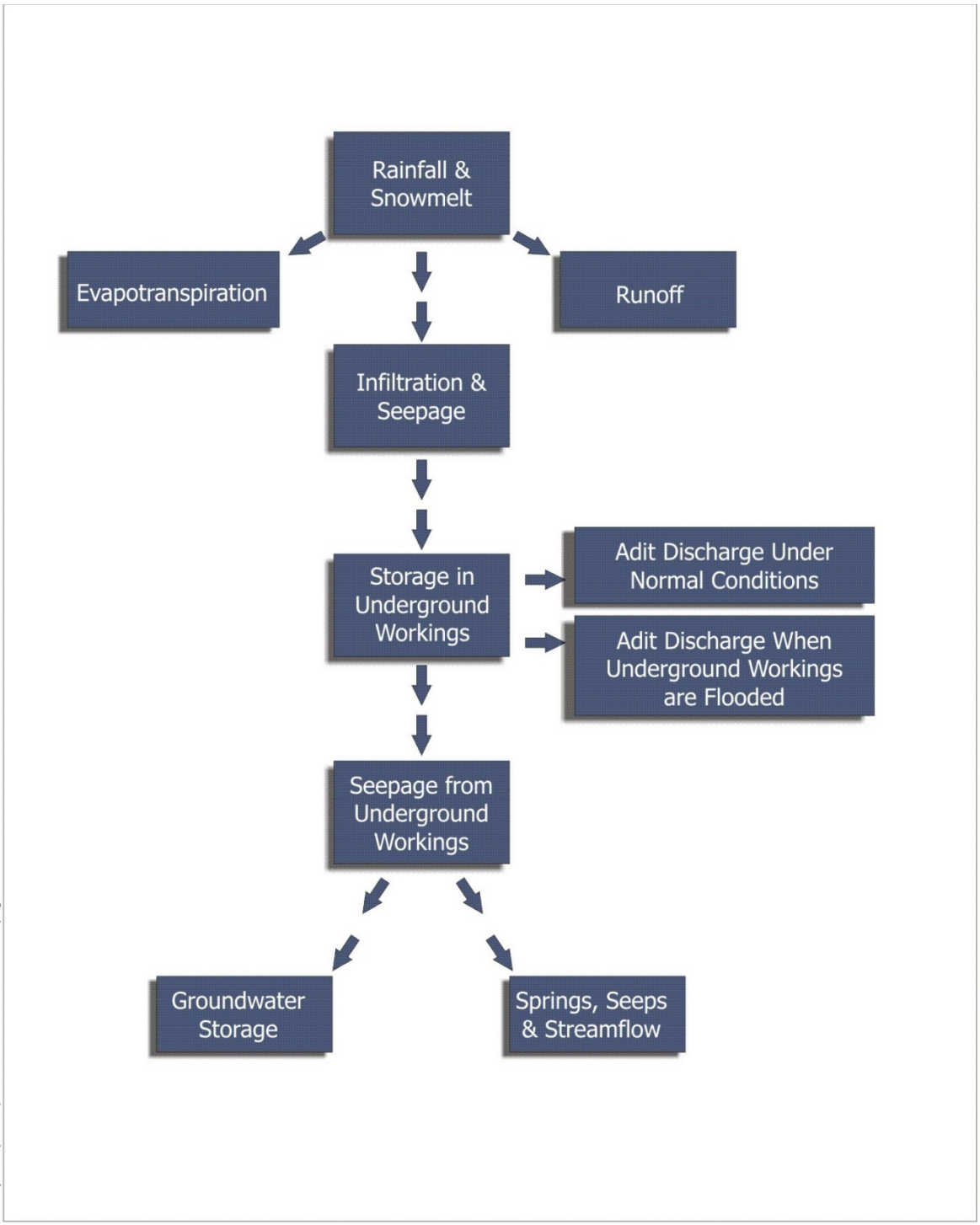
CDM has been retained by the Montana Department of Environmental Quality (DEQ) to develop a water balance model for the Troy Mine to predict expected discharge from the mine workings, if any, after mine closure. The purpose of this memorandum is to present the results of our analysis of existing data that we used to predict whether the Troy Mine will fill with water after pumping ceases to a level that will allow discharge of mine water to the surface. If the mine workings are predicted to discharge, how long it will take to do so and how much discharge may be expected will also be predicted. A review of the existing data and the conceptual water balance are available in a Technical Memorandum prepared by CDM dated January 16, 2009.

The Troy Mine is an underground copper and silver mine located south of the town of Troy in Lincoln County, MT. ASARCO began operating the mine in 1982 and halted production in 1993 due to low metals prices. The mine was sold to Revett Silver Company and production resumed under Genesis, a subsidiary of Revett, in 2005. In 2006, Genesis submitted a Revised Reclamation Plan, for which an Environmental Assessment (EA) must be completed. In support of the EA, this Memorandum assesses the possibility of mine flooding discharging to the surface.

Conceptual Water Balance Model

The conceptual water balance is shown in Figure 1 and is discussed in detail in the January 16, 2009 Technical Memorandum. The water that enters the mine all originates as rainfall or snowmelt above or near the underground workings. This precipitation, minus the portion lost to evapotranspiration, overland or subsurface runoff, enters the groundwater system adjacent to the mine workings and potentially seeps through the mine walls or enters fractures that connect to the mine. The water received by the underground workings may be held as storage or it may seep out through fractures or porous formations. If the underground workings are flooded, water may discharge from the service adit, the lowest

Figure 1. Conceptual Model of Mine Water Balance



potential connection to the surface. Under normal conditions, there is some discharge from the service adit due to water entering from the adit walls and back. It is only the water entering or leaving the mine workings that is of concern in this analysis of whether the or not the mine workings will flood to an elevation which will result in discharge from the mine workings via the service adit.

The conceptual model of mine flooding developed in this study is based on the following assumptions about groundwater in the vicinity of the mine:

- The geology of the rock around the mine workings is fractured metamorphic rock, which allows significant flow through the fractures.
- The aquifers adjacent to the mine workings are local, unconfined aquifers which have the potential to fluctuate rapidly in response to precipitation and runoff patterns as well as mine dewatering activities.
- If pumping ceases and water levels recover, there is a potential for water to discharge through the service adit at a known elevation (4225 ft.).

Figure 2 is a conceptual drawing of a flooded mine that will discharge through an adit. In this scenario, water levels have recovered to an elevation sufficiently high to permit overflow through a discharge point, in this case the service adit of the Troy Mine. Figure 3 shows an alternate scenario in which the recovered water level remains below the overflow point and the mine does not discharge. Determining which scenario occurs in the future after pumping has ceased depends on the recovered elevation of the local aquifer. This is essentially a groundwater analysis problem, which requires an understanding of the local geology and aquifers that we do not have. Therefore, the ability to analyze this problem completely is compromised, and we are limited to the storage data collected by the mine operators to interpret the potential behavior of the local systems under future conditions.

Methods

Because no quantitative information is available about the groundwater conditions surrounding the underground workings, it is not possible to directly calculate the mine water's effect on the surrounding water table. Additionally, there is no way to calculate the magnitude of flows into the underground workings or natural seepage out of the workings. However, it is possible to calculate the difference between inflow and outflow from the change in storage over a given time period. The basic method employed here is the analysis of mine inflow volumes as determined from the pumping rates and storage changes measured by the mine operators through the years. The inflow to the mine workings can be defined as the pumping rate plus the change in storage:

Figure 2. Conceptual Model of Mine Discharging through Adit

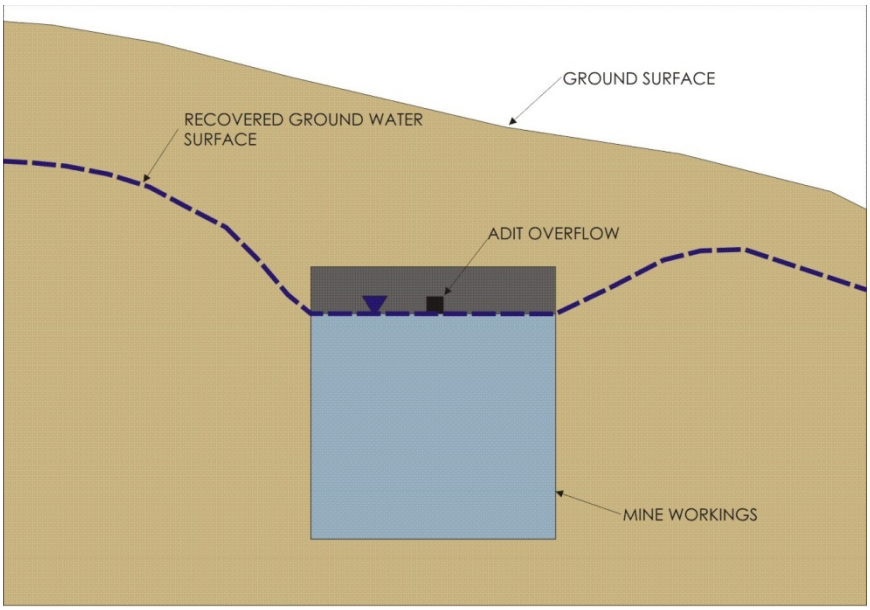
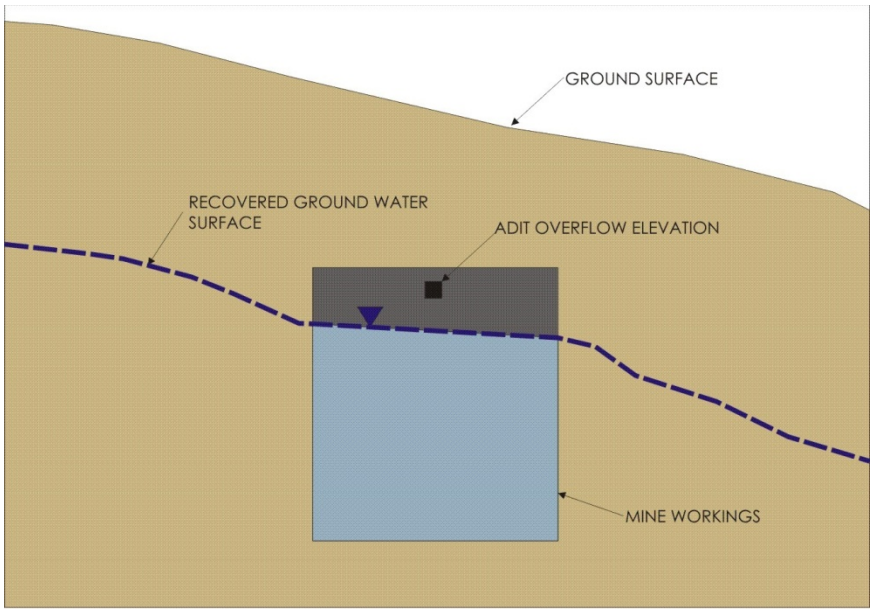


Figure 3. Conceptual Model of Mine without Discharge to Surface



$$I = Q_p + \Delta S$$

Where:

I is the mine inflow for the period
Q_p is the pumping rate for the period
ΔS is the change in mine storage for the period.

It is possible that portions of the mine discharge to the surrounding formations where the local water table is below the mine water elevation. This potential is highest when the mine pool is at a high elevation and the local aquifers are depressed after a dry period such as normally occurs in late summer. However, records indicate that this mine generally receives inflow in excess of any outflow, and in this analysis we will use the term mine inflow to mean the net difference between inflow and outflow from the mine workings.

Relationships for inflow were established based on the hypothesis that inflow to the underground workings would be dependent on rain and snowmelt amounts and on water levels in the underground workings. Rain and snowmelt, acting through the groundwater pathway, are believed to be the primary source of water input to the underground workings. When groundwater levels are higher, it follows that the head difference between water in the underground workings and the surrounding groundwater is greater and, therefore, inflow to the underground workings will be greater. Therefore, inflow is proposed to be a function of both recent rain and snowmelt and the elevation of the local groundwater surface:

$$I = f(R, H)$$

Where R is a rainfall and snowmelt and H is a measure of head difference between the mine pool and the local aquifer. The sum of rainfall plus snowmelt is a logical measure of water that has potential to enter the mine. To show that the inflow to the underground workings is related to rainfall and snowmelt, inflow was plotted for each year alongside rainfall and snowmelt.

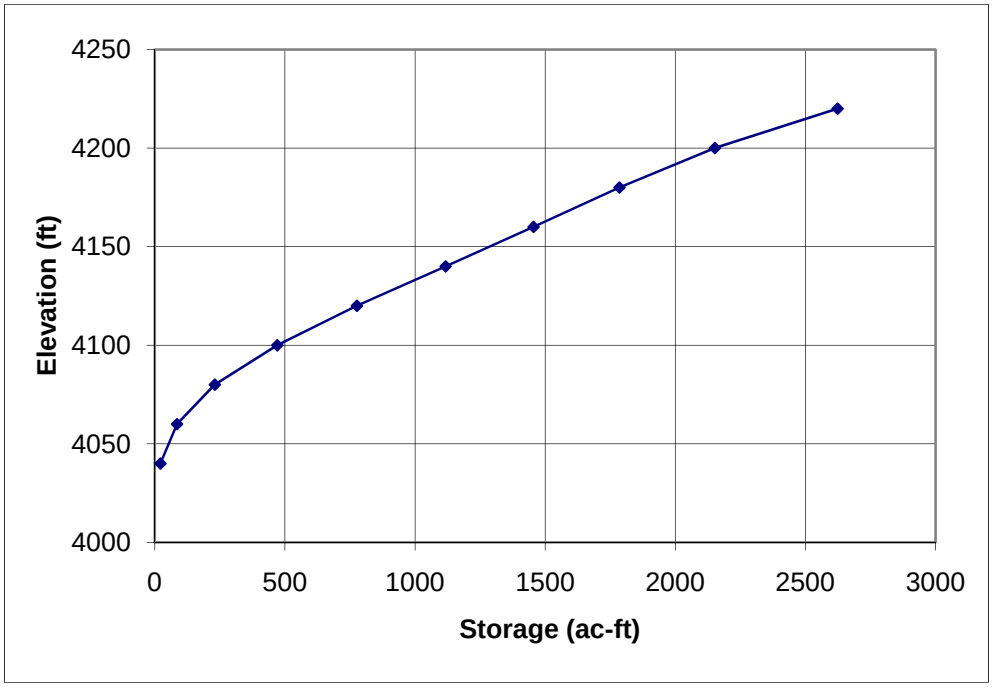
Rain and snowmelt was plotted against inflow over several different time-scales to determine the most appropriate time scale for analysis. This resulted in a method for predicting the inflow to the mine for any precipitation/runoff condition. For the annual time scale, an average value of total rain plus snowmelt was used as the input variable for the years 2004 through 2008 giving a set of four different inflows for these years. Then the actual value of inflow for each year was compared to the value predicted by the linear correlation. This predicted inflow was then plotted against the average water elevation in the underground workings during each year. A second linear correlation was then calculated for inflow as a function of water elevation and was used to predict the expected effect of water level on the change in storage.

With this information, it is possible to estimate the potential for surface discharge from the underground workings and the expected outflow. Further calculations can predict the time until discharge with an assumed initial mine pool elevation and typical precipitation conditions.

Analysis and Results

Our analysis of mine water levels relies on the elevation-storage curve developed by Genesis, Inc. (2004) which is shown in Figure 4 after conversion to acre-feet (ac-ft). This relationship is based on mine surveys of the extent of workings at sequential elevations in the mine with allowance for remaining pillars.

Figure 4. Water Elevation vs. Storage Relation for Troy Mine

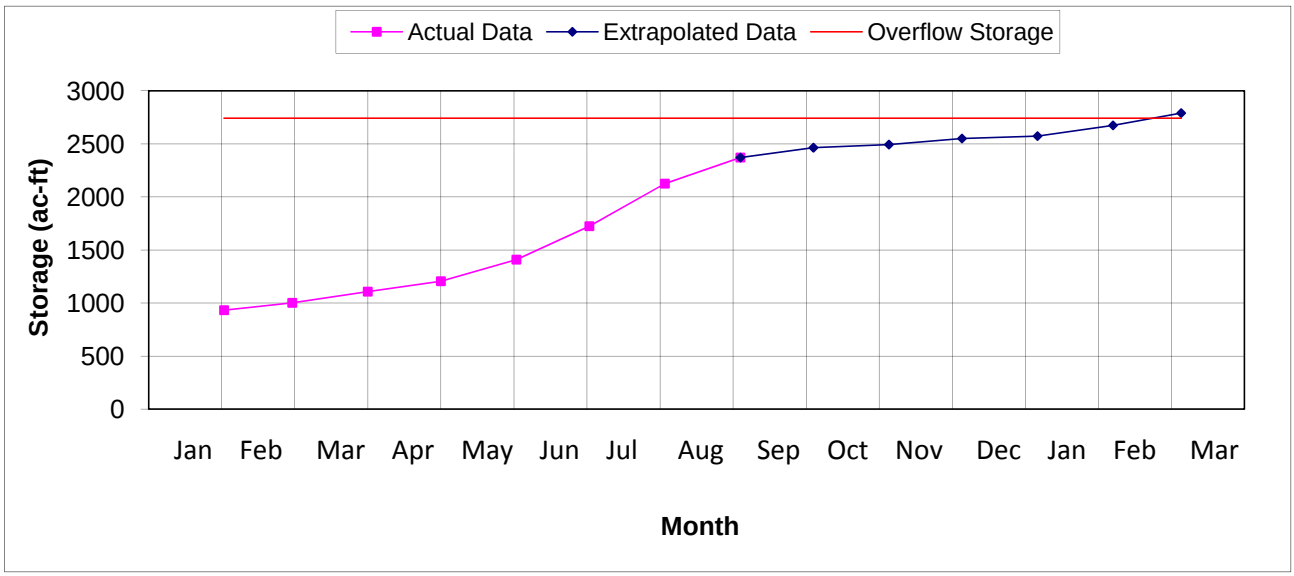


Potential for Mine Flooding

The discharge of mine water from a flooded mine appears to be a real possibility based on data collected in water year 2003 when mine pumping did not occur. Figure 5 plots cumulative mine water storage from January 2003 through August 2003 (end of month values). At the end of August 2003, the storage volume was 2371 ac-ft, which corresponds to an elevation of 4209 ft, the highest recorded water level in this portion of the mine. This level is just 16 feet short of the adit overflow elevation of 4225 ft. In September pumping resumed, the storage volume did not exceed 2371 ac-ft, and pumping continued at a higher rate into 2004, decreasing the storage volume. If the pumping volumes are added to the cumulative volume at the

end of August 2003, it is seen that the storage volume could have continued to increase, potentially exceeding the storage volume of 2,742 ac-ft (corresponding to a discharge elevation of 4225 feet) in February 2004. Thus, if pumping had not resumed, the mine may have started discharging in a relatively short period of time. On the other hand, it is expected that inflow rates decrease with higher water elevations. Therefore, it is also possible that the inflows would have decreased with increasing water elevation sufficiently that the mine would not have discharged. In the following analysis, an attempt is made to determine which of these scenarios is most likely based on analysis of available data.

Figure 5. Measured and Extrapolated Cumulative Mine Water Storage, 2003 – 2004.



Relationship between Inflow and Precipitation Events

As described in the methods section, the relationship for inflow was separated into a function dependent on rain and snowmelt history and a function dependent on water elevation. The first step was to develop the relationship between inflow and precipitation and runoff. This was initiated by examining the temporal sequence of rain and snowmelt at a local SNOTEL site with the inflow to the mine.

Daily precipitation and snow-water equivalent data were gathered from Natural Resources Conservation Service SNOwpack TELemetry (SNOTEL) site 932, Poorman Creek (Natural Resources Conservation Service, 2008). The SNOTEL site is located approximately 14.7 miles to the southeast of Troy Mine. It is located at an elevation of 5100 feet, near the middle of the range of surface elevations directly overlying the mine (4600 feet to 5580 feet). Data for accu-

mulated precipitation are available for water years 1999 to 2008 and snow-water equivalent data are available from water year 1969 to 2008. Because of its relative proximity to the mine and its similar elevation, the Poorman Creek SNOTEL site should adequately represent precipitation conditions in the mine area.

The analysis was conducted on monthly, seasonal and annual time scales with special attention paid to lag between surface events and the inflow. The graphs located in Appendix A (Rain+Snow, Storage vs Time) show that the monthly change in storage within the underground workings follows the amount of rainfall and snowmelt very well. However, the lag time between the peak of rainfall plus snowmelt to the peak change in storage is inconsistent. The amount of time that the change in storage peak follows the rainfall plus snowmelt peak varies from zero to two months. In attempting to correlate rainfall and snowmelt with change in storage plus pumped volume during periods of pumping, several time scales were used. The correlation on a monthly basis was weak, with an r-squared of 0.3. When the change in storage was lagged one month behind the rainfall and snowmelt, the correlation weakened even further. The data was then reorganized by season: winter being January, February, March; spring being April, May, June and so on. This improved the correlation to an r-squared of 0.61. On an annual basis, the r-squared improved to 0.73. After removing 2007 from the data, the correlation improved further to an r-squared of 0.87. Because of the poorer correlations for the shorter time scales, the annual time scale was adopted for this analysis.

Figure 6 shows the relationship between mine inflow and rain plus snowmelt on an annual basis for water years 2004 through 2006 and 2008. The data for 2007 is excluded from this analysis because it is suspect for reasons explained later in this memorandum.

Based on the period of record from 1999 to 2008, the average annual rain plus snowmelt for the Poorman Creek SNOTEL site was 79.5 inches. Using the correlation relation established above, this amount of precipitation predicts an average annual inflow into the mine of 1418 ac-ft. To eliminate the effects of rainfall and snowmelt from the inflow relation, predicted inflows were calculated using the relationship in Figure 6 and then subtracted from the actual inflows measured in the corresponding years. These residual amounts were then added to the average annual inflow of 1418 ac-ft resulting in a set of adjusted inflows that are independent of rainfall and precipitation effects to the extent that the data allow. Table 1 summarizes this calculation.

Figure 6. Correlation between Mine Inflow and Rain plus Snowmelt for Water Years 2004 – 2006 and 2008

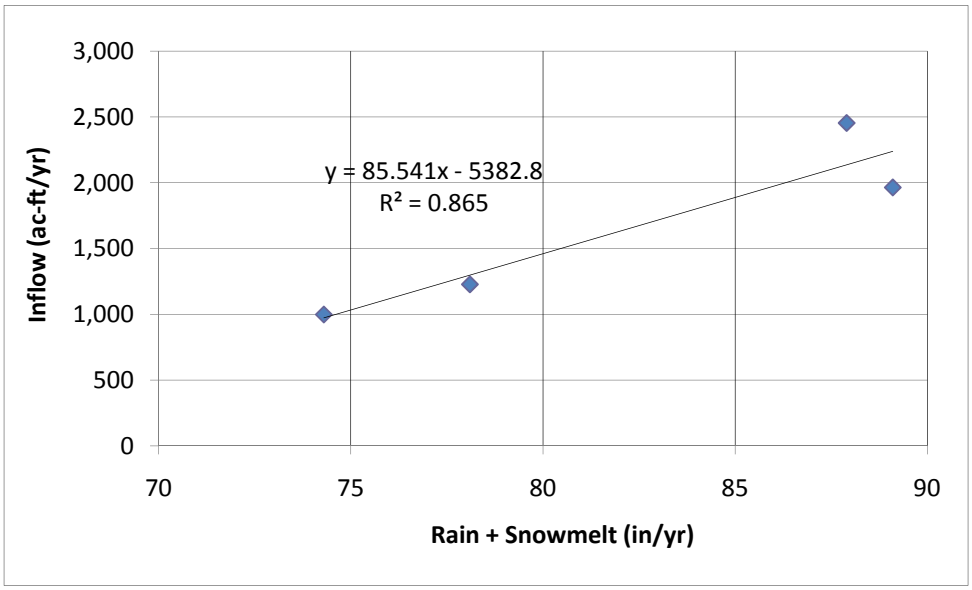


Table 1. Variables and Results of Adjusted Inflow Calculation.

Year	Average Elev (ft)	Measured Inflow (ac-ft)	Rain+snow (in/yr)	Predicted Inflow (ac-ft)	Residual (ac-ft)	Adjusted Inflow (ac-ft)	Q (cfs)
2008	4082.8	2454	87.9	2130	324.2	1736.4	2.4
2006	4169.9	1228	78.1	1291	-63.5	1348.8	1.9
2005	4189.8	999	74.3	966	32.6	1444.9	2.0
2004	4189.9	1965	89.1	2233	-267.5	1144.7	1.6

Relationship between Inflow and Water Elevation

Cumulative mine inflows for the years that the pool elevation was being controlled by pumping are plotted in Figure 7. These curves show that mine flow is generally relatively small and consistent through the fall and winter months and increases greatly, but by varying amounts, in the spring before tapering to lower rates in the summer. As shown in Figure 8, which shows storage levels in the mine throughout this period, stored water was rather high in 2004 through 2006, averaging 1854 ac-ft. In 2007, the water level was drawn down and remained relatively low through 2008. Figure 7 shows clearly the effects of maintaining a low storage level in 2008: the annual inflow for this year was the highest in the pumping period although annual rain plus snowmelt was higher in 2004.

Figure 7 also shows that mine inflow was negative during the winter in 2007. This suggests that water was flowing out of the mine for this period by means other than pumping. Inspection of Figure 8 shows that the mine was being rapidly drawn down through this period. That water would not be flowing into the mine during a period of rapid drawdown is physically difficult to explain and it is suspected that either the storage data or the pumping rates are in error during this period. Therefore, data from water year 2007 have not been used in this analysis.

With a relation between rainfall plus snowmelt and inflow established on an annual basis, the residual information can be used to develop information on the relation between water elevation and inflow. Conceptually the mine workings can be thought of as a large diameter well

Figure 7. Cumulative Inflow for Water Years 2004 through 2008

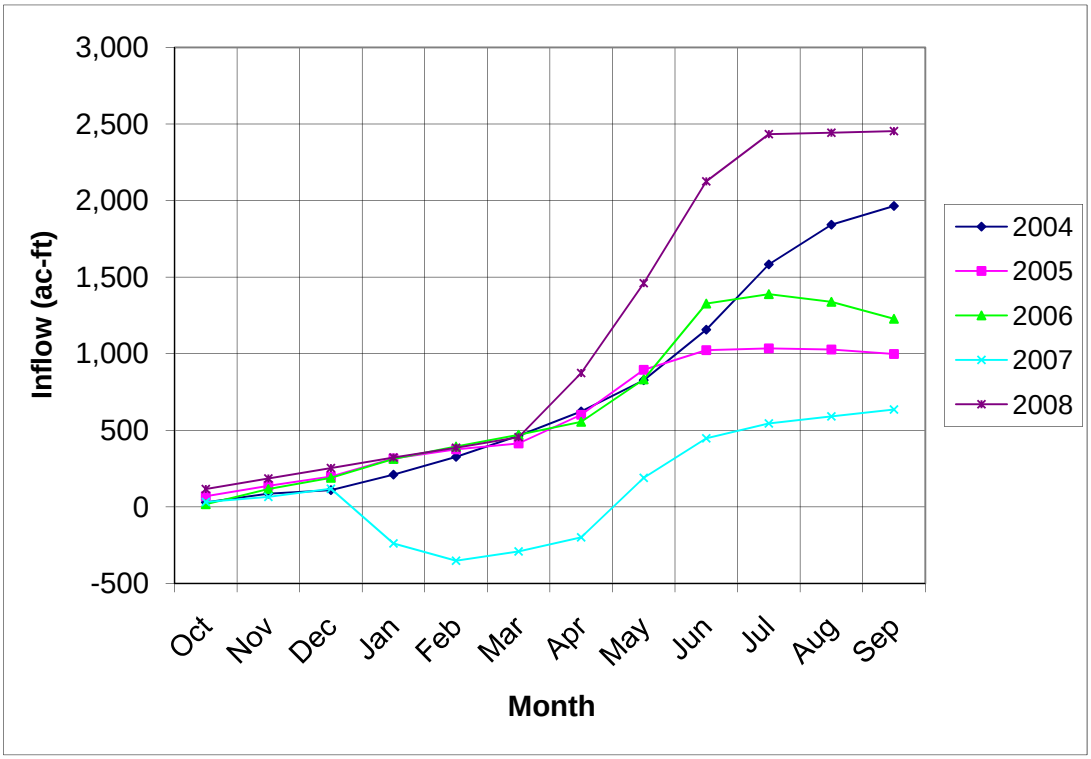
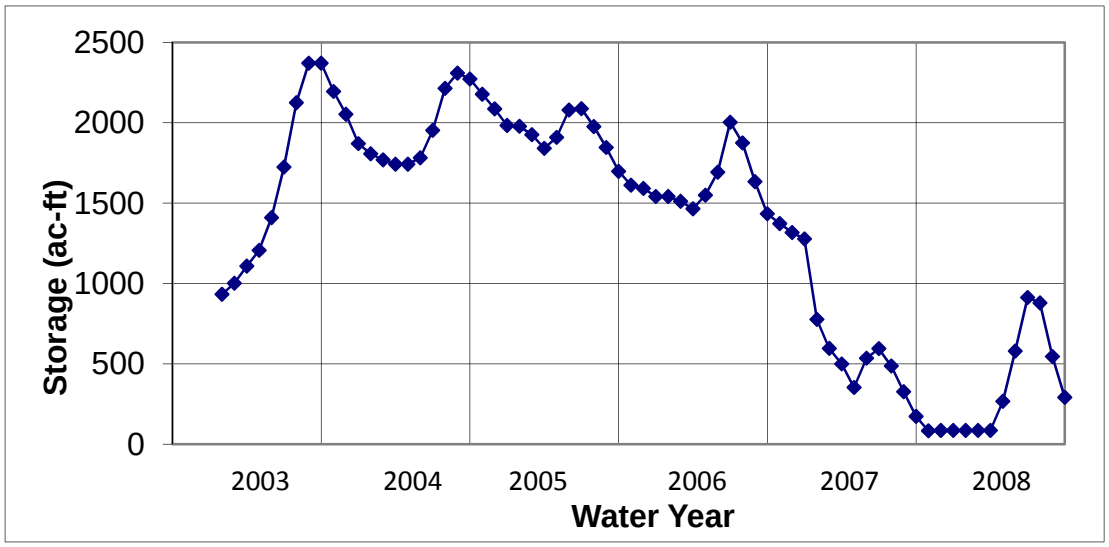


Figure 8. Mine Water Storage 2003 through 2008.



located within an unconfined aquifer. Because the time period for pumping in this analysis is a year, which is relatively long in most pumping applications, the relation of inflow and water elevation should approximate a Theis curve (Freeze and Cherry, 1979). The equation for the Theis curve is:

$$h_0 - h = \frac{Q}{4\pi T} W(u)$$

where $W(u)$ is the well function

$$u = \frac{r^2 s_y}{4Tt}$$

h_0 is the initial height of the water table

h is the height of the water table at distance r and time t

Q is the flow into the well

r is the radial distance from the well

S_y is the specific yield for an unconfined aquifer

T is the transmissivity of the aquifer

t is time since initiation of pumping

This linear equation relates water elevation (h) and inflow (Q). Plotting water elevation versus inflow for the four years of data presented in Table 1 and fitting a linear regression line through the points results in the graph shown in Figure 9. The r-squared for this correlation is 0.75. Extrapolating the line to the point where $h = h_0$ results in a predicted initial value (or recovered value) for h_0 of 4413 ft., well above the adit overflow elevation of 4225 ft. This suggests the water level in the mine will rise to the adit discharge level when pumping ceases.

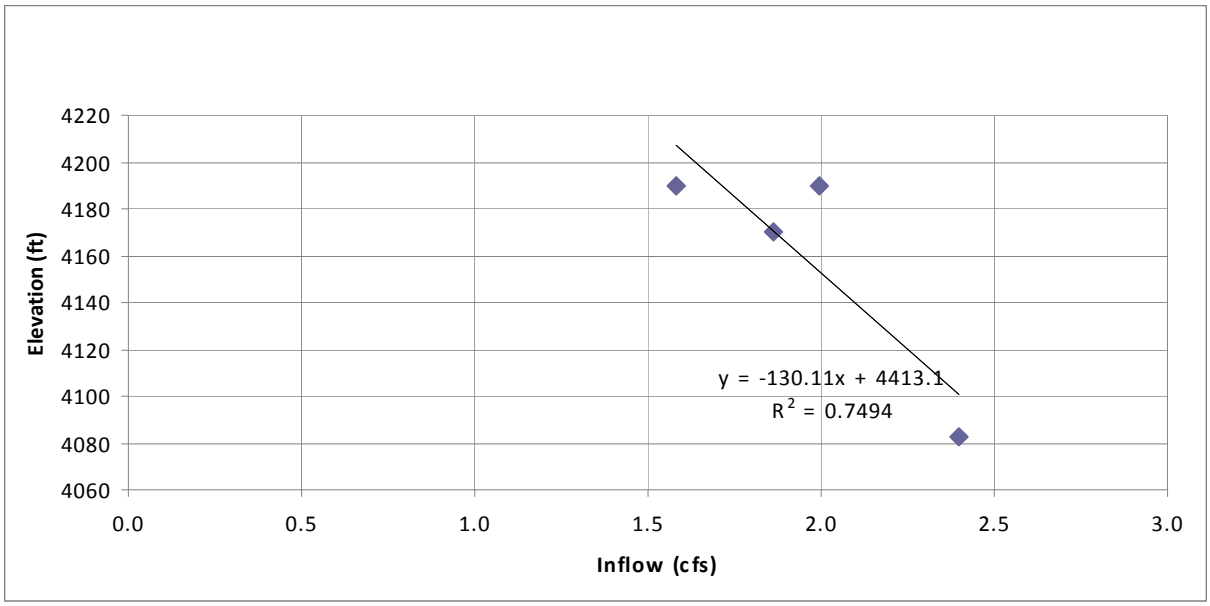
As a check on the validity of the Theis equation in this application, it is shown that a consistent set of aquifer parameters can be derived from the slope of the linear regression (negative 130). If we assume that the typical radius at the edge of the mine workings is related to the area of workings at elevation 4220 ft, the radius for computational purposes is about 800 ft. We can also use a specific yield of 0.05 for fractured crystalline rock (the range is typically zero to 0.10, Freeze and Cherry, 1979), we can calculate from the Theis equation that the formation transmissivity is about 4×10^{-4} ft^2/s. If we assume that the thickness of the affected aquifer is about 400 ft., this corresponds to a hydraulic conductivity of about 3×10^{-5} cm/s, which is mid-range in the expected hydraulic conductivities of fractured metamorphic rocks (Freeze and Cherry, 1979). Thus, a reasonable set of hydraulic parameters appears to be consistent with the slope calculated from the data. Note that this is not an attempt to derive actual hydraulic parameters; this calculation is merely a check that it is physically probable that the calculated slope can occur.

Timing and Quantity of Overflow

The relations derived in the previous sections can be used to estimate the time frame in which the mine workings will fill to the overflow point as well as the potential discharge volume. The average precipitation/runoff condition of 79.5 inches per year is assumed and the water elevation versus inflow relation is applied to calculate when the mine will fill to the overflow point. Then the average inflow at that elevation is used to calculate the average annual discharge from the adit due to the mine workings overflow. An additional assumption is that the inflow is distributed through the year approximately as it was in 2006, a year with close to average rain plus snowmelt.

If the mine starts completely pumped down to elevation 4020 in October and then the pumps are shut down, the calculations indicate that the mine will fill under average rain plus snowmelt conditions sometime in June of the following water year, 21 months later. Thereafter, the average rate of discharge to the service adit is anticipated to be about 1.5 cfs or 1,050 ac-ft per

Figure 9. Relation of Water Elevation to Adjusted Mine Inflow.



year. It is possible that the discharge will cease in August and September because of the lowered local water table in these months.

Annual and Seasonal Variations in Adit Discharge

Given the great variations from year to year and within any year in inflow to the mine, it is expected that discharges from the overflowing adit will vary both annually and seasonally. Given, the limited available data, estimates of natural variation in mine discharge rates cannot be made precisely and cannot accurately assess discharge rates during years in which precipitation is substantially higher or lower than during the years for which mine outflow data are available. The additional data necessary to refine this analysis can only be collected during unusually high or low precipitation years, and it cannot reasonably be expected that such opportunities will occur during the time frame in which this environmental analysis must be completed. Other methods of mine discharge estimation would require that data (ground water elevations, spring locations and flow rates, etc) have been collected prior to mining. Such data do not exist and cannot be obtained.

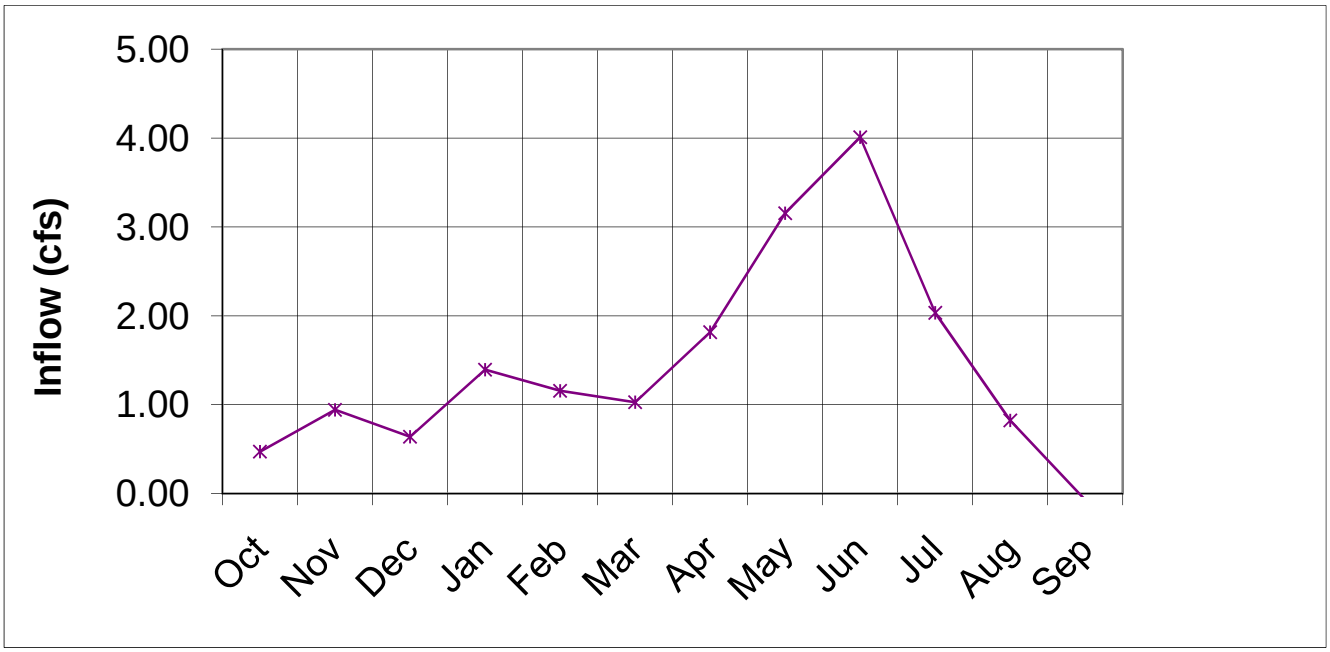
The relationship of water elevation to mine inflow (with no mine discharge) was determined based on four years of storage records. Within these years, 2004 was the wettest year (89.1 inches rain plus snowmelt) and 2005 was the driest (74.3 inches of rain plus snowmelt).

Comparing the calculated annual inflow for these years compared to the mean annual inflow shows that inflows were 39% higher than average in 2004 and 30% lower than average in 2005. If these ratios are assumed to apply to the inflow that would occur at the discharge elevation, the range of annual discharges varies from 1.0 to 2.0 cfs.

These two years, however, are not extreme precipitation years at the Poorman Creek SNOTEL site. In 2002 rain plus snow was about 104.1 inches and 2001 had 45.4 inches at this site, much greater and lesser amounts than were observed in 2004 and 2005. If we attempt to convert these more extreme amounts to inflows using the relationship derived for years 2004 through 2006 plus 2008, considerable extrapolation of the relation is required. In fact, the inflow predicted for 2001 is negative, indicating the inapplicability of this relation during drier years. Without storage-elevation data for more extreme years, it is not possible to predict with any certainty the behavior of adit discharge in extreme precipitation years. However, using the maximum rain plus snow value in 2002 (104.1 inches) from the ten-year period of record at Poorman Creek, an estimated annual adit discharge of 3.6 cfs is calculated. For lack of better data, this figure may approximate a 10-year return interval annual discharge.

Determining seasonal variations in predicted adit discharge is also problematic. As discussed previously, the attempts to develop robust, predictive models of monthly or seasonal flow were not successful. However, an estimation of the seasonal variation in predicted discharge for average conditions can be developed from the high storage level records of 2004 to 2006. Using the mean monthly values for these three years, and proportioning them by the ratio of the predicted annual average flow (1.45 cfs) to the annual flows for this period (1.93 cfs), the monthly flows presented in Figure 10 were calculated. The peak monthly flow is 4.0 cfs in June and the minimum is zero in September, when no discharge is expected. Inspection of the mine inflow data for individual months from 2004 to 2006 and correcting to average annual discharge from the mine adit indicates that a maximum discharge of 6.25 cfs could occur at the adit. In this 36 month period of record, four months would have had no discharge (always the August-September period). However, 2006, when the peak monthly discharge is predicted, was not an extremely high precipitation year so larger discharges than 6.25 cfs are possible.

Figure 10. Average expected monthly mine discharges based on 2004 to 2006 mine inflow data.



References

Freeze, R. A. and J. A. Cherry, 1979. Groundwater, Sections 2.3, 2.5 and 8.3. Prentice-Hall, Englewood Cliffs, N.J.

Genesis, Inc., 2004. Mine Flooding Report, Troy Mine.

Appendix C
Mine Water Management Analysis

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Technical Memorandum

To: *Emily Corsi, Herb Rolfes - DEQ*
Bobbie Lacklen, John McKay - KNF

From: *Bill Bucher, Kim Chase - CDM*

Date: *December 3, 2010*

Subject: *Mine Water Management Analysis - Troy Mine*

CDM has been retained by the Montana Department of Environmental Quality (DEQ) to analyze proposed mine water management alternatives for the Troy Mine. The purpose of this memorandum is to present the results of analysis of water management alternatives to be considered in the Draft Environmental Assessment (EA) for closure of the Troy Mine. This memorandum only addresses the physical management of water; water chemistry issues are being addressed separately.

The Troy Mine is an underground copper and silver mine located south of the town of Troy in Lincoln County, MT. ASARCO began operating the mine in 1982 and halted production in 1993 due to low metals prices. The mine was sold to Revett Silver Company and production resumed under Genesis, a subsidiary of Revett, in 2005. In 2006, Genesis submitted a Revised Reclamation Plan in support of this EA. This memorandum analyzes water management alternatives presented in the EA.

It has previously been shown in the *Mine Water Balance Analysis – Troy Mine* Technical Memorandum (CDM, 2010) that the Troy Mine is expected to discharge mine water after closure. The three closure alternatives to be evaluated in the draft EA consider different water management scenarios:

- Alternative 1 is the original closure proposal from the 1978 reclamation Plan. It would close the adits with non-hydraulic plugs, which would allow the mine water to discharge from the portals. Mine water would then infiltrate to the groundwater system. The glacial till near the mill site probably is not sufficiently permeable to allow infiltration of the expected quantity of water, and there is likely a substantial risk that saturation of this material could trigger landslides and slumping of material into the creek, causing further pollution. In addition there would be a direct discharge to Stanley Creek from the adit that

would not meet State water quality standards and would not be authorized. Therefore, this alternative is not being considered further in this water management analysis.

- Alternative 2 is the revised reclamation plan of March 2006 proposed by Genesis. In this alternative, the conveyor and service adits would be closed with non-hydraulic plugs, and the mine water would be carried by the existing tailings and reclaim water lines to the decant ponds. At the ponds, the water would infiltrate and evaporate, and metals would be adequately attenuated by the underlying soils to preserve ground and surface water quality in the area.

- Alternative 3 is the agency mitigated alternative. In this alternative, the both the Service and Conveyor adits would be closed with partial backfill only and the mine water would be captured inside the entrances and transported to the decant ponds for treatment and disposal. The existing tailings lines would be removed and replaced with a new, buried line with at least 6.9 cubic feet per second (cfs) capacity. If there is insufficient capacity in the new transport line or a leak or other upset, part or all of the flow would be diverted automatically to the reclaim water line that is presently in place. Sensors installed in the line would detect these conditions and Supervisory Control and Data Acquisition (SCADA) instrumentation would automatically open and close appropriate valves and alert maintenance personnel. The decant ponds would be bermed to prevent the entry of storm water. They will be constructed about 10 feet deep and lined with gravel to prevent the growth of aquatic vegetation.

The analysis of water management for a discharging mine in Alternatives 2 and 3 is the main focus of this memorandum.

Management of Mine Discharge

Mine water discharging from the service and conveyor adits at Troy Mine will be transported through a system of pipelines to the existing decant ponds in the tailings pond area under Alternatives 2 and 3. The locations of these facilities are shown in Figure 1. The question to be answered through a water balance analysis is whether the decant ponds will eventually fill and overtop or if infiltration and evaporation are sufficient to maintain the pond level below this elevation. The following information is needed to develop a water balance for the decant ponds at the tailings impoundment:

- Discharge from the mine adits

- Pond Area

- Pond volume and stage-volume relationship

- Evaporation and precipitation information near the pond

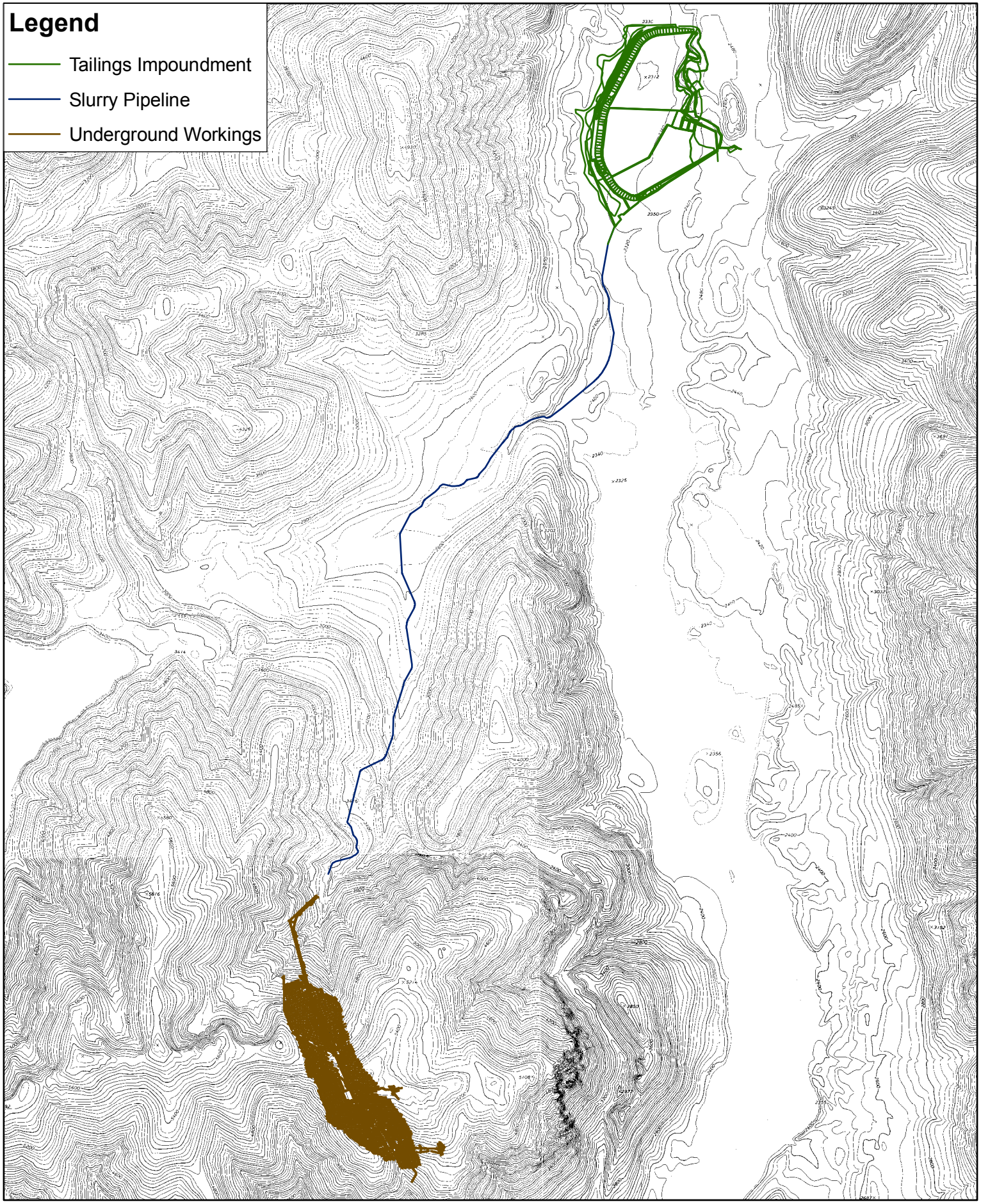

Figure 1: Location of Underground Workings, Pipeline, and Tailings Impoundment

0 0.2 0.4 0.8 1.2 Miles

CDM

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- Infiltration rate below the pond

For a detailed water balance analysis, a ten-year period with monthly time steps was selected to provide sufficient time to allow a general balance of inputs and outputs and to capture extreme conditions that would correspond roughly to a ten-year recurrence interval. The selected time period was the period of record for the Poorman Creek SNOTEL site, where the available record runs from 1999 through 2008. The Poorman Creek period of record is important to this analysis because the estimated mine discharges are tied to precipitation records at Poorman Creek in the mine water balance memorandum (CDM 2010). Monthly values for the mine discharge and climatic data were developed for the period 1999 -2009 as input to the pond water balance model.

Mine Discharge Data

In the *Mine Water Balance Analysis – Troy Mine* Technical Memorandum, CDM developed an annual relationship between rain plus snowmelt and mine discharge. This relationship demonstrated that the mine would generally discharge water after closure and quantified the annual amount of discharge. Although no robust predictive model of monthly discharge could be developed, evaluation of mine inflows on a monthly basis during a period of high mine water level resulted in an approximate distribution of expected mine discharge through a typical year. To produce the monthly data set, the predictive model was used to calculate estimated annual mine discharge based on precipitation records at the Poorman Creek SNOTEL. The average monthly distribution of mine discharge was then estimated by adding the typical distribution to the difference between the annual distribution for a particular year and the average annual discharge:

$$Q_{Myrx} = Q_{Ayrx} - Q_{Aave} + Q_{Mave}$$

Where: Q_{Myrx} is the calculated monthly discharge for year x

Q_{Ayrx} is the predicted annual flow for year x

Q_{Aave} is the predicted average annual flow

Q_{Mave} is the typical monthly discharge.

Table 1 shows the calculation of the predicted annual discharge based on precipitation at the Poorman Creek SNOTEL site and Table 2 shows the estimated monthly mine discharges for the period of record 1999-2008. The equation used to calculate the monthly discharges occasionally results in negative discharges; these discharges are set to zero.

Table 1. Predicted Annual Inflow and Discharge (Q_{Ayrx}) Based on Inflow Analysis Relations

Year	Rain+ Snowmelt (in)	Predicted Inflow (ac-ft)	Predicted Inflow (cfs)	Adjusted Inflow (cfs)*	Estimated Discharge (cfs)
1999	76.0	1118	1.54	1.54	1.14
2000	84.4	1837	2.54	2.54	1.87
2001	45.4	-1499	-2.07	0.76	0.56
2002	104.1	3522	4.86	4.86	3.59
2003	69.4	554	0.76	0.76	0.56
2004	89.1	2239	3.09	3.09	2.28
2005	74.3	973	1.34	1.34	0.99
2006	78.1	1298	1.79	1.79	1.32
2007	79.0	1375	1.90	1.90	1.40
2008	87.9	2136	2.95	2.95	2.18

*Because the inflow prediction equation results in a negative mine inflow for 2001, the mine inflow is conservatively set to the next lowest inflow (2003).

Table 2. Estimated Monthly Discharges at Mine Adit Elevation 4225 ft.

	Estimated Monthly Discharge (cfs)									
Month	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Oct	0.17	0.90	0.00	2.62	0.00	1.31	0.02	0.35	0.43	1.21
Nov	0.64	1.37	0.06	3.09	0.06	1.78	0.49	0.82	0.90	1.68
Dec	0.33	1.07	0.00	2.79	0.00	1.48	0.19	0.52	0.60	1.37
Jan	1.09	1.82	0.51	3.54	0.51	2.23	0.94	1.27	1.35	2.13
Feb	0.85	1.58	0.28	3.30	0.28	1.99	0.70	1.03	1.11	1.89
Mar	0.72	1.46	0.15	3.17	0.15	1.87	0.58	0.91	0.99	1.76
Apr	1.51	2.24	0.94	3.96	0.94	2.65	1.36	1.69	1.77	2.55
May	2.85	3.58	2.27	5.30	2.27	3.99	2.70	3.03	3.11	3.89
Jun	3.70	4.44	3.13	6.16	3.13	4.85	3.56	3.89	3.97	4.74
Jul	1.73	2.46	1.15	4.18	1.15	2.87	1.58	1.91	1.99	2.77
Aug	0.52	1.25	0.00	2.97	0.00	1.66	0.37	0.70	0.78	1.56
Sep	0.00	0.36	0.00	2.07	0.00	0.77	0.00	0.00	0.00	0.66

The estimated monthly discharges presented in Table 2 do not account for the water that originates in that portion of the service adit below the high point of 4,225 ft. or a corresponding high point in the conveyor adit. These adit discharges have been measured semi-annually by the mine operator from July 2005 to February 2008 using weirs. The flows vary relatively little with the average February flow of the two adits being 0.67 cfs and the average July flow being 0.74 cfs. The 0.67 cfs flow was applied to the months of August through March, and the

0.74 cfs flow was applied to the months of April through July, resulting in the total estimated mine discharges shown in Table 3.

Table 3. Estimated Monthly Total Mine Discharges (QM_{yrx})

	Estimated Total Mine Discharge (cfs)									
Month	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Oct	0.84	1.57	0.67	3.29	0.67	1.98	0.69	1.02	1.10	1.88
Nov	1.31	2.04	0.73	3.76	0.73	2.45	1.16	1.49	1.57	2.35
Dec	1.00	1.74	0.67	3.46	0.67	2.15	0.86	1.19	1.27	2.04
Jan	1.76	2.49	1.18	4.21	1.18	2.90	1.61	1.94	2.02	2.80
Feb	1.52	2.25	0.95	3.97	0.95	2.66	1.37	1.70	1.78	2.56
Mar	1.39	2.13	0.82	3.84	0.82	2.54	1.25	1.58	1.66	2.43
Apr	2.25	2.98	1.68	4.70	1.68	3.39	2.10	2.43	2.51	3.29
May	3.59	4.32	3.01	6.04	3.01	4.73	3.44	3.77	3.85	4.63
Jun	4.44	5.18	3.87	6.90	3.87	5.59	4.30	4.63	4.71	5.48
Jul	2.47	3.20	1.89	4.92	1.89	3.61	2.32	2.65	2.73	3.51
Aug	1.19	1.92	0.67	3.64	0.67	2.33	1.04	1.37	1.45	2.23
Sep	0.67	1.03	0.67	2.74	0.67	1.44	0.67	0.67	0.67	1.33

Climatic Data at the Tailings Pond

Precipitation data were taken from the Troy, MT weather station 248390 (Western Regional Climate Center 2009). This station is located 9.5 miles north of the tailings facility at an elevation of 1929 ft. It has 48 years of record. The elevation of the tailings ponds is about 2,400 feet, somewhat higher than Troy, so increased precipitation might be expected at this site. However, without local information, the Troy weather station data cannot be reliably adjusted to the site.

Five years of pan evaporation data, 1963-1967, are available from the tailings facility (Genesis, Inc. 2008). To estimate the evaporation amounts for the period 1999-2008, the record was extended using data from Station 4328 at Hungry Horse Dam near Columbia Falls, MT. This station is located at an elevation of 3,160 feet. Fifty-eight years of pan evaporation data, 1948 to 2007, are available from the National Climatic Data Center. The data from the tailings facility were compared to the evaporation values at Hungry Horse Dam and a correction factor was created. Before using the corrected data, a coefficient of 0.75 was applied to the data to adjust for the increased energy and therefore increased evaporation experienced in an evaporation pan as opposed to a lake or pond (Haan et al, 1994).

Average annual precipitation at the Troy, MT weather station is 24.5 inches for the period 1960-2009. November and December are the wettest months and July and August are the driest. Average annual adjusted evaporation is 15.7 inches. The greatest evaporation is generally experienced in August.

In most years, precipitation will exceed evaporation. Therefore, if the area of disposal ponds is increased, any accelerated loss of water due to evaporation will more than be compensated for by increased precipitation, and larger pond areas would not equate to greater disposal of water.

Estimation of Infiltration Rate

There are several sources of information on infiltration rates in the vicinity of the tailings ponds including estimates of seepage from the ponds as well as measurements of the hydraulic conductivity of the underlying materials in the vicinity of the ponds. Seepage was estimated in the Operating Plan (Asarco, 1976) to range between 292 and 803 gallons per minute (gpm), whereas the Draft Environmental Impact Statement (USFS-DSL, 1978) estimated 1,170 gpm. The Tailing Impoundment Design and Operation report (Pfahl, 1989) estimated seepage at 845 gpm based on a simplified water balance. Unfortunately, insufficient information is provided to determine the area over which seepage calculations occurred. Without this information, it is not possible to calculate infiltration on a unit area basis. In Alternatives 2 and 3, the current decant pond would be used to dispose of the mine discharge. This may be a reasonable solution if the bottom of the decant pond is not sealed by slimes. Alternatively, a new pond could be excavated directly in native materials and used to dispose of the discharge water. An estimate of infiltration rate based on hydraulic properties of the native materials is appropriate in the analysis of long-term water disposal options.

The Interim Report of Findings Hydrologic and Hydrogeologic Assessment prepared by Summit et al (1996) offers the most comprehensive data for the materials underlying the tailings pond area. This report includes logs from ten test borings, seven monitoring wells and seven sandpoints in the vicinity of the tailings ponds. Data from a hydraulic conductivity test and other information related to infiltration rates are presented. The Summit report measured a hydraulic conductivity of 8.4 feet per day using a well in the middle of the tailings pond and one just below the pond berm. The boring logs from these wells and other wells in the area indicated the unit measured was primarily fine sand. This hydraulic conductivity value is within the expected range for sandy materials.

In November of 1995, ASARCO personnel decreased the flow rate to the decant pond for seven days. During this time, Summit reported a 4.5 foot drop in water levels in the decant pond. The report does not state the amount that the flow rate was decreased or whether flow ceased altogether, so it is not possible to calculate an exact infiltration rate from this information. However, a 4.5 foot drop in water level over the area of the decant pond for a seven-day period equates to a rate of infiltration of 0.64 feet per day and provides a potential pond infiltration rate.

Further data on the infiltration rate at the decant ponds was obtained in 2001 during a tracer test conducted by Hydrometrics (2001). During a period of low mine water discharge, all discharge to the decant ponds was suspended and a 24-day salt tracer test was conducted.

During this period, the ponds dropped at a typical rate of about 0.4 feet per day, somewhat lower than the rate determined in the 1995 study. The infiltration rates used in our analyses vary from 8.4 feet per day for good infiltration conditions to a minimum of 0.4 feet per day.

Water Balance at the Tailings Pond

Precipitation on the surface of the tailings and mine water delivered to the decant ponds are the major input values for a water balance calculation at the tailings facility. The primary outputs are seepage and evaporation from the decant ponds. The general equation used to determine the change (Δ) in storage of water at the decant ponds or tailings impoundment is as follows:

$$\Delta Storage = Precipitation + Mine\ Discharge - (Evaporation + Seepage)$$

Because information on the size of the proposed disposal facilities is not included in the proposed Alternatives, the procedure followed in this analysis was to set the size of the proposed disposal facility based on the other inputs to the model. For simplicity, it was assumed that an infiltration pond of a certain area had a capacity of 10 feet of water and vertical sides. This approximate design would need to be revised based on site conditions and other factors during implementation of the pond disposal alternative. In the model input, the pond area was varied to determine at what size the pond would overflow at some time under the 10-year climatic record.

An initial model run was undertaken with the assumption that the hydraulic conductivity of the underlying materials at the site was 8.4 feet/day, a value derived from aquifer tests by Summit et al (1996). A review of the well logs in the vicinity of the east edge of the tailings pond indicates that ground water would be located about 50 feet below the pond bottom. This information was inserted into Darcy's equation to translate the hydraulic conductivity into an infiltration rate:

$$v = k\,i$$

where v = the Darcy velocity
k = hydraulic conductivity (ft/day) and
i = the gradient.

To calculate the gradient, the following terms are defined:

h_A = the height of the pond bottom above the aquifer in feet, and
h_W = the depth of water in the pond in feet.

For vertical flow, the gradient, i, is the total head ($h_A + h_w$) divided by the length of the media through which it passes (h_A) or, for 50 foot separation from the aquifer:

$$i = (h_A + h_w)/ h_A$$

$$i = (50 + h_w)/50$$

Referring to the spreadsheet model "Water Management" and work sheet "1.6-acre Pond" on the attached compact disc, for a pond with a maximum depth of 10 feet, the infiltration rate will vary from 8.4 to 10.1 ft/ft^2 – day. Because of the depth to the aquifer is large, the amount of water in a pond with a maximum 10-foot depth does not have a great effect on the magnitude of the infiltration rate. Running the model with various-sized ponds and the precipitation rates for the period of record shows that a 1.6-acre pond that is 10 feet deep would not overtop. Note that the model indicates the pond only fills with water during the wettest portion of 2002, which was the wettest year in the period of record. In part, this is because the infiltration rate modeled (at least 403 acre-feet for a 30-day month) is sufficiently high to accommodate the mine discharge rate, which only averaged 292 acre-feet. Neither precipitation nor evaporation exceed one acre-foot per month, and are almost inconsequential in this calculation. Only when mine inflows exceed those of June 2002 does the model predict the 1.6-acre pond would fill.

It is likely that the high infiltration rate used in the preceding calculation will not be realistic, at least in the long term, due to siltation or vegetation accumulating in the pond. Although pond maintenance should minimize these effects, it is still probable that some decrease in performance will be experienced over time. Therefore, a spreadsheet calculation was also developed to size a pond for the minimum infiltration rate of 0.4 ft per day reported in 2001 by Hydrometrics. Referring to the spreadsheet model "Water Management" and worksheet "23-acre Pond" on the attached compact disc, at this lower infiltration rate, a 23-acre pond is required to prevent overtopping a 10-foot deep pond. For this pond configuration, the model indicates the pond would hold water during early summer in four of the wet years, 2000, 2002, 2004 and 2008. Although the effects of precipitation and evaporation are somewhat more important with a larger surface area pond, they are still generally less than 10 acre-feet per month with minor effects on the calculation.

Implementation

The calculations presented in the previous section suggest that disposal of water through use of a pond is feasible given the transmissive quality of the underlying soils. Even a 23-acre pond would be quite feasible to construct, although it would have significant maintenance requirements. Because the existing 4-acre decant pond system has successfully infiltrated excess mine water during operations, it is expected that this same facility can continue to handle mine discharge water after mine closure. Normally these ponds infiltrate about 2,500 gpm (5.6 cfs) and have infiltrated 3,000 gpm (6.7 cfs), which is nearly the maximum design flow assumed in this memorandum (6.9 cfs) (personal communication, Doug Parker, Hydrometrics, June 16, 2010). If the existing ponds are maintained with a depth of about 10 feet, are gravel lined to increase infiltration, and vegetation growth is controlled, the infiltration rate

should be maintained. The infiltration ponds would need a berm constructed around them to prevent storm water from flowing into them.

Summary

This memorandum presents an analysis of the expected feasibility of mine water disposal in the vicinity of the tailings ponds. Based on previous work, the mine will discharge an average of 2.1 cfs from its adits after pumping ceases and water reaches the overflow elevation of the adits. Flows are expected to range from 0.67 cfs to 6.90 cfs with the largest discharges generally expected in the months of May and June in relatively wet years.

A spreadsheet water balance model was developed for the water disposal pond and used to evaluate 10 years of discharge and climatic data including precipitation, evaporation, and infiltration. The infiltration rates modeled were based on an aquifer test performed at the tailings pond and an observation of infiltration rates at the decant pond. It is not known how representative these data are of the soil conditions in the area. A range of pond sizes, depths, and infiltration rates was modeled using actual discharge plus precipitation rates. The various pond designs were sufficient to contain all expected inflows during the 10-year evaluation period. An important conclusion of this analysis is that the pond size is almost entirely dependent on the magnitude of the mine water discharge and infiltration rate of the subsurface, and relatively unaffected by precipitation and evaporation.

Water disposal ponds sized from 1.6 to 23 acres are feasible to build and maintain. The current decant ponds, which are about 4 acres in size fall within the modeled range of sizes. These ponds have successfully infiltrated the mine discharge for the period of operation of the mine and, with proper maintenance, should continue to infiltrate the discharges expected post closure. To prevent plugging of the ponds and ensure they are not overwhelmed with storm water runoff, berms should be constructed around the ponds to exclude entry of storm water runoff from the surrounding area.

References

CDM, 2010. Mine Water Balance Analysis - Troy Mine. Technical Memorandum to Emily Corsi and Herb Rolfes, Montana Department of Environmental Quality dated April 12, 2010.

Haan, C.T., B.J. Barfield, J.C. Hayes. 1994. Design Hydrology and Sedimentology for Small Catchments. Academic Press. San Diego, CA.

Western Regional Climate Center. Troy Montana Climate Data. 2 Sept 2009. <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mttroy>

Genesis, Inc. 2008. Troy Mine Precipitation and Evaporation Data. Unpublished Spreadsheet.

Genesis, Inc. 2006. Troy Mine Revised Reclamation Plan. Troy, MT.

Hydrometrics, Inc., 2001. Mine Water Plume Location and Identification, Phase 1 results and Phase 2, & 3 Workplan, Sterling Troy Mine. Prepared for Genesis Inc./Sterling Mining Company, October.

Summit Envirosolutions and McCulley, Frick, and Gilman, Inc. 1996. Interim Report of Findings Hydrologic and Hydrogeologic Assessment, ASARCO Troy Mine. Troy, Montana.

Appendix D
Troy Mine Metals Attenuation Study-
Secondary Processes

Department of Environmental Quality

Troy Mine
Copper Attenuation Study – Secondary Processes

July 8, 2010

Final

Contents

Section 1 Introduction

Section 2 Modeling Methodology

2.1 Water Analyses Internal Consistency Evaluation 2
2.2 PHREEQC Thermodynamic Database 5
2.3 Oxidation-Reduction Potential (ORP) 5

Section 3 Geochemical Modeling Results

3.1 Mineral Saturation States 7
3.2 Mixing Scenarios 10

Section 4 Bench-Scale Tests

4.1 Sample Collection 11
4.2 Jar Test Procedures 12
4.3 Results 13

Section 5 Conclusions

Section 6 References

Attachment 1 Analytical Reports
Attachment 2 Photographs

Section 1
Introduction

The fate of the copper, antimony, lead, uranium, arsenic, cadmium, and other metals within the waters discharged to the decant pond is of great interest, as one of the alternatives is to discharge the mine water to the decant pond and to allow natural attenuation mechanisms to remove the metals from solution. Currently (during active operation of the mine), Genesis is using the decant ponds to settle out suspended sediment from the tailings slurry which is piped from the mill. The decant water is then pumped to the mill circuit via a return line. The system is currently semi-closed in that some, but not all of the water is recirculated. As the decant ponds are not lined, some of the decant pond water seeps through the bottom of the pond into the underlying aquifer.

In 2001 Hydrometrics conducted a tracer study in which sodium chloride (salt) was added to the decant ponds (Hydrometrics, 2001). The migration of the salt into the underlying and downgradient groundwater was then monitored by measuring the conductivity within the existing wells. The report concluded that while the deep wells and decant ponds appear to be hydraulically connected, the response time is long, suggesting that the decant water is transported predominantly within shallow sand and gravels above the zone of the then existing wells. Shallow monitoring wells were installed as part of the study.

While the decant pond water appeared to be traveling downgradient of the ponds within the shallow alluvial system, the copper concentrations in the shallow wells were either below the laboratory reporting limit or were significantly lower than in the decant pond water, suggesting that the copper was being removed via some geochemical process. In 2004, a study was conducted in order to determine the fate and transport of copper beneath the decant ponds (Land and Water, 2004). The soil beneath the decant ponds was analyzed for total copper as well as electron microprobe and sequential extraction analyses. The results indicated that copper was attenuated within the upper foot of soil via the precipitation of secondary copper phases (carbonates, silicates, and oxides) as well as adsorption onto organic matter.

Because it is not certain whether the attenuation mechanism(s) occurring within the sediments below the decant pond would have a finite duration or would perpetually precipitate copper within or immediately beneath the pond, the agencies determined that testing should be conducted to evaluate secondary attenuation processes which may occur if copper migrates beyond the decant pond and mixes with downgradient groundwater. The investigation was expanded to include other metals in addition to copper.

The evaluation consisted of two parts;

1) Initial geochemical modeling using analyses of the groundwater downgradient of the decant ponds, decant pond water, and mine water to determine if iron hydroxide is predicted to precipitate. Mixing of the decant pond water with the groundwater simulates the current situation during active mining, where mill water would mix with groundwater. In order to simulate a second, post closure scenario, mine water was mixed with groundwater.

2) Jar testing to determine the fraction of metals removed during precipitation of iron hydroxide.

Section 2
Modeling Methodology

A geochemical model, PHREEQC (Parkhurst and Appelo, 1999), was used to predict the geochemical reactions that will occur in response to mixing mine water (decant water) with the native groundwater downgradient of the toe ponds. PHREEQC is a thermodynamic equilibrium program designed to model chemical speciation in aqueous solutions, determine the saturation states of solutions with minerals and gases, and predict the results of various reactions, such as dissolution of minerals and oxidation.

The modeling shows which phases or minerals are predicted to become supersaturated (if any) as a result of mixing of the waters. Minerals that are supersaturated would eventually precipitate (assuming the mineral forms at low temperature) as equilibrium is established.

2.1 Water Analyses Internal Consistency Evaluation

The analyses were checked for internal consistency using both charge balance and mass balance relationships. Any solution containing a mixture of positively and negatively charged ions must have an overall charge balance of zero (the sum of the negative ions must equal the sum of the positive ions). If an analysis reported by a lab does not have a calculated charge balance near zero, then it indicates either that one or more errors have occurred in the analysis and/or that ions are present that were not analyzed for.

By evaluating both the mass balance and charge balance, conclusions can be drawn about the accuracy and completeness of the analyses. The possible mass balance and charge balance combinations and the corresponding interpretations are shown in **Table 2-1.**

The charge balance was calculated from the lab analyses as follows:

$$(\Sigma(\text{Cations x charge}) - \Sigma(\text{Anions x charge}))/ (\Sigma(\text{Cations x charge}) + \Sigma(\text{Anions x charge})) \times 100\% \quad (2\text{-}2)$$

Where "cations" refers to the molar concentration of positively-charged ions (moles/L) and "anions" to the molar concentration of negatively-charged ions.

Mass balance is the comparison of the total mass of constituents in solution measured by an analysis called "total dissolved solids" (TDS-Measured) compared to a summation of all the constituents measured in each individual analysis (TDS-Calculated). TDS is determined by evaporating a measured volume of the solution to dryness and weighing the residual salts. Again, if the measured TDS is different from the calculated TDS, either some parameter is missing or there is an error in the analysis.

The mass balance was calculated using the following relationship:

TDS-Calculated /TDS-Measured (2-3)

TDS was calculated by summing the concentrations of all species in mg/L. Adjustments were made in cases where the species that would be formed upon evaporation were in a different form than that provided by the laboratory. For instance, silicon reported as "Si" (atomic mass = 28.09 g/mole) was converted to "SiO_2" (atomic mass = 60.09 g/mole) using the factor 2.14 (60.09g/mole / 28.09 g/mole = 2.14). In addition, the bicarbonate concentration was multiplied by a factor of 0.49 to account for loss of carbon dioxide gas during evaporation.

Table 2-1 – Interpretation of Charge and Mass Balance Results

TDS-Calculated/ TDS-Measured	Charge Balance	Interpretation[1]
>1	Positive	Cations are over-reported
>1	Negative	Anions are over-reported
<1	Negative	Cations are under-reported and/or one or more important cations were not analyzed
<1	Positive	Anions are under-reported and/or one or more important anions were not analyzed

1. Note that the interpretation represents the least complex explanation. In some cases, multiple problems with an analysis may have caused the inconsistencies.

The acceptability criteria for the internal consistency checks are reported in **Table 2-2**.

Table 2-2 Chemical Analysis Acceptability Criteria

Test	Criteria
Charge Balance	+-10%
Calculated TDS/Measured TDS	0.9-1.1

The wells used to represent the downgradient groundwater were selected by looking at the chemistry, particularly the iron content within the water (see Section 3). A summary of the waters used in the modeling is provided in **Table 2-3**

Table 2-3 – Summary of Water Samples Used for PHREEQC Geochemical Modeling – EPA Column Experiment.

Sample ID	Date Sampled	Notes
Decant 1	5/14/09	Decant pond
MW-01-15	5/13/09 6/08/09[1]	Well along southern edge of the decant pond. Screened at a depth of approximately 40 feet below ground surface (bgs).
MW 95-4[2]	5/12/09	Well located just north of the southernmost toe pond (in between ponds). Screened at a depth of approximately 15 feet bgs.
MW 95-5[2]	5/12/09	Located downgradient of the toe ponds and screened at a depth of approximately 10 feet bgs.

1. Resampled for dissolved copper due to a suspected laboratory error.
2. Completed at or near the groundwater table within a sand and gravel zone.

The internal consistency checks of the data along with the chemical data used in the modeling are shown in **Table 2-4.**

Table 2-4 – Summary of analytical data Used in the PHREEQC Modeling (mg/L dissolved unless noted otherwise)

Parameter	Decant 1	MW-01-15	MW 95-4	MW 95-5
Date Sampled	5/14/09	6/08/09	5/12/09	5/12/09
Temperature (°C)	9.5	14.1	8	8.8
pH-Lab	7.6	7.5	6.5	5.9
pH-Field	7.45	7.3	7.3	6.04
Total Alkalinity (as $CaCO_3$)	82	85	77	31
Chloride	4	4	1	<1
Sulfate (as SO_4)	33	41	111	3
Sulfide	0.04	<0.04	0.22	<0.04
Ammonia (as N)	6.0	3.64	3.72	<0.05
Nitrite + Nitrate (as N)	17.6	14.5	0.02	0.09
Phosphorous (as P)	0.134	0.025	0.014	0.016
Arsenic	0.002	<0.001	0.002	<0.001
Antimony	0.046	0.029	<0.003	<0.003
Barium	0.097	0.107	0.114	0.016
Cadmium	0.00089	0.00136	0.00093	0.00089
Calcium	17	23	29	6
Copper	0.028	0.009[2]	<0.001	0.002
Iron	0.06	<0.05	7.84	0.18
Lead	0.0026	<0.0005	<0.0005	<0.0005
Magnesium	4	5	8	1
Manganese	0.554	0.467	2.43	0.457
Potassium	27	23	17	5
Silica	8.5	11.4	46.4	60.8
Sodium	31	32	13	5
Uranium	0.0029	0.0018	<0.0003	<0.0003
Conductivity (µmhos/cm)	427	405	445	82
TDS Measured	305	247	292	97
TDS Calculated	259	259	286	100
Charge Balance (%)[1]	-0.44	1.59	-1.93	2.71
TDS-C/TDS-M	0.85	1.05	0.98	1.03

1. Calculated using PHREEQC.

2. Re-sampled due to an apparent lab error.

The results indicate that all of the waters meet the chemical analysis acceptability criteria with the exception of Decant 1, which has a mass balance which is out of range. As the charge balance is very good, the error could simply be an over-reporting of the TDS analysis, which would have no impact on the modeling. There may also be a neutral species that was not included within the analysis, but this would have minimal impact on the modeling

2.2 PHREEQC Thermodynamic Database

The PHREEQC database is provided as a starting point and often new phases need to be added to address specific modeling requirements. The thermodynamic database used by PHREEQC was supplemented to include several additional iron phases. The phases that were added and the thermodynamic data used are shown in **Table 2-5**.

Table 2-5 - Summary of Thermodynamic Data Added to the PHREEQC Database

Phase	Reaction	Log Ksp	ΔHr° (kcal)
Troilite	Fe^{+2} (aq) + S^{-2} (aq) → FeS (troilite)	19.1	-10.9
Pyrite	Fe^{+2} (aq) + S^{0} (aq) + S^{-2} (aq) → FeS_2 (pyrite)	29.3	-27.6
Marcasite	Fe^{+2} (aq) + S^{0} (aq) + S^{-2} (aq) → FeS_2 (marcasite)	28.6	-26.6
Mackinawite	Fe^{+2} (aq) + S^{-2} (aq) → FeS (mackinawite)	17.6	-8.5
Mackinawite (alkaline)[1]	Fe^{+2} (aq) + HS^{-} (aq) → FeS (mackinawite) + H^{+}	-3.5	-
Greigite	Fe^{+2} (aq) + 2 Fe^{+3} (aq) + 4 S^{2-} (aq) → Fe_3S_4 (greigite)	90.4	-57.4
Magnetite	$3Fe^{+2} + 4H_2O \rightarrow Fe_3O_4 + 8H^{+} + 2e^{-}$	-45.8	-
Lepidocrocite	$Fe^{+2} + 2H_2O \rightarrow$ γ-FeOOH + $3H^{+} + e^{-}$	-16.7	-

1. "alkaline" refers to the solubility of the mackinawite phase which forms at pH>7 (Rickard, 2006)

More common phases, such as hematite were already included in the PHREEQC database and are not included in **Table 2-5**. Pyrite was in the PHREEQC database, but only the solubility constant (log Ksp) was provided. The log Ksp was recalculated, along with the enthalpy (**ΔHr°**) to make sure the data were consistent.

2.3 Oxidation-Reduction Potential (ORP)

The oxidation-reduction potential (ORP) of the solution (also referred to as "Eh") is one of the most important parameters for geochemical modeling, but is also one of the most difficult to accurately measure.

Eh was calculated several ways for potential use in the modeling, including the following:

- From the platinum electrode measurements collected in the field
- From the sulfate/sulfide redox couple
- From the nitrite/ammonia redox couple

ORP Calculation Methods

Oxidation reduction potential (ORP) is used by the PHREEQC model to determine the relative proportions of the parameters that have more than one oxidation state in solution. For example iron can exist in solution as ferric iron (Fe^{+3}) or as ferrous iron (Fe^{+2}). The ORP can be directly measured using a platinum electrode, which has several problems, including interferences by sediment, certain ions, or dissolved organic matter. Lindberg and Runnels (1984) recommend evaluating the redox couples within a solution, such as sulfate/sulfide, ferrous iron/ferric iron, or nitrate/nitrite to determine the ORP and if the system is in redox equilibrium. Often, the Eh measured by the platinum electrode is a mixed potential resulting from multiple redox couples. The Eh can be calculated for each redox couple and compared. The system can be considered in redox equilibrium only when the Eh determined from each couple is the same. A summary of Eh values calculated using various methods along with dissolved oxygen (DO) values for comparison is presented in **Table 2-6**. The ferric/ferrous couple was not used due to the very low aqueous concentrations of ferric iron at low Eh and near-neutral pH. Obtaining ferric iron by difference (subtracting ferrous iron from total iron) could not be performed due to the low concentration of dissolved ferric iron in these systems (dissolved ferrous and total iron are essentially identical) and the error in the analytical techniques. Dissolved oxygen (DO) concentrations are listed in the table for comparison.

Table 2-6 Summary of Eh Values Calculated Using Different Methods

Parameter	Decant 1	MW-01-15	MW 95-4	MW 95-5		
$Eh_{Pt\ Electrode}$ (mV)	397	351	272	397		
$Eh_{SO4-2/S-2}$ (mV)	-200	>198[2]	-183	>-110[2]		
$Eh_{NO2-/NH4+}$ (mV)[1]	347	349	336	>452[3]		
DO (mg/L)	8.90	4.35	0.18	1.77		

1. The assumption was made that nitrate+nitrite = nitrite

2. Using the detection limit of 0.04 mg/L for sulfide, so the Eh can be considered a minimum.

3. Using the detection limit of 0.05 mg/L for ammonia, so the Eh can be considered a minimum

Eh Pt electrode = The Eh as determined using the platinum electrode

$Eh_{SO4-2/S-2}$ = The Eh calculated from the sulfate/sulfide couple

$Eh_{NO2-/NH4+}$ = The Eh calculated from the nitrite/ammonia couple

A comparison of the Eh values indicates that in general, the waters are not in redox equilibrium. For instance, well MW 95-4 contains both significant sulfide (a reduced form) and nitrite or nitrate (an oxidized form), which would not occur together under equilibrium conditions. The decant water contains significant concentrations of both ammonia and oxygen. Given enough time, the ammonia will be oxidized by the DO, producing nitrite and/or nitrate and water.

Section 3
Geochemical Modeling Results

3.1 Mineral Saturation States

The PHREEQC model uses a term called the saturation index (SI) to quantify the degree of saturation of a mineral. SI is defined as follows:

$$SI = Log\ (IAP/Ksp) \qquad (3\text{-}1)$$

Where IAP is the ion activity product and Ksp is the solubility product constant for the phase in question. For phases at saturation, IAP=Ksp and SI = 0. A negative SI indicates that the phase is unsaturated (IAP<Ksp) while a positive SI (IAP>Ksp) indicates the phase is supersaturated. In practice, a range of 0±0.5 SI units is considered saturated due to uncertainties in analytical and thermodynamic data (Hem, 1970). In the present study, a value of 0±1.0 SI units was used to allow for additional uncertainties in the redox measurements and Eh calculations.

The mineral saturation states for the unmixed waters are provided in **Table 3-1**.

Table 3-1 – Summary of Saturation Indices (SIs) Determined Using PHREEQC

Phase	MW 95-4	MW 95-5	MW-01-15	Decant 1
Barite ($BaSO_4$)	0.85	-1.30	0.35	0.33
Poorly Ordered Mackinawite (FeS)	0.68	-2.93	-2.94	-3.21
Alkaline Mackinawite (FeS)	0.68	-	-3.13	-3.26
Amorphous $Fe(OH)_3$	-	0.90	**1.76**[1]	**2.48**[2]
Siderite ($FeCO_3$)	0.62	-2.51	-3.01	-3.35
Vivianite ($Fe_3(PO_4)_2$ $8H_2O$)	-0.31	-8.94	-10.96	-10.32
Rhodochrosite ($MnCO_3$)	0.42	-1.78	-0.13	0.01
Amorphous Silica (SiO_2)	-0.25	-0.14	-0.92	-1.00

1.Supersaturation likely due to using half the reporting limit for the iron concentration (0.025 mg/L)

2.Supersaturation likely due to uncertainties in the reported iron concentration (0.06 mg/L) so close to the reporting limit of 0.05 mg/L

Bold indicates supersaturated phases

Shaded cells represent phases at equilibrium (SI=0±1 SI unit)

Minerals that are at saturation (SI = 0 ± 1) are in equilibrium and will not precipitate or dissolve unless the geochemical conditions are changed. Supersaturated solutions (SI >1) are predicted to precipitate, while undersaturated phases (SI<1) are predicted to dissolve (if present).

In addition to the minerals shown above, other minerals which were not included in the thermodynamic database are possible. For example, there is field evidence for the presence of the mineral delafossite ($CuFeO_2$), based on the work conducted by Land and Water (2004).

Ferrous Iron Minerals

Ferrous iron minerals have the capacity to coprecipitate copper. The high pH mackinawite phase investigated by Rickard (2006) which has been named "alkaline mackinawite" for the purposes of this report was only included for sites which had pH values greater than 7 (MW 95-4, MW-01-15, and Decant 1).

Well MW 95-4 is at saturation with respect to the iron monosulfide mackinawite, as well as siderite, and vivianite, all of which are ferrous iron (Fe^{+2}) minerals. The other waters, being more oxidized are undersaturated with respect to the ferrous iron minerals.

Amorphous Silica

Amorphous silica is at saturation for all of the waters analyzed. However, silica does not typically incorporate copper into precipitates except as inclusions of other phases, such as iron oxyhydroxides or sulfides.

Barite

Barite is at saturation in all of the waters except for well MW 95-5. Barite does not typically coprecipitate metals such as copper.

Rhodochrosite

Rhodocrosite is at saturation in all of the waters except for MW 95-5. Rhodochrosite likely does not incorporate copper into the crystal structure of the mineral to a great extent as divalent copper and divalent manganese have significantly different ionic radii (71 picometers [pm] for divalent copper vs 80 pm for divalent manganese). However, as the ionic radii are within 30% of each other limited substitution of copper for manganese in the mineral structure may be possible according to "Goldschmidt's Rules."

Amorphous $Fe(OH)_3$

Amorphous $Fe(OH)_3$ is calculated to be at saturation in well MW 95-5 and is supersaturated for well MW-01-15 and Decant 1. The supersaturation of MW-01-15 is likely due to the use of half the reporting limit for the iron concentration. For Decant 1, the iron concentration may be in error, as the value reported is close to the reporting limit, where instrument "noise" is usually significant. Instrument noise is the fluctuation in laboratory results as the limitations of the analytical method are approached. In th case, the error is minimal, as supersaturation or saturation of amorphous $Fe(OH)_3$ are both indications that the mineral is present in the system already or will precipitate given enough time.

Another explanation for the supersaturation of amorphous $Fe(OH)_3$ is that fine particulate iron is being included in the dissolved analysis. Studies have shown that very fine grained particulate matter (less than 0.45 microns in diameter) can pass through the filters. During processing (digestion) of the sample the fine particles dissolve and are included as part of the dissolved fraction of iron.

Comparison of Historic Iron Concentrations

As the presence of iron in the groundwater is important for the removal mechanism being investigated, a review of the historic iron concentrations within the groundwater was conducted. In May 2009, well MW 95-5, had surprisingly low iron compared to the March 2001 analysis where a concentration of 36 mg/L was measured. **Figure 1** shows that both wells MW 95-4 and MW 95-5 have had large variations in dissolved iron concentrations since 1995. The decrease in iron concentration in MW-95-5 from 36 mg/L to 0.08 mg/L in April 2003 and 0.18 mg/L in May 2009 was likely due to oxidation of the iron by decant water, infiltration, or dust control irrigation. It appears that the downgradient groundwater at times is influenced by oxygenated water of unknown origin that may be seasonal in nature or the result of changes in decant water influx (i.e. Mine Flooding study from September 2002 through February 2004) or the water balance of the groundwater system.

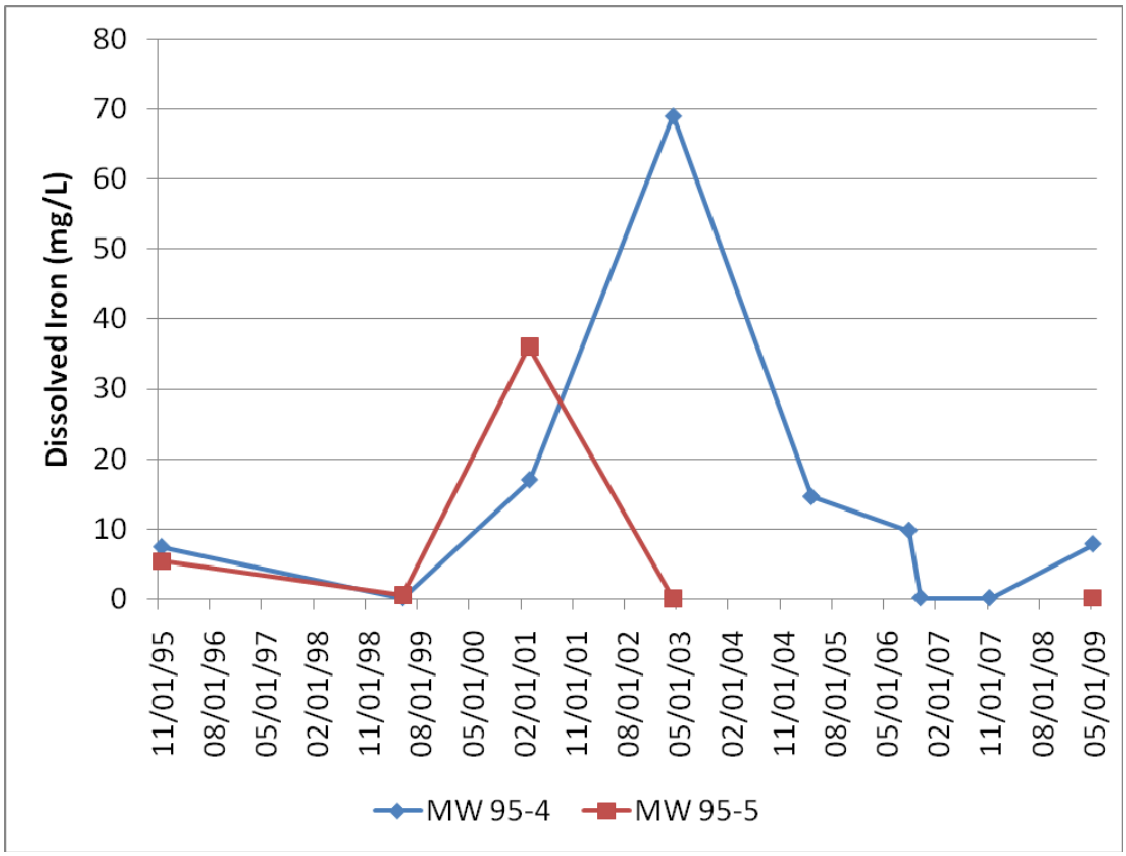

Figure 1 – Variations in dissolved iron concentrations with time for wells MW 95-4 and MW 95-5.

Iron concentrations within wells MW-1, MW-2, and MW-3 have also varied significantly, as shown in **Figure 2**. The inconsistency in the iron concentrations within the downgradient groundwaters may indicate that the secondary removal process is more effective at some times than others due possibly to seasonal processes.

3.2 Mixing Scenarios

Mixing scenarios were modeled using the waters from well MW-01-15 and well MW 95-4 in equal proportions. The decant water was not modeled, as it has the same measured Eh value and an even higher DO concentration than MW-01-15. The mixing ratio was set at 50% for each water as this is the optimal degree of mixing where both iron and DO concentrations are high. At lower fractions of MW 95-4 the iron concentration becomes lower, while at greater fractions the DO (and Eh) becomes lower. The water from well MW-01-15 is beneath the decant ponds and is the water that will eventually travel downgradient to mix with the natural groundwater.

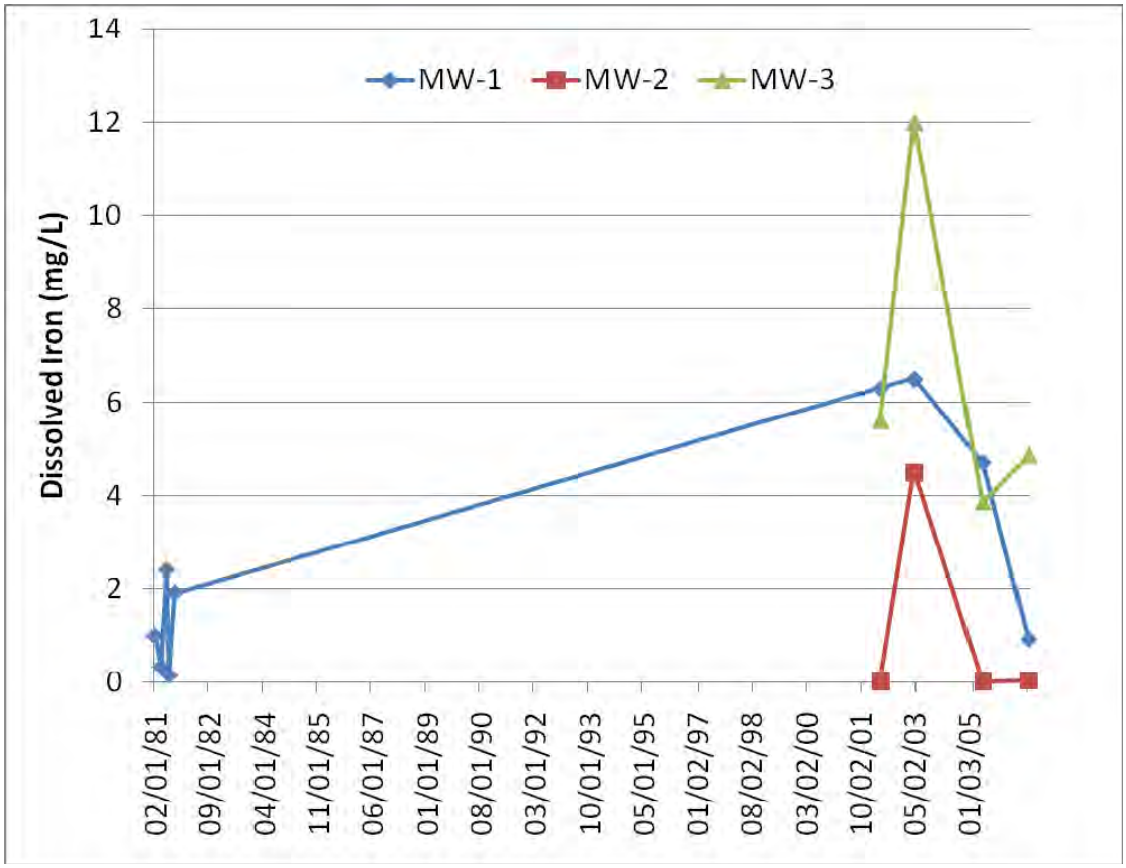

Figure 2 – Variations in dissolved iron concentrations with time for wells MW-1, MW-2 and MW-3

The results of the mixing modeling using three different assumptions to set the Eh of the mixture is shown in **Table 3-2**.

Table 3-2 – Summary of the 50:50 Mixing Simulation Results Using PHREEQC

Scenario	Iron Precipitated as $Fe(OH)_3$	Percent of Iron Precipitated
MW 95-4 and MW-01-15, Assume all of the DO in the mixture reacts with the iron	3.90 mg/L	100%
MW 95-4 and MW-01-15, Assume that the Eh attained by the mixture is the same as for well MW 95-5 (397 mV)	3.90 mg/L	100%
MW 95-4 and MW-01-15, Assume that the final Eh is the average of the two waters mixed (83 mV)	3.87 mg/L	98.3%

The Eh of the mixture had to be set within PHREEQC, as the model does not accurately predict the final Eh of the mixture. The three scenarios were as follows:

- Assume all of the DO in the mixture reacts with the iron – The DO provided by the decant water is allowed to react with any ferrous iron present in MW 95-4. While this makes sense from an equilibrium standpoint, oxygen does not usually attain equilibrium within surface waters.

- Assume that the Eh attained by the mixture is the same as for well MW 95-5 (397 mV) – As it is likely that well MW 95-5 has already undergone mixing, the use of the "final" Eh of a real site water is reasonable. As the mine or decant water is similar to an oxygenated infiltration water in terms of the redox properties, this is a reasonable assumption.

- Assume that the final Eh is the average of the two waters – While this scenario is the least likely of the three, it was included in order to show the result of a lower final Eh. In reality, the Eh of mixed waters is rarely linear as this method implies.

The results show that the mixing of the decant-influenced water (MW-01-15) and the natural groundwater (MW 95-4) results in the precipitation of $Fe(OH)_3$. Should copper from the decant or mine water ever reach the area of MW 95-4, the precipitation of the amorphous ferric hydroxide would likely result in coprecipitation of copper as follows:

$$2x\ Fe^{+3} + 3\text{-}3x\ Cu^{+2} + 6\ OH^{-} \rightarrow Fe_{2x}Cu_{3\text{-}3x}(OH)_6\ (s) \qquad (3\text{-}2)$$

Where "x" is the fraction of iron in the precipitated phase (Other divalent [charge of +2] metals would be removed in a similar fashion). However, the value of x is difficult to predict and determination of the relative fractions of iron and copper in the coprecipitate requires bench-scale testing.

Section 4
Bench-Scale Tests

4.1 Sample Collection

To determine the relative fractions of iron and copper in the coprecipitate, samples were collected for bench-scale testing. Three locations were selected at the Troy Mine site for sampling. To represent post-mining water quality, water was collected underground in the mine behind the Seven East dam. This water was chosen as an appropriate closure mine water surrogate because it was collected in an area of little recent blasting activity evidenced by its relatively low ammonia content (from explosives residues). Mine water would be discharged at closure to the decant pond, which was selected as the second sampling location. The third sample was ground water collected from location MW 95-4, at the farthest downgradient edge of the tailings impoundment.

On December 16, 2009, after meeting with mine personnel and reviewing safety procedures, sampling personnel mobilized to well MW95-4 for sampling. A static water level was collected and then MW 95-4 was purged of approximately 5 well volumes using a disposable bailer. Field water quality readings were collected throughout the purging using a portable water quality meter. After purging the well, a sample was analyzed using field test equipment to check for ferrous iron concentrations in the well water. Results showed approximately 5 mg/L of ferrous iron; this was above the minimum requirement of 2 mg/L, so analytical and jar test samples were collected. Samples collected for laboratory analysis were immediately preserved in the field. The preserved samples would be laboratory analyzed to determine the initial concentrations of metals. An additional volume was collected for jar testing in unpreserved jugs.

The decant pond was sampled next. Due to the cold temperatures and icy conditions, access to the pond was limited to the pump dock. A hole was chipped through the ice to gain access to the pond water. Field readings were collected and then analytical and jar test samples were collected, as before.

Mine water was then collected next from behind the underground dam. Field readings, analytical samples, and jar test samples were collected, similar to the previous locations.

Field notes and photographs were collected during the sampling process, and are attached.

4.2 Jar Test Procedures

Once the sampling was completed, jar tests were performed using the unpreserved samples. A control plus mixtures were selected for testing, as follows:

- Control - 1000 mL MW 95-4 water
- Jar 1 - 250 mL of MW 95-4 water with 750 mL decant water (25% A+ 75% B)
- Jar 2 - 500 mL of MW 95-4 water with 500 mL decant water (50% A+ 50% B)
- Jar 3 - 750 mL of MW 95-4 water with 250 mL decant water (75% A+ 25% B)
- Jar 4 - 250 mL of MW 95-4 water with 750 mL mine water (25% A+ 75% C)
- Jar 5 - 500 mL of MW 95-4 water with 500 mL mine water (50% A+ 50% C)
- Jar 6 - 750 mL of MW 95-4 water with 250 mL mine water (75% A+ 25% C)
- Jar 7 - 500 mL of MW 95-4 water with 500 mL mine water + 20mL 25% hydrogen peroxide [H_2O_2] (75% A+ 25% C + H_2O_2)

The appropriate volumes of each water sampled were added and mixed in each test jar, and then the jars were allowed to react for duration of 20 days (from December 16, 2009 to January 5, 2010).

The mixed samples were allowed to react at room temperature within the uncovered sample jars. After the reaction period, a portion of each test jar was filtered, preserved, and submitted to the lab. Field parameters were again collected from the test jars. The remaining volume from each jar was labeled and archived.

All test jars were photographed prior to and after filtration.

4.3 Results

The results of the jar testing are summarized in **Table 4-1,** while the full analytical reports are provided as Attachment 1.

Table 4-1 - Summary of Jar Test Results

Sample	Description	Antimony (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Uranium (mg/L)	Lead (mg/L)
MW95-4	Field Sample	<0.001	<0.003	<0.00008	0.006	15.5	5.34	0.0005	<0.0005
Decant Pond	Field Sample	0.068	<0.003	<0.00008	0.032	<0.05	0.862	0.0033	0.0008
Mine Water	Field Sample	0.015	<0.003	<0.00008	0.114	<0.05	0.105	0.0011	0.0010
Jar 1	25% MW95-4 75% Decant	0.046	<0.001	0.0001	0.007	0.008	2.17	0.0017	<0.0005
Jar 2	50% MW95-4 50% Decant	0.026	<0.001	0.0001	0.005	0.009	3.49	0.0003	<0.0005
Jar 3	75% MW95-4 25% Decant	0.010	<0.001	0.0002	0.003	0.008	4.86	0.0004	<0.0005
Jar 4	25% MW95-4 75% Mine	0.010	<0.001	<0.0001	0.012	<0.005	1.52	0.0007	<0.0005
Jar 5	50% MW95-4 50% Mine	0.006	<0.001	0.0001	0.005	0.007	2.74	0.0004	<0.0005
Jar 6	75% MW95-4 25% Mine	0.002	<0.001	0.0002	0.003	<0.005	4.47	<0.0003	<0.0005
Jar 7	50% MW95-4 50% Mine w/ H_2O_2	0.007	<0.001	<0.0001	0.002	0.005	2.79	<0.0003	<0.0005
Control	100% MW95-4	<0.001	<0.001	0.0002	0.002	0.009	6.03	<0.0003	<0.0005

The differences in the reporting limit for arsenic were due to the fact that the three initial samples were analyzed using the standard reporting limit used by the laboratory. For all subsequent samples low level arsenic analyses were requested. However, the higher initial reporting limit was not a problem, as all subsequent analyses, including the control were below the low level reporting limit.

Reductions in concentrations of iron, copper, and to a lesser extent, antimony and uranium were observed as a result of mixing mine or decant water with the natural groundwater. Arsenic (as discussed above) and cadmium were below the analytical reporting limit in all three source waters. However, cadmium was detected in several of the mixed samples. As it is impossible to have a concentration in a mixture greater than either of the two component waters, it suggests a laboratory error, which is to be expected at levels so close to the reporting limit.

Due to the effect of dilution when two waters are mixed, the percent removals were calculated from the concentrations that would have resulted as a result of mixing alone (without coprecipitation or adsorption). The results are shown in **Table 4-2**.

Table 4-2 - Metal Removal Efficiency (Factoring in Dilution)

Sample	Antimony - Dilution (mg/L)	Percent Antimony Removal	Copper - Dilution (mg/L)	Percent Copper Removal	Iron - Dilution (mg/L)	Percent Iron Removal	Manganese - Dilution (mg/L)	Percent Manganese Removal	Uranium - Dilution (mg/L)	Percent Uranium Removal
Jar 1	0.051	10.5%	0.0255	72.5%	3.9	99.8%	2.0	-9.5%	0.0026	34.6%
Jar 2	0.035	25.2%	0.019	73.7%	7.8	99.9%	3.1	-12.5%	0.0019	84.2%
Jar 3	0.018	44.8%	0.0125	76.0%	11.6	99.9%	4.2	-15.2%	0.0012	66.7%
Jar 4	0.012	14.0%	0.087	86.2%	3.9	99.9%	1.4	-7.5%	0.0010	26.3%
Jar 5	0.008	27.3%	0.06	91.7%	7.8	99.9%	2.7	-0.6%	0.0008	50.0%
Jar 6	0.005	59.0%	0.033	90.9%	11.6	100.0%	4.0	-10.9%	0.0007	76.9%
Jar 7	0.008	15.2%	0.06	96.7%	7.8	99.9%	2.7	-2.5%	0.0	81.3%
Control	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Greater than 99% of the iron was removed during the 20 day duration of the jar tests, indicating that sufficient time was given to oxidize the ferrous iron to ferric iron and result in precipitation. The red-brown color of the jar tests indicated that iron oxyhydroxides had precipitated (see Attachment 2 for photographs). However, the manganese did not oxidize, even in the sample to which hydrogen peroxide was added (jar 7).

In general, copper was coprecipitated with the iron to a greater extent than antimony or uranium. However, the water of concern for the post-closure scenario would be mine water which had a significantly lower antimony (0.015 mg/L for the mine water vs. 0.068 for the current decant water) and uranium (0.0033 mg/L vs. 0.0011 mg/L) concentrations. An estimated 73-76% of the copper was removed from the decant/groundwater mixtures, with the removal efficiency increasing with increasing fractions of groundwater.

A similar trend was observed for the mine water/groundwater mixtures, although the efficiency was higher, ranging from 92-98% removal. Greater removal efficiencies may be expected at mixtures containing groundwater fractions higher than 75%. This higher groundwater fraction would be expected at the leading edge of any decant water plume containing copper that could hypothetically migrate from the tailings ponds in the future.

Section 5
Conclusions

The results of the modeling and bench-scale testing show that should the initial removal mechanisms documented by Land and Water (2004) to occur beneath the decant ponds become less effective over time, there are additional existing

geochemical mechanisms capable of removing at least 73-98% of the copper, 11-59% of the antimony, and 35-84% of the uranium from groundwater.

Section 6
References

Hem, 1970. *Study and Interpretation of the Chemical Characteristics of Natural Water*. 2nd ed. U.S. Geological Survey Water-Supply Paper 1473.

Hydrometrics. 2001. *Mine Water Plume Location and Identification Phase 1 Results and Phase 2 & 3 Workplan*. Prepared for Genesis Inc./Sterling Mining Company. October 2001.

Land and Water Conulting, Inc. 2004. *Assessment of Fate and Transport of Copper in Decant Pond System – Troy Mine. Lincoln County, Montana*. Prepared for Revett Mining Company. January 2004.

Langmuir, D. 1971. Eh-pH determination. In R.E. Carver Ed. *Procedures in Sedimentary Petrology*. Wiley, New York. p. 597-635.

Lindberg, R.D. and D.D. Runnells. 1984. Ground water redox reactions: An analysis of equilibrium state applied to Eh measurements and geochemical modeling. *Science.* v. 225. p. 925-927.

Parkhurst, D.L. and Appelo, C.A.J. 1999. User's Guide to PHREEQC (Version 2)- A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. USGS Water-Resources Investigations Report 99-4259.

Rickard, D. 2006. The solubility of FeS. *Geochimica Cosmochimica Acta*, v. 70 p. 5779-5789.

Attachment 1
Analytical Reports

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ANALYTICAL SUMMARY REPORT

January 28, 2010

Paul Kukay
Genesis Inc.
7000 Asarco Rd
Troy, MT 59935

Workorder No.: H10010040

Project Name: Troy Mine Jar Testing

Energy Laboratories Inc received the following 8 samples for Genesis Inc. on 1/5/2010 for analysis.

Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
H10010040-001	Control - 010410	01/04/10 14:56	01/05/10	Aqueous	Metals by ICP/ICPMS, Dissolved
H10010040-002	Jar1 - 010410	01/04/10 15:02	01/05/10	Aqueous	Same As Above
H10010040-003	Jar2 - 010410	01/04/10 15:10	01/05/10	Aqueous	Same As Above
H10010040-004	Jar3 - 010410	01/04/10 15:16	01/05/10	Aqueous	Same As Above
H10010040-005	Jar4 - 010410	01/04/10 15:25	01/05/10	Aqueous	Same As Above
H10010040-006	Jar5 - 010410	01/04/10 15:30	01/05/10	Aqueous	Same As Above
H10010040-007	Jar6 - 010410	01/04/10 15:35	01/05/10	Aqueous	Same As Above
H10010040-008	Jar7 - 010410	01/04/10 15:40	01/05/10	Aqueous	Same As Above

BRANCH LABORATORY LOCATIONS
eli-b - Energy Laboratories, Inc. - Billings, MT, EPA # MT00005
eli-c - Energy Laboratories, Inc. - Casper, WY, EPA# WY00002
eli-g - Energy Laboratories, Inc. - Gillette, WY, EPA# WY00006
eli-h - Energy Laboratories, Inc. - Helena, MT, EPA# MT00945
eli-r - Energy Laboratories, Inc. - Rapid City, SD, EPA# SD00012
eli-t - Energy Laboratories, Inc. - College Station, TX, EPA# TX01520

SUBCONTRACTING ANALYSIS
Subcontracting of sample analyses to an outside laboratory may be required. If so, ENERGY LABORATORIES, INC. will utilize its branch laboratories or qualified contract laboratories for this service. Any such laboratories are indicated within the Laboratory Analytical Report.

SAMPLE TEMPERATURE COMPLIANCE: 4°C (±2°C)
Temperature of samples received may not be considered properly preserved by accepted standards. Samples that are hand delivered immediately after collection shall be considered acceptable if there is evidence that the chilling process has begun.

ELI appreciates the opportunity to provide you with this analytical service. For additional information, including certifications, and analytical services visit our web page www.energylab.com.

Report Approved By:_____

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@enerylab.com

LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-001
Client Sample ID Control - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 14:56
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	ND	mg/L		0.001		E200.8	01/08/10 23:35 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/08/10 23:35 / dck
Cadmium	0.0002	mg/L		0.0001		E200.8	01/08/10 23:35 / dck
Copper	0.002	mg/L		0.001		E200.8	01/08/10 23:35 / dck
Iron	0.009	mg/L		0.005		E200.8	01/12/10 01:28 / dck
Manganese	6.03	mg/L		0.005		E200.8	01/09/10 20:32 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-002
Client Sample ID Jar1 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:02
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.046	mg/L		0.001		E200.8	01/08/10 23:42 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/08/10 23:42 / dck
Cadmium	0.0001	mg/L		0.0001		E200.8	01/08/10 23:42 / dck
Copper	0.007	mg/L		0.001		E200.8	01/08/10 23:42 / dck
Iron	0.008	mg/L		0.005		E200.8	01/12/10 01:48 / dck
Manganese	2.17	mg/L		0.005		E200.8	01/08/10 23:42 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-003
Client Sample ID Jar2 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:10
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.026	mg/L		0.001		E200.8	01/08/10 23:48 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/08/10 23:48 / dck
Cadmium	0.0001	mg/L		0.0001		E200.8	01/08/10 23:48 / dck
Copper	0.005	mg/L		0.001		E200.8	01/08/10 23:48 / dck
Iron	0.009	mg/L		0.005		E200.8	01/12/10 02:36 / dck
Manganese	3.49	mg/L		0.005		E200.8	01/08/10 23:48 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-004
Client Sample ID Jar3 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:16
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.010	mg/L		0.001		E200.8	01/09/10 00:43 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/09/10 00:43 / dck
Cadmium	0.0002	mg/L		0.0001		E200.8	01/09/10 00:43 / dck
Copper	0.003	mg/L		0.001		E200.8	01/09/10 00:43 / dck
Iron	0.008	mg/L		0.005		E200.8	01/09/10 00:43 / dck
Manganese	4.86	mg/L		0.005		E200.8	01/09/10 21:39 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-005
Client Sample ID Jar4 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:25
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.010	mg/L		0.001		E200.8	01/09/10 00:50 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/09/10 00:50 / dck
Cadmium	ND	mg/L		0.0001		E200.8	01/09/10 00:50 / dck
Copper	0.012	mg/L		0.001		E200.8	01/09/10 00:50 / dck
Iron	ND	mg/L		0.005		E200.8	01/09/10 00:50 / dck
Manganese	1.52	mg/L		0.005		E200.8	01/09/10 00:50 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-006
Client Sample ID Jar5 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:30
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.006	mg/L		0.001		E200.8	01/09/10 00:56 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/09/10 00:56 / dck
Cadmium	0.0001	mg/L		0.0001		E200.8	01/09/10 00:56 / dck
Copper	0.005	mg/L		0.001		E200.8	01/09/10 00:56 / dck
Iron	0.007	mg/L		0.005		E200.8	01/09/10 00:56 / dck
Manganese	2.74	mg/L		0.005		E200.8	01/09/10 00:56 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-007
Client Sample ID Jar6 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:35
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.002	mg/L		0.001		E200.8	01/09/10 01:03 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/09/10 01:03 / dck
Cadmium	0.0002	mg/L		0.0001		E200.8	01/09/10 01:03 / dck
Copper	0.003	mg/L		0.001		E200.8	01/09/10 01:03 / dck
Iron	ND	mg/L		0.005		E200.8	01/09/10 01:03 / dck
Manganese	4.47	mg/L		0.005		E200.8	01/09/10 01:03 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine Jar Testing
Lab ID: H10010040-008
Client Sample ID Jar7 - 010410

Report Date: 01/28/10
Collection Date: 01/04/10 15:40
DateReceived: 01/05/10
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Antimony	0.007	mg/L		0.001		E200.8	01/09/10 01:10 / dck
Arsenic	ND	mg/L		0.001		E200.8	01/09/10 01:10 / dck
Cadmium	ND	mg/L		0.0001		E200.8	01/09/10 01:10 / dck
Copper	0.002	mg/L		0.001		E200.8	01/09/10 01:10 / dck
Iron	0.005	mg/L		0.005		E200.8	01/09/10 01:10 / dck
Manganese	2.79	mg/L		0.005		E200.8	01/09/10 01:10 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine Jar Testing

Report Date: 01/28/10
Work Order: H10010040

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_100108A		
Sample ID: QCS-090602A,090609	6	Initial Calibration Verification Standard								01/08/10 13:32
Antimony		0.0499	mg/L	0.050	100	90	110			
Arsenic		0.0497	mg/L	0.0050	99	90	110			
Cadmium		0.0258	mg/L	0.0010	103	90	110			
Copper		0.0507	mg/L	0.010	101	90	110			
Iron		0.261	mg/L	0.030	102	90	110			
Manganese		0.247	mg/L	0.010	99	90	110			
Sample ID: ICSA-090423A	6	Interference Check Sample A								01/08/10 13:39
Antimony		0.000189	mg/L	0.050						
Arsenic		0.000151	mg/L	0.0050						
Cadmium		0.000421	mg/L	0.0010						
Copper		0.00118	mg/L	0.010						
Iron		99.6	mg/L	0.030	100	70	130			
Manganese		0.00223	mg/L	0.010						
Sample ID: ICSAB-090423A,09010	6	Interference Check Sample AB								01/08/10 13:46
Antimony		0.000153	mg/L	0.050		0	0			
Arsenic		0.0105	mg/L	0.0050	105	70	130			
Cadmium		0.0101	mg/L	0.0010	101	70	130			
Copper		0.0208	mg/L	0.010	104	70	130			
Iron		96.9	mg/L	0.030	97	70	130			
Manganese		0.0220	mg/L	0.010	110	70	130			
Sample ID: QCS-090602A,090609	6	Initial Calibration Verification Standard								01/08/10 22:07
Antimony		0.0498	mg/L	0.050	100	90	110			
Arsenic		0.0498	mg/L	0.0050	100	90	110			
Cadmium		0.0263	mg/L	0.0010	105	90	110			
Copper		0.0503	mg/L	0.010	101	90	110			
Iron		0.264	mg/L	0.030	104	90	110			
Manganese		0.251	mg/L	0.010	101	90	110			
Sample ID: ICSA-090423A	6	Interference Check Sample A								01/08/10 22:14
Antimony		0.000180	mg/L	0.050						
Arsenic		0.000103	mg/L	0.0050						
Cadmium		0.000326	mg/L	0.0010						
Copper		0.00123	mg/L	0.010						
Iron		98.6	mg/L	0.030	99	70	130			
Manganese		0.00219	mg/L	0.010						
Sample ID: ICSAB-090423A,09010	6	Interference Check Sample AB								01/08/10 22:20
Antimony		0.000156	mg/L	0.050		0	0			
Arsenic		0.0104	mg/L	0.0050	104	70	130			
Cadmium		0.0101	mg/L	0.0010	101	70	130			
Copper		0.0207	mg/L	0.010	104	70	130			
Iron		96.3	mg/L	0.030	96	70	130			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine Jar Testing

Report Date: 01/28/10
Work Order: H10010040

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_100108A		
Sample ID: ICSAB-090423A,09010	6	Interference Check Sample AB								01/08/10 22:20
Manganese		0.0210	mg/L	0.010	105	70	130			
Sample ID: QCS-090602A,090609	6	Initial Calibration Verification Standard								01/09/10 05:14
Antimony		0.0493	mg/L	0.050	99	90	110			
Arsenic		0.0494	mg/L	0.0050	99	90	110			
Cadmium		0.0259	mg/L	0.0010	104	90	110			
Copper		0.0504	mg/L	0.010	101	90	110			
Iron		0.254	mg/L	0.030	99	90	110			
Manganese		0.256	mg/L	0.010	103	90	110			
Sample ID: ICSA-090423A	6	Interference Check Sample A								01/09/10 05:21
Antimony		0.000209	mg/L	0.050						
Arsenic		0.000148	mg/L	0.0050						
Cadmium		0.000313	mg/L	0.0010						
Copper		0.00130	mg/L	0.010						
Iron		97.9	mg/L	0.030	98	70	130			
Manganese		0.00207	mg/L	0.010						
Sample ID: ICSAB-090423A,09010	6	Interference Check Sample AB								01/09/10 05:27
Antimony		0.000150	mg/L	0.050		0	0			
Arsenic		0.0102	mg/L	0.0050	102	70	130			
Cadmium		0.00988	mg/L	0.0010	99	70	130			
Copper		0.0208	mg/L	0.010	104	70	130			
Iron		98.9	mg/L	0.030	99	70	130			
Manganese		0.0217	mg/L	0.010	108	70	130			
Method: E200.8										Batch: R59545
Sample ID: LRB	6	Method Blank				Run: ICPMS204-B_100108A				01/08/10 14:46
Antimony		ND	mg/L	3E-05						
Arsenic		ND	mg/L	2E-05						
Cadmium		ND	mg/L	1E-05						
Copper		ND	mg/L	3E-05						
Iron		ND	mg/L	6E-05						
Manganese		3E-05	mg/L	2E-05						
Sample ID: LFB	6	Laboratory Fortified Blank				Run: ICPMS204-B_100108A				01/08/10 14:53
Antimony		0.0511	mg/L	0.050	102	85	115			
Arsenic		0.0497	mg/L	0.0050	99	85	115			
Cadmium		0.0495	mg/L	0.0010	99	85	115			
Copper		0.0485	mg/L	0.010	97	85	115			
Iron		4.91	mg/L	0.030	98	85	115			
Manganese		0.0497	mg/L	0.010	99	85	115			
Sample ID: H10010040-003AMS	6	Sample Matrix Spike				Run: ICPMS204-B_100108A				01/08/10 23:55
Antimony		0.0751	mg/L	0.0050	98	70	130			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine Jar Testing

Report Date: 01/28/10
Work Order: H10010040

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8										Batch: R59545
Sample ID: H10010040-003AMS	6	Sample Matrix Spike				Run: ICPMS204-B_100108A				01/08/10 23:55
Arsenic		0.0505	mg/L	0.0050	100	70	130			
Cadmium		0.0484	mg/L	0.0010	97	70	130			
Copper		0.0525	mg/L	0.010	95	70	130			
Iron		4.81	mg/L	0.030	96	70	130			
Manganese		3.40	mg/L	0.010		70	130			A
Sample ID: H10010041-001CMS	6	Sample Matrix Spike				Run: ICPMS204-B_100108A				01/09/10 01:57
Antimony		0.0507	mg/L	0.0050	101	70	130			
Arsenic		0.0501	mg/L	0.0050	100	70	130			
Cadmium		0.0498	mg/L	0.0010	96	70	130			
Copper		0.0467	mg/L	0.010	93	70	130			
Iron		4.84	mg/L	0.030	97	70	130			
Manganese		17.2	mg/L	0.010		70	130			A
Sample ID: H10010041-001CMSD	6	Sample Matrix Spike Duplicate				Run: ICPMS204-B_100108A				01/09/10 02:04
Antimony		0.0498	mg/L	0.0050	100	70	130	1.7	20	
Arsenic		0.0505	mg/L	0.0050	100	70	130	0.6	20	
Cadmium		0.0495	mg/L	0.0010	95	70	130	0.6	20	
Copper		0.0472	mg/L	0.010	94	70	130	1.1	20	
Iron		4.89	mg/L	0.030	98	70	130	1.1	20	
Manganese		17.3	mg/L	0.010		70	130	0.6	20	A

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine Jar Testing

Report Date: 01/28/10
Work Order: H10010040

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_100109B		
Sample ID: QCS-090602A,090609		Initial Calibration Verification Standard							01/09/10 18:57	
Manganese		0.248	mg/L	0.010	99	90	110			
Sample ID: ICSA-090423A		Interference Check Sample A							01/09/10 19:03	
Manganese		0.00225	mg/L	0.010						
Sample ID: ICSAB-090423A,09010		Interference Check Sample AB							01/09/10 19:10	
Manganese		0.0224	mg/L	0.010	112	70	130			
Sample ID: QCS-090602A,090609		Initial Calibration Verification Standard							01/10/10 00:14	
Manganese		0.251	mg/L	0.010	101	90	110			
Method: E200.8										Batch: R59556
Sample ID: LRB		Method Blank				Run: ICPMS204-B_100109B			01/09/10 20:11	
Manganese		4E-05	mg/L	2E-05						
Sample ID: LFB		Laboratory Fortified Blank				Run: ICPMS204-B_100109B			01/09/10 20:18	
Manganese		0.0510	mg/L	0.010	102	85	115			
Sample ID: H10010040-001AMS		Sample Matrix Spike				Run: ICPMS204-B_100109B			01/09/10 20:39	
Manganese		5.96	mg/L	0.010		70	130			A
Sample ID: H10010040-001AMSD		Sample Matrix Spike Duplicate				Run: ICPMS204-B_100109B			01/09/10 20:45	
Manganese		5.96	mg/L	0.010		70	130	0	20	A
Sample ID: H10010041-001CMS		Sample Matrix Spike				Run: ICPMS204-B_100109B			01/09/10 21:53	
Manganese		16.1	mg/L	0.010		70	130			A
Sample ID: H10010041-001CMSD		Sample Matrix Spike Duplicate				Run: ICPMS204-B_100109B			01/09/10 21:59	
Manganese		14.2	mg/L	0.010		70	130	13	20	A

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine Jar Testing

Report Date: 01/28/10
Work Order: H10010040

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_100111A		
Sample ID: QCS-090602A,090609		Initial Calibration Verification Standard								01/11/10 17:17
Iron		0.260	mg/L	0.030	**102**	90	110			
Sample ID: ICSA-090423A		Interference Check Sample A								01/11/10 17:24
Iron		101	mg/L	0.030	**101**	70	130			
Sample ID: ICSAB-090423A,09010		Interference Check Sample AB								01/11/10 17:30
Iron		101	mg/L	0.030	**101**	70	130			
Sample ID: QCS-090602A,090609		Initial Calibration Verification Standard								01/12/10 05:25
Iron		0.255	mg/L	0.030	**100**	90	110			
Sample ID: ICSA-090423A		Interference Check Sample A								01/12/10 05:32
Iron		101	mg/L	0.030	**101**	70	130			
Sample ID: ICSAB-090423A,09010		Interference Check Sample AB								01/12/10 05:38
Iron		99.9	mg/L	0.030	**100**	70	130			
Method: E200.8										Batch: R59601
Sample ID: LRB		Method Blank				Run: ICPMS204-B_100111A				01/12/10 01:01
Iron		0.0004	mg/L	6E-05						
Sample ID: LFB		Laboratory Fortified Blank				Run: ICPMS204-B_100111A				01/12/10 01:08
Iron		4.85	mg/L	0.030	**97**	85	115			
Sample ID: H10010040-003AMS		Sample Matrix Spike				Run: ICPMS204-B_100111A				01/12/10 02:43
Iron		4.86	mg/L	0.030	**97**	70	130			
Sample ID: H10010040-003AMSD		Sample Matrix Spike Duplicate				Run: ICPMS204-B_100111A				01/12/10 02:50
Iron		4.85	mg/L	0.030	**97**	70	130	**0.1**	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

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Workorder Receipt Checklist

Genesis Inc Troy Mine

H10010040

Login completed by: Tracy L. Lorash

Date and Time Received: 1/5/2010 1:26 PM

Reviewed by: BL2000\wjohnson

Received by: TLL

Reviewed Date: 1/27/2010 12:39:03 PM

Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed w hen relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees w ith sample labels?	Yes ☐	No ☑	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received w ithin holding time?	Yes ☑	No ☐	
Container/Temp Blank temperature:	4.4°C On Ice		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☑	No ☐	Not Applicable ☐

Contact and Corrective Action Comments:

Jar 3 has 010409 as part of sample ID and as the date. Contacted Dustin and it is supposed to read 010410. Tl

ENERGY LABORATORIES

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name: CAMP DRESSER MCKEE / CDM	Project Name, PWS, Permit, Etc.: TROY MINE JAR TESTING	Sample Origin State: MT	EPA/State Compliance: Yes ☐ No ☒
Report Mail Address: 50 W 14TH ST, #200 HELENA, MT 59601	Contact Name: DUSTIN KLEMPEL Phone/Fax: (406) 441-1405	Email: KLEMPEL DT@CDM.COM	Sampler: (Please Print) DUSTIN T KLEMPEL
Invoice Address: P.O. BOX 1660 TROY, MT 59935	Invoice Contact & Phone: PAUL KUKAY (406) 295-5882 x221	Purchase Order: —	Quote/Bottle Order: —

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

- ☐ DW
- ☐ GSA
- ☐ POTW/WWTP
- ☐ State: _____
- ☐ Other: _____
- ☐ A2LA
- ☐ EDD/EDT (Electronic Data) Format: _____
- ☐ LEVEL IV
- ☐ NELAC

Contact ELI prior to **RUSH** sample submittal for charges and scheduling – See Instruction Page

Comments: ALL SAMPLES FIELD FILTERED & PRESERVED BY SAMPLER

Shipped by: Hand del.
Cooler ID(s): —
Receipt Temp: 4.4 °C
On Ice: (Yes) No
Custody Seal (Y) N
Bottles/Coolers B (C)
Intact (Y) N
Signature Match (Y) N

ANALYSIS REQUESTED

	SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX (Number of Containers; Sample Type: A W S V B O; Air Water Soils/Solids Vegetation Bioassay Other)	LOW LEVEL DISSOLVED METALS*	SEE ATTACHED	Normal Turnaround (TAT)	RUSH	LABORATORY USE ONLY
1	CONTROL-010410	01/04/10	1456	L	X				H10010040
2	JAR1-010410		15:02		X				
3	JAR2-010410		15:10		X				
4	JAR3-010410		15:16		X				
5	JAR4-010410		15:25		X				
6	JAR5-010410		15:30		X				
7	JAR6-010410		15:35		X				
8	JAR7-010410		15:40		X				
9									
10									

*LOW LEVEL DISSOLVED METALS = COPPER, ANTIMONY, IRON, MANGANESE, CADMIUM, ARSENIC

Custody Record MUST be Signed

Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
DUSTIN KLEMPEL	01/05/09 13:26	[signature]			
Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
			Received by Laboratory: Tracy Larsen	Date/Time: 1/5/10 13:26	Signature: [signature]

Sample Disposal: Return to Client: _____ Lab Disposal: _____

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report. Visit our web site at www.energylab.com for additional information, downloadable fee schedule, forms, and links.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-001
Client Sample ID MW 95-4

Report Date: 01/07/10
Collection Date: 12/16/09 10:20
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	6.4	s.u.		0.1		A4500-H B	12/17/09 17:50 / hm
Conductivity	801	umhos/cm		1		A2510 B	12/17/09 17:47 / hm
Solids, Total Dissolved TDS @ 180 C	561	mg/L		10		A2540 C	12/18/09 09:09 / JG
INORGANICS							
Alkalinity, Total as CaCO3	80	mg/L		1		A2320 B	12/17/09 20:25 / hm
Bicarbonate as HCO3	97	mg/L		1		A2320 B	12/17/09 20:25 / hm
Carbonate as CO3	ND	mg/L		1		A2320 B	12/17/09 20:25 / hm
Chloride	1	mg/L		1		E300.0	12/17/09 22:13 / hm
Sulfate	320	mg/L		1		E300.0	12/17/09 22:13 / hm
Sodium Adsorption Ratio (SAR)	0.63	unitless		0.01		Calculation	01/07/10 10:10 / wjj
Fluoride	ND	mg/L		0.1	4	A4500-F C	12/18/09 13:31 / JG
Sulfide	ND	mg/L		0.04		A4500 S-D	12/21/09 11:30 / eli-b
Hardness as CaCO3	232	mg/L		1		A2340 B	12/24/09 10:32 / sld
AGGREGATE ORGANICS							
Organic Carbon, Total (TOC)	3.2	mg/L		0.5		A5310 C	12/21/09 15:40 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	5.7	mg/L	D	0.5		E350.1	12/21/09 16:24 / stp
Nitrogen, Nitrate+Nitrite as N	ND	mg/L		0.01		E353.2	12/18/09 14:55 / stp
Phosphorus, Orthophosphate as P	ND	mg/L		0.001		E365.1	12/18/09 17:01 / stp
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.8	12/17/09 19:00 / dck
Antimony	ND	mg/L		0.003		E200.8	12/17/09 19:00 / dck
Arsenic	ND	mg/L		0.003		E200.8	12/17/09 19:00 / dck
Barium	0.255	mg/L		0.005		E200.8	12/17/09 19:00 / dck
Beryllium	ND	mg/L		0.001		E200.8	12/17/09 19:00 / dck
Cadmium	ND	mg/L		0.00008		E200.8	12/17/09 19:00 / dck
Calcium	62	mg/L		1		E200.7	12/17/09 15:30 / sld
Chromium	ND	mg/L		0.001		E200.8	12/17/09 19:00 / dck
Copper	0.006	mg/L		0.001		E200.8	12/17/09 19:00 / dck
Iron	15.5	mg/L		0.05		E200.7	12/17/09 15:30 / sld
Lead	ND	mg/L		0.0005		E200.8	12/17/09 19:00 / dck
Magnesium	19	mg/L		1		E200.7	12/17/09 15:30 / sld
Manganese	5.34	mg/L		0.005		E200.8	12/18/09 13:06 / dck
Mercury	ND	mg/L		0.00001		E200.8	12/17/09 19:00 / dck
Nickel	ND	mg/L		0.01		E200.8	12/17/09 19:00 / dck
Potassium	25	mg/L		1		E200.7	12/17/09 15:30 / sld
Selenium	ND	mg/L		0.001		E200.8	12/17/09 19:00 / dck
Silica	43.1	mg/L		0.2		E200.8	12/18/09 13:06 / dck

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-001
Client Sample ID MW 95-4

Report Date: 01/07/10
Collection Date: 12/16/09 10:20
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Silver	ND	mg/L		0.0005		E200.8	12/17/09 19:00 / dck
Sodium	22	mg/L		1		E200.7	12/23/09 10:25 / sld
Thallium	ND	mg/L		0.0002		E200.8	12/17/09 19:00 / dck
Uranium	0.0005	mg/L		0.0003		E200.8	12/17/09 19:00 / dck
Zinc	0.01	mg/L		0.01		E200.8	12/17/09 19:00 / dck
METALS, TOTAL							
Iron	17.4	mg/L		0.03		E200.7	12/22/09 12:41 / sld

Report Definitions:
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-002
Client Sample ID Decant Pond

Report Date: 01/07/10
Collection Date: 12/16/09 11:10
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	8.1	s.u.		0.1		A4500-H B	12/17/09 17:51 / hm
Conductivity	685	umhos/cm		1		A2510 B	12/17/09 17:49 / hm
Solids, Total Dissolved TDS @ 180 C	436	mg/L		10		A2540 C	12/18/09 09:09 / JG
INORGANICS							
Alkalinity, Total as CaCO3	100	mg/L		1		A2320 B	12/17/09 20:31 / hm
Bicarbonate as HCO3	120	mg/L		1		A2320 B	12/17/09 20:31 / hm
Carbonate as CO3	ND	mg/L		1		A2320 B	12/17/09 20:31 / hm
Chloride	6	mg/L		1		E300.0	12/17/09 22:29 / hm
Sulfate	68	mg/L		1		E300.0	12/17/09 22:29 / hm
Sodium Adsorption Ratio (SAR)	2.55	unitless		0.01		Calculation	01/07/10 10:10 / wjj
Fluoride	0.3	mg/L		0.1	4	A4500-F C	12/18/09 13:31 / JG
Sulfide	ND	mg/L		0.04		A4500 S-D	12/21/09 11:30 / eli-b
Hardness as CaCO3	78	mg/L		1		A2340 B	12/18/09 12:19 / abb
AGGREGATE ORGANICS							
Organic Carbon, Total (TOC)	1.2	mg/L		0.5		A5310 C	12/21/09 15:51 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	11.2	mg/L	D	0.5		E350.1	12/21/09 16:26 / stp
Nitrogen, Nitrate+Nitrite as N	37.6	mg/L	D	0.5		E353.2	12/18/09 15:01 / stp
Phosphorus, Orthophosphate as P	0.070	mg/L		0.001		E365.1	12/18/09 17:02 / stp
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.8	12/17/09 19:07 / dck
Antimony	0.068	mg/L		0.003		E200.8	12/17/09 19:07 / dck
Arsenic	ND	mg/L		0.003		E200.8	12/17/09 19:07 / dck
Barium	0.091	mg/L		0.005		E200.8	12/17/09 19:07 / dck
Beryllium	ND	mg/L		0.001		E200.8	12/17/09 19:07 / dck
Cadmium	ND	mg/L		0.00008		E200.8	12/17/09 19:07 / dck
Calcium	22	mg/L		1		E200.7	12/17/09 15:39 / sld
Chromium	ND	mg/L		0.001		E200.8	12/17/09 19:07 / dck
Copper	0.032	mg/L		0.001		E200.8	12/17/09 19:07 / dck
Iron	ND	mg/L		0.05		E200.7	12/17/09 15:39 / sld
Lead	0.0008	mg/L		0.0005		E200.8	12/17/09 19:07 / dck
Magnesium	6	mg/L		1		E200.7	12/17/09 15:39 / sld
Manganese	0.862	mg/L		0.005		E200.8	12/17/09 19:07 / dck
Mercury	ND	mg/L		0.00001		E200.8	12/17/09 19:07 / dck
Nickel	ND	mg/L		0.01		E200.8	12/17/09 19:07 / dck
Potassium	32	mg/L		1		E200.7	12/17/09 15:39 / sld
Selenium	ND	mg/L		0.001		E200.8	12/17/09 19:07 / dck
Silica	9.7	mg/L		0.2		E200.8	12/17/09 19:07 / dck

Report Definitions:
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-002
Client Sample ID Decant Pond

Report Date: 01/07/10
Collection Date: 12/16/09 11:10
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Silver	ND	mg/L		0.0005		E200.8	12/17/09 19:07 / dck
Sodium	52	mg/L		1		E200.7	12/17/09 15:39 / sld
Thallium	ND	mg/L		0.0002		E200.8	12/17/09 19:07 / dck
Uranium	0.0033	mg/L		0.0003		E200.8	12/17/09 19:07 / dck
Zinc	ND	mg/L		0.01		E200.8	12/17/09 19:07 / dck
METALS, TOTAL							
Iron	0.45	mg/L		0.03		E200.7	12/22/09 12:44 / sld

Report Definitions:
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-003
Client Sample ID Mine Water

Report Date: 01/07/10
Collection Date: 12/16/09 13:10
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.5	s.u.		0.1		A4500-H B	12/17/09 17:52 / hm
Conductivity	288	umhos/cm		1		A2510 B	12/17/09 17:50 / hm
Solids, Total Dissolved TDS @ 180 C	184	mg/L		10		A2540 C	12/18/09 09:10 / JG
INORGANICS							
Alkalinity, Total as CaCO3	70	mg/L		1		A2320 B	12/17/09 20:52 / hm
Bicarbonate as HCO3	85	mg/L		1		A2320 B	12/17/09 20:52 / hm
Carbonate as CO3	ND	mg/L		1		A2320 B	12/17/09 20:52 / hm
Chloride	ND	mg/L		1		E300.0	12/17/09 22:46 / hm
Sulfate	42	mg/L		1		E300.0	12/17/09 22:46 / hm
Sodium Adsorption Ratio (SAR)	0.11	unitless		0.01		Calculation	01/07/10 10:10 / wjj
Fluoride	ND	mg/L		0.1	4	A4500-F C	12/18/09 13:31 / JG
Sulfide	ND	mg/L		0.04		A4500 S-D	12/21/09 11:30 / eli-b
Hardness as CaCO3	114	mg/L		1		A2340 B	12/24/09 10:32 / sld
AGGREGATE ORGANICS							
Organic Carbon, Total (TOC)	ND	mg/L		0.5		A5310 C	12/21/09 16:00 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	0.39	mg/L		0.05		E350.1	12/21/09 16:00 / stp
Nitrogen, Nitrate+Nitrite as N	7.4	mg/L	D	0.1		E353.2	12/18/09 15:03 / stp
Phosphorus, Orthophosphate as P	0.003	mg/L		0.001		E365.1	12/18/09 17:03 / stp
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.8	12/17/09 19:14 / dck
Antimony	0.015	mg/L		0.003		E200.8	12/17/09 19:14 / dck
Arsenic	ND	mg/L		0.003		E200.8	12/17/09 19:14 / dck
Barium	0.047	mg/L		0.005		E200.8	12/17/09 19:14 / dck
Beryllium	ND	mg/L		0.001		E200.8	12/17/09 19:14 / dck
Cadmium	ND	mg/L		0.00008		E200.8	12/17/09 19:14 / dck
Calcium	30	mg/L		1		E200.7	12/17/09 15:42 / sld
Chromium	ND	mg/L		0.001		E200.8	12/17/09 19:14 / dck
Copper	0.114	mg/L		0.001		E200.8	12/17/09 19:14 / dck
Iron	ND	mg/L		0.05		E200.7	12/17/09 15:42 / sld
Lead	0.0010	mg/L		0.0005		E200.8	12/17/09 19:14 / dck
Magnesium	10	mg/L		1		E200.7	12/17/09 15:42 / sld
Manganese	0.105	mg/L		0.005		E200.8	12/17/09 19:14 / dck
Mercury	ND	mg/L		0.00001		E200.8	12/17/09 19:14 / dck
Nickel	ND	mg/L		0.01		E200.8	12/17/09 19:14 / dck
Potassium	ND	mg/L		1		E200.7	12/17/09 15:42 / sld
Selenium	ND	mg/L		0.001		E200.8	12/17/09 19:14 / dck
Silica	5.8	mg/L		0.2		E200.8	12/17/09 19:14 / dck

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ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc.
Project: Troy Mine
Lab ID: H09120170-003
Client Sample ID Mine Water

Report Date: 01/07/10
Collection Date: 12/16/09 13:10
DateReceived: 12/17/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Silver	ND	mg/L		0.0005		E200.8	12/17/09 19:14 / dck
Sodium	3	mg/L		1		E200.7	12/23/09 10:28 / sld
Thallium	ND	mg/L		0.0002		E200.8	12/17/09 19:14 / dck
Uranium	0.0011	mg/L		0.0003		E200.8	12/17/09 19:14 / dck
Zinc	0.02	mg/L		0.01		E200.8	12/17/09 19:14 / dck
METALS, TOTAL							
Iron	ND	mg/L		0.03		E200.7	12/22/09 12:47 / sld

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A2510 B									Analytical Run: COND_091217A	
Sample ID: ICV1_091217A		Initial Calibration Verification Standard							12/17/09 17:45	
Conductivity		716	umhos/cm	1.0	**100**	90	110			
Method: A2510 B									Batch: 091217A-COND-PROBE-W	
Sample ID: LCS1_091217A		Laboratory Control Sample				Run: COND_091217A			12/17/09 17:46	
Conductivity		1400	umhos/cm	1.0	**99**	90	110			
Sample ID: H09120186-001ADUP		Sample Duplicate				Run: COND_091217A			12/17/09 17:54	
Conductivity		520	umhos/cm	1.0				**0.1**	10	
Method: A2540 C									Batch: 7607	
Sample ID: MB-7607		Method Blank				Run: ACCU-124 (14410200)_091218			12/18/09 09:13	
Solids, Total Dissolved TDS @ 180 C		6	mg/L	1						
Sample ID: LCS-7607		Laboratory Control Sample				Run: ACCU-124 (14410200)_091218			12/18/09 09:07	
Solids, Total Dissolved TDS @ 180 C		1010	mg/L	10	**100**	90	110			
Sample ID: H09120186-002AMS		Sample Matrix Spike				Run: ACCU-124 (14410200)_091218			12/18/09 09:10	
Solids, Total Dissolved TDS @ 180 C		2140	mg/L	10	**99**	80	120			
Sample ID: H09120186-002AMSD		Sample Matrix Spike Duplicate				Run: ACCU-124 (14410200)_091218			12/18/09 09:11	
Solids, Total Dissolved TDS @ 180 C		2140	mg/L	10	**99**	80	120	**0**	10	
Method: A4500-H B									Batch: 091217A-PH-W	
Sample ID: LCS1_091217A		Laboratory Control Sample				Run: PH2_091217A			12/17/09 17:44	
pH		7.06	s.u.	0.10	**101**	99	101			
Method: A2320 B									Batch: R59017	
Sample ID: MBLK		Method Blank				Run: MAN-TECH_091217A			12/17/09 17:18	
Alkalinity, Total as CaCO3		ND	mg/L	0.9						
Sample ID: LCS		Laboratory Control Sample				Run: MAN-TECH_091217A			12/17/09 17:25	
Alkalinity, Total as CaCO3		570	mg/L	4.0	**95**	90	110			
Sample ID: H09120170-002A MS		Sample Matrix Spike				Run: MAN-TECH_091217A			12/17/09 20:38	
Alkalinity, Total as CaCO3		730	mg/L	4.0	**104**	90	110			
Sample ID: H09120170-002A MSD		Sample Matrix Spike Duplicate				Run: MAN-TECH_091217A			12/17/09 20:46	
Alkalinity, Total as CaCO3		710	mg/L	4.0	**102**	90	110	**1.6**	20	

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A4500 S-D									Analytical Run: SUB-B140740	
Sample ID: ICV1_091221A		Initial Calibration Verification Standard							12/21/09 11:30	
Sulfide		0.216	mg/L	0.040	106	90	110			
Method: A4500 S-D									Batch: B_091221A-SULFIDE-MB-W	
Sample ID: B09121305-002BMS		Sample Matrix Spike				Run: SUB-B140740			12/21/09 11:30	
Sulfide		9.14	mg/L	1.0	90	70	130			
Sample ID: B09121305-002BMSD		Sample Matrix Spike Duplicate				Run: SUB-B140740			12/21/09 11:30	
Sulfide		8.99	mg/L	1.0	89	70	130	1.6	30	
Sample ID: MBLK1_091221A		Method Blank				Run: SUB-B140740			12/21/09 11:30	
Sulfide		ND	mg/L	0.02						
Sample ID: LFB1_091221A		Laboratory Fortified Blank				Run: SUB-B140740			12/21/09 11:30	
Sulfide		0.220	mg/L	0.040	109	70	130			
Method: A4500-F C									Analytical Run: PH_091218A	
Sample ID: ICV1_091218A		Initial Calibration Verification Standard							12/18/09 13:31	
Fluoride		0.746	mg/L	0.10	99	90	110			
Method: A4500-F C									Batch: 091218A-F-ISE-W	
Sample ID: MBLK1_091218A		Method Blank				Run: PH_091218A			12/18/09 13:31	
Fluoride		ND	mg/L	0.03						
Sample ID: LFB1_091218A		Laboratory Fortified Blank				Run: PH_091218A			12/18/09 13:31	
Fluoride		0.477	mg/L	0.10	95	90	110			
Sample ID: LCS1_091218A		Laboratory Control Sample				Run: PH_091218A			12/18/09 13:31	
Fluoride		0.746	mg/L	0.10	96	90	110			
Sample ID: H09120170-001ADUP		Sample Duplicate				Run: PH_091218A			12/18/09 13:31	
Fluoride		0.0398	mg/L	0.10					20	
Sample ID: H09120170-002AMS		Sample Matrix Spike				Run: PH_091218A			12/18/09 13:31	
Fluoride		0.753	mg/L	0.10	96	85	115			
Sample ID: H09120170-002AMSD		Sample Matrix Spike Duplicate				Run: PH_091218A			12/18/09 13:31	
Fluoride		0.745	mg/L	0.10	94	85	115	1.1	20	

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E300.0									Analytical Run: IC101-H_091218A	
Sample ID: CCV	2	Continuing Calibration Verification Standard							12/17/09 20:34	
Chloride		23	mg/L	1.0	92	90	110			
Sulfate		50	mg/L	1.0	101	90	110			
Sample ID: ICV	2	Initial Calibration Verification Standard							12/17/09 20:51	
Chloride		2.4	mg/L	1.0	97	90	110			
Sulfate		9.4	mg/L	1.0	94	90	110			
Method: E300.0									Batch: R59015	
Sample ID: LFB	2	Laboratory Fortified Blank				Run: IC101-H_091218A			12/17/09 21:07	
Chloride		24	mg/L	1.0	98	90	110			
Sulfate		53	mg/L	1.0	106	90	110			
Sample ID: MBLK	2	Method Blank				Run: IC101-H_091218A			12/17/09 21:24	
Chloride		ND	mg/L	0.05						
Sulfate		ND	mg/L	0.1						
Sample ID: H09120175-001A MS	2	Sample Matrix Spike				Run: IC101-H_091218A			12/17/09 23:19	
Chloride		26	mg/L	1.0	96	90	110			
Sulfate		61	mg/L	1.0	106	90	110			
Sample ID: H09120175-001A MSD	2	Sample Matrix Spike Duplicate				Run: IC101-H_091218A			12/17/09 23:35	
Chloride		26	mg/L	1.0	96	90	110	0.2	20	
Sulfate		60	mg/L	1.0	105	90	110	1.1	20	
Method: A5310 C									Analytical Run: SUB-C127879	
Sample ID: ICV-5085		Initial Calibration Verification Standard							12/21/09 09:15	
Organic Carbon, Total (TOC)		10.4	mg/L	0.50	104	90	110			
Method: A5310 C									Batch: C_R127879	
Sample ID: MBLK		Method Blank				Run: SUB-C127879			12/21/09 09:40	
Organic Carbon, Total (TOC)		0.06	mg/L	0.04						
Sample ID: LCS-5085		Laboratory Control Sample				Run: SUB-C127879			12/21/09 14:59	
Organic Carbon, Total (TOC)		10.3	mg/L	0.50	103	90	110			
Sample ID: H09120170-003E		Sample Matrix Spike				Run: SUB-C127879			12/21/09 17:21	
Organic Carbon, Total (TOC)		5.14	mg/L	0.50	99	85	115			
Sample ID: H09120170-003E		Sample Matrix Spike Duplicate				Run: SUB-C127879			12/21/09 17:31	
Organic Carbon, Total (TOC)		5.36	mg/L	0.50	103	85	115	4.1	10	

Qualifiers:

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E350.1								Analytical Run: NUTRIENTS_091221A		
Sample ID: ICV-1		Initial Calibration Verification Standard							12/21/09 15:16	
Nitrogen, Ammonia as N		1.01	mg/L	0.10	101	90	110			
Sample ID: ICB		Initial Calibration Blank, Instrument Blank							12/21/09 15:24	
Nitrogen, Ammonia as N		-0.0100	mg/L	0.10		0	0			
Sample ID: CCV-19		Continuing Calibration Verification Standard							12/21/09 15:52	
Nitrogen, Ammonia as N		0.530	mg/L	0.10	106	90	110			
Sample ID: CCV-32		Continuing Calibration Verification Standard							12/21/09 16:18	
Nitrogen, Ammonia as N		0.530	mg/L	0.10	106	90	110			
Method: E350.1								Batch: A2009-12-21_5_NH3_01		
Sample ID: LCS-2		Laboratory Control Sample				Run: NUTRIENTS_091221A			12/21/09 15:18	
Nitrogen, Ammonia as N		8.19	mg/L	0.19	103	90	110			
Sample ID: LFB-3		Laboratory Fortified Blank				Run: NUTRIENTS_091221A			12/21/09 15:20	
Nitrogen, Ammonia as N		1.00	mg/L	0.10	100	90	110			
Sample ID: MBLK-6		Method Blank				Run: NUTRIENTS_091221A			12/21/09 15:26	
Nitrogen, Ammonia as N		ND	mg/L	0.02						
Sample ID: H09120170-003CMS		Sample Matrix Spike				Run: NUTRIENTS_091221A			12/21/09 16:02	
Nitrogen, Ammonia as N		1.43	mg/L	0.10	104	90	110			
Sample ID: H09120170-003CMSD		Sample Matrix Spike Duplicate				Run: NUTRIENTS_091221A			12/21/09 16:04	
Nitrogen, Ammonia as N		1.40	mg/L	0.10	101	90	110	2.1	20	
Sample ID: H09120168-001BDUP		Sample Duplicate				Run: NUTRIENTS_091221A			12/21/09 16:22	
Nitrogen, Ammonia as N		5.19	mg/L	0.47				0	20	

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E353.2									Analytical Run: NUTRIENTS_091218A	
Sample ID: ICV-1		Initial Calibration Verification Standard								12/18/09 14:33
Nitrogen, Nitrate+Nitrite as N		1.01	mg/L	0.050	**101**	90	110			
Sample ID: CCV-4		Continuing Calibration Verification Standard								12/18/09 14:39
Nitrogen, Nitrate+Nitrite as N		0.520	mg/L	0.050	**104**	90	110			
Sample ID: ICB		Initial Calibration Blank, Instrument Blank								12/18/09 14:43
Nitrogen, Nitrate+Nitrite as N		-0.0100	mg/L	0.050		0	0			
Method: E353.2									Batch: A2009-12-18_5_NO3_01	
Sample ID: LCS-2		Laboratory Control Sample				Run: NUTRIENTS_091218A				12/18/09 14:35
Nitrogen, Nitrate+Nitrite as N		18.9	mg/L	0.095	**103**	90	110			
Sample ID: LFB-3		Laboratory Fortified Blank				Run: NUTRIENTS_091218A				12/18/09 14:37
Nitrogen, Nitrate+Nitrite as N		1.03	mg/L	0.050	**103**	90	110			
Sample ID: MBLK-7		Method Blank				Run: NUTRIENTS_091218A				12/18/09 14:45
Nitrogen, Nitrate+Nitrite as N		ND	mg/L	0.010						
Sample ID: H09120170-001CMS		Sample Matrix Spike				Run: NUTRIENTS_091218A				12/18/09 14:57
Nitrogen, Nitrate+Nitrite as N		0.970	mg/L	0.050	**97**	90	110			
Sample ID: H09120170-001CMSD		Sample Matrix Spike Duplicate				Run: NUTRIENTS_091218A				12/18/09 14:59
Nitrogen, Nitrate+Nitrite as N		0.970	mg/L	0.050	**97**	90	110	**0**	20	

Qualifiers:

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E365.1									Analytical Run: FIA202-HE_091218B	
Sample ID: ICV		Initial Calibration Verification Standard								12/18/09 16:54
Phosphorus, Orthophosphate as P		0.249	mg/L	0.010	**100**	90	110			
Sample ID: CCV		Continuing Calibration Verification Standard								12/18/09 16:57
Phosphorus, Orthophosphate as P		0.252	mg/L	0.010	**101**	90	110			
Sample ID: ICB		Initial Calibration Blank, Instrument Blank								12/18/09 16:59
Phosphorus, Orthophosphate as P		0.00103	mg/L	0.010		0	0			
Method: E365.1										Batch: R59073
Sample ID: LCS		Laboratory Control Sample				Run: FIA202-HE_091218B				12/18/09 16:55
Phosphorus, Orthophosphate as P		3.11	mg/L	0.010	**101**	90	110			
Sample ID: LFB		Laboratory Fortified Blank				Run: FIA202-HE_091218B				12/18/09 16:56
Phosphorus, Orthophosphate as P		0.206	mg/L	0.010	**103**	90	110			
Sample ID: MBLK		Method Blank				Run: FIA202-HE_091218B				12/18/09 17:00
Phosphorus, Orthophosphate as P		ND	mg/L	0.001						
Sample ID: H09120170-003AMS		Sample Matrix Spike				Run: FIA202-HE_091218B				12/18/09 17:04
Phosphorus, Orthophosphate as P		0.196	mg/L	0.010	**97**	90	110			
Sample ID: H09120170-003AMSD		Sample Matrix Spike Duplicate				Run: FIA202-HE_091218B				12/18/09 17:05
Phosphorus, Orthophosphate as P		0.196	mg/L	0.010	**97**	90	110	**0.1**	20	
Sample ID: H09120198-002ADUP		Sample Duplicate				Run: FIA202-HE_091218B				12/18/09 17:08
Phosphorus, Orthophosphate as P		0.0306	mg/L	0.010				**4.6**	20	
Method: E200.7										Batch: 7638
Sample ID: MB-7638		Method Blank				Run: ICP1-HE_091222A				12/22/09 12:35
Iron		ND	mg/L	0.008						
Sample ID: LCS-7638		Laboratory Control Sample				Run: ICP1-HE_091222A				12/22/09 12:38
Iron		2.46	mg/L	0.030	**98**	85	115			
Sample ID: H09120185-001AMS5		Sample Matrix Spike				Run: ICP1-HE_091222A				12/22/09 12:59
Iron		2.36	mg/L	0.030	**93**	70	130			
Sample ID: H09120185-001AMSD5		Sample Matrix Spike Duplicate				Run: ICP1-HE_091222A				12/22/09 13:02
Iron		2.57	mg/L	0.030	**101**	70	130	**8.4**	20	

Qualifiers:

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ND - Not detected at the reporting limit.

QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Analytical Run: ICP1-HE_091217B	
Sample ID: ICV	5	Initial Calibration Verification Standard								12/17/09 14:22
Calcium		41.9	mg/L	1.0	**105**	95	105			
Iron		4.12	mg/L	0.030	**103**	95	105			
Magnesium		41.8	mg/L	1.0	**104**	95	105			
Potassium		38.6	mg/L	1.0	**97**	95	105			
Sodium		40.5	mg/L	1.0	**101**	95	105			
Sample ID: CCV-1	5	Continuing Calibration Verification Standard								12/17/09 14:30
Calcium		26.0	mg/L	1.0	**104**	95	105			
Iron		2.59	mg/L	0.030	**103**	95	105			
Magnesium		25.4	mg/L	1.0	**101**	95	105			
Potassium		24.3	mg/L	1.0	**97**	95	105			
Sodium		25.6	mg/L	1.0	**102**	95	105			
Sample ID: ICSA	5	Interference Check Sample A								12/17/09 14:44
Calcium		556	mg/L	1.0	**111**	80	120			
Iron		199	mg/L	0.030	**99**	80	120			
Magnesium		572	mg/L	1.0	**114**	80	120			
Potassium		0.0146	mg/L	1.0		0	0			
Sodium		0.0725	mg/L	1.0		0	0			
Sample ID: ICSAB	5	Interference Check Sample AB								12/17/09 14:47
Calcium		478	mg/L	1.0	**96**	80	120			
Iron		186	mg/L	0.030	**93**	80	120			
Magnesium		528	mg/L	1.0	**106**	80	120			
Potassium		20.3	mg/L	1.0	**102**	80	120			
Sodium		21.9	mg/L	1.0	**109**	80	120			
Sample ID: CCV	5	Continuing Calibration Verification Standard								12/17/09 14:51
Calcium		27.1	mg/L	1.0	**108**	90	110			
Iron		2.70	mg/L	0.030	**108**	90	110			
Magnesium		26.3	mg/L	1.0	**105**	90	110			
Potassium		24.2	mg/L	1.0	**97**	90	110			
Sodium		25.1	mg/L	1.0	**100**	90	110			
Sample ID: CCV	5	Continuing Calibration Verification Standard								12/17/09 15:33
Calcium		22.7	mg/L	1.0	**91**	90	110			
Iron		2.39	mg/L	0.030	**95**	90	110			
Magnesium		22.9	mg/L	1.0	**92**	90	110			
Potassium		24.0	mg/L	1.0	**96**	90	110			
Sodium		25.3	mg/L	1.0	**101**	90	110			
Sample ID: ICSA	5	Interference Check Sample A								12/17/09 15:54
Calcium		474	mg/L	1.0	**95**	80	120			
Iron		180	mg/L	0.030	**90**	80	120			
Magnesium		513	mg/L	1.0	**103**	80	120			

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QA/QC Summary Report

Client: Genesis Inc.
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Report Date: 01/07/10
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Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Analytical Run: ICP1-HE_091217B	
Sample ID: ICSA	5	Interference Check Sample A							12/17/09 15:54	
Potassium		-0.0107	mg/L	1.0		0	0			
Sodium		0.0732	mg/L	1.0		0	0			
Sample ID: ICSAB	5	Interference Check Sample AB							12/17/09 15:57	
Calcium		464	mg/L	1.0	93	80	120			
Iron		194	mg/L	0.030	97	80	120			
Magnesium		487	mg/L	1.0	97	80	120			
Potassium		19.9	mg/L	1.0	99	80	120			
Sodium		20.3	mg/L	1.0	101	80	120			
Method: E200.7									Batch: R59005	
Sample ID: MBLK	5	Method Blank				Run: ICP1-HE_091217B			12/17/09 15:02	
Calcium		ND	mg/L	0.1						
Iron		0.002	mg/L	0.002						
Magnesium		0.06	mg/L	0.02						
Potassium		ND	mg/L	0.04						
Sodium		ND	mg/L	0.1						
Sample ID: LFB	5	Laboratory Fortified Blank				Run: ICP1-HE_091217B			12/17/09 15:05	
Calcium		8.98	mg/L	1.0	90	85	115			
Iron		0.916	mg/L	0.030	91	85	115			
Magnesium		9.14	mg/L	1.0	91	85	115			
Potassium		9.76	mg/L	1.0	98	85	115			
Sodium		9.16	mg/L	1.0	92	85	115			
Sample ID: LCS	5	Laboratory Control Sample				Run: ICP1-HE_091217B			12/17/09 15:08	
Calcium		20.2	mg/L	1.0	101	90	110			
Iron		2.04	mg/L	0.030	102	90	110			
Magnesium		20.5	mg/L	1.0	102	90	110			
Potassium		19.7	mg/L	1.0	99	90	110			
Sodium		21.1	mg/L	1.0	106	90	110			
Sample ID: H09120169-001BMS2	5	Sample Matrix Spike				Run: ICP1-HE_091217B			12/17/09 15:24	
Calcium		43.8	mg/L	1.0	97	70	130			
Iron		1.91	mg/L	0.030	96	70	130			
Magnesium		66.2	mg/L	1.0	97	70	130			
Potassium		20.0	mg/L	1.0	95	70	130			
Sodium		44.4	mg/L	1.0	103	70	130			
Sample ID: H09120169-001BMSD2	5	Sample Matrix Spike Duplicate				Run: ICP1-HE_091217B			12/17/09 15:27	
Calcium		44.7	mg/L	1.0	101	70	130	1.9	20	
Iron		1.93	mg/L	0.030	96	70	130	0.8	20	
Magnesium		64.4	mg/L	1.0	88	70	130	2.7	20	
Potassium		20.1	mg/L	1.0	95	70	130	0.7	20	
Sodium		42.3	mg/L	1.0	93	70	130	4.7	20	

Qualifiers:

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Analytical Run: ICP1-HE_091222A	
Sample ID: ICV		Initial Calibration Verification Standard								12/22/09 10:31
Iron		3.88	mg/L	0.030	97	95	105			
Sample ID: CCV-1		Continuing Calibration Verification Standard								12/22/09 10:39
Iron		2.53	mg/L	0.030	101	95	105			
Sample ID: ICSA		Interference Check Sample A								12/22/09 10:49
Iron		196	mg/L	0.030	98	80	120			
Sample ID: ICSAB		Interference Check Sample AB								12/22/09 10:52
Iron		181	mg/L	0.030	91	80	120			
Sample ID: CCV		Continuing Calibration Verification Standard								12/22/09 12:16
Iron		2.44	mg/L	0.030	98	90	110			
Sample ID: ICSA		Interference Check Sample A								12/22/09 13:58
Iron		180	mg/L	0.030	90	80	120			
Sample ID: ICSAB		Interference Check Sample AB								12/22/09 14:01
Iron		180	mg/L	0.030	90	80	120			
Method: E200.7										Batch: R59144
Sample ID: MBLK		Method Blank				Run: ICP1-HE_091222A				12/22/09 11:09
Iron		0.005	mg/L	0.002						
Sample ID: LFB		Laboratory Fortified Blank				Run: ICP1-HE_091222A				12/22/09 11:12
Iron		1.00	mg/L	0.030	100	85	115			
Sample ID: LCS		Laboratory Control Sample				Run: ICP1-HE_091222A				12/22/09 11:15
Iron		1.96	mg/L	0.030	98	90	110			
Sample ID: H09120198-006EMS2		Sample Matrix Spike				Run: ICP1-HE_091222A				12/22/09 12:22
Iron		1.92	mg/L	0.030	96	70	130			
Sample ID: H09120198-006EMSD2		Sample Matrix Spike Duplicate				Run: ICP1-HE_091222A				12/22/09 12:26
Iron		1.91	mg/L	0.030	95	70	130	0.7	20	

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Analytical Run: ICP1-HE_091223A	
Sample ID: ICV		Initial Calibration Verification Standard								12/23/09 09:30
Sodium		41.0	mg/L	1.0	**103**	95	105			
Sample ID: CCV-1		Continuing Calibration Verification Standard								12/23/09 09:38
Sodium		25.6	mg/L	1.0	**102**	95	105			
Sample ID: ICSA		Interference Check Sample A								12/23/09 09:52
Sodium		0.0690	mg/L	1.0		0	0			
Sample ID: ICSAB		Interference Check Sample AB								12/23/09 09:55
Sodium		21.8	mg/L	1.0	**109**	80	120			
Sample ID: CCV		Continuing Calibration Verification Standard								12/23/09 09:59
Sodium		26.1	mg/L	1.0	**104**	90	110			
Sample ID: ICSA		Interference Check Sample A								12/23/09 12:37
Sodium		0.0589	mg/L	1.0		0	0			
Sample ID: ICSAB		Interference Check Sample AB								12/23/09 12:40
Sodium		21.8	mg/L	1.0	**109**	80	120			
Sample ID: ICSA		Interference Check Sample A								12/23/09 13:57
Sodium		0.0611	mg/L	1.0		0	0			
Sample ID: ICSAB		Interference Check Sample AB								12/23/09 14:01
Sodium		21.3	mg/L	1.0	**107**	80	120			
Sample ID: ICSA		Interference Check Sample A								12/23/09 20:02
Sodium		0.0665	mg/L	1.0		0	0			
Sample ID: ICSAB		Interference Check Sample AB								12/23/09 20:06
Sodium		20.3	mg/L	1.0	**102**	80	120			
Method: E200.7									Batch: R59176	
Sample ID: MBLK		Method Blank				Run: ICP1-HE_091223A				12/23/09 10:06
Sodium		ND	mg/L	0.1						
Sample ID: LFB		Laboratory Fortified Blank				Run: ICP1-HE_091223A				12/23/09 10:09
Sodium		10.2	mg/L	1.0	**102**	85	115			
Sample ID: LCS		Laboratory Control Sample				Run: ICP1-HE_091223A				12/23/09 10:12
Sodium		20.9	mg/L	1.0	**105**	90	110			
Sample ID: H09120170-003BMS2		Sample Matrix Spike				Run: ICP1-HE_091223A				12/23/09 10:31
Sodium		23.3	mg/L	1.0	**103**	70	130			
Sample ID: H09120170-003BMSD2		Sample Matrix Spike Duplicate				Run: ICP1-HE_091223A				12/23/09 10:34
Sodium		23.5	mg/L	1.0	**104**	70	130	**0.9**	20	

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7										Batch: R59176
Sample ID: LFB		Laboratory Fortified Blank				Run: ICP1-HE_091223A				12/23/09 11:44
Sodium		10.2	mg/L	1.0	102	85	115			

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_091217A		
Sample ID: QCS-090602A,090609	18	Initial Calibration Verification Standard								12/17/09 16:14
Aluminum		0.256	mg/L	0.10	102	90	110			
Antimony		0.0503	mg/L	0.050	101	90	110			
Arsenic		0.0503	mg/L	0.0050	101	90	110			
Barium		0.0504	mg/L	0.10	101	90	110			
Beryllium		0.0257	mg/L	0.0010	103	90	110			
Cadmium		0.0261	mg/L	0.0010	104	90	110			
Chromium		0.0499	mg/L	0.010	100	90	110			
Copper		0.0511	mg/L	0.010	102	90	110			
Lead		0.0509	mg/L	0.010	102	90	110			
Manganese		0.254	mg/L	0.010	102	90	110			
Mercury		0.00197	mg/L	0.0010	99	90	110			
Nickel		0.0498	mg/L	0.010	100	90	110			
Selenium		0.0497	mg/L	0.0050	99	90	110			
Silicon		0.500	mg/L	0.10	100	90	110			
Silver		0.0255	mg/L	0.0050	102	90	110			
Thallium		0.0510	mg/L	0.10	102	90	110			
Uranium		0.0199	mg/L	0.0010	100	90	110			
Zinc		0.0511	mg/L	0.010	102	90	110			
Sample ID: ICSA-090423A	18	Interference Check Sample A								12/17/09 16:20
Aluminum		44.4	mg/L	0.10	111	70	130			
Antimony		0.000263	mg/L	0.050						
Arsenic		0.000181	mg/L	0.0050						
Barium		0.000322	mg/L	0.10						
Beryllium		5.00E-06	mg/L	0.0010						
Cadmium		0.000452	mg/L	0.0010						
Chromium		0.000533	mg/L	0.010						
Copper		0.00151	mg/L	0.010						
Lead		7.50E-05	mg/L	0.010						
Manganese		0.00244	mg/L	0.010						
Mercury		3.00E-05	mg/L	0.0010						
Nickel		0.00123	mg/L	0.010						
Selenium		1.20E-05	mg/L	0.0050						
Silicon		0.00272	mg/L	0.10		0	0			
Silver		0.000206	mg/L	0.0050						
Thallium		3.80E-05	mg/L	0.10						
Uranium		1.10E-05	mg/L	0.0010						
Zinc		0.00113	mg/L	0.010						
Sample ID: ICSAB-090423A,09010	18	Interference Check Sample AB								12/17/09 16:27
Aluminum		44.6	mg/L	0.10	112	70	130			
Antimony		0.000177	mg/L	0.050		0	0			
Arsenic		0.0111	mg/L	0.0050	111	70	130			
Barium		7.80E-05	mg/L	0.10		0	0			

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_091217A		
Sample ID: ICSAB-090423A,09010	18	Interference Check Sample AB								12/17/09 16:27
Beryllium		ND	mg/L	0.0010		0	0			
Cadmium		0.0112	mg/L	0.0010	**112**	70	130			
Chromium		0.0228	mg/L	0.010	**114**	70	130			
Copper		0.0233	mg/L	0.010	**117**	70	130			
Lead		6.80E-05	mg/L	0.010		0	0			
Manganese		0.0250	mg/L	0.010	**125**	70	130			
Mercury		1.90E-05	mg/L	0.0010		0	0			
Nickel		0.0234	mg/L	0.010	**117**	70	130			
Selenium		0.0109	mg/L	0.0050	**109**	70	130			
Silicon		0.00297	mg/L	0.10		0	0			
Silver		0.0213	mg/L	0.0050	**106**	70	130			
Thallium		3.20E-05	mg/L	0.10		0	0			
Uranium		7.00E-06	mg/L	0.0010		0	0			
Zinc		0.0120	mg/L	0.010	**120**	70	130			
Sample ID: QCS-090602A,090609	18	Initial Calibration Verification Standard								12/17/09 21:27
Aluminum		0.255	mg/L	0.10	**102**	90	110			
Antimony		0.0508	mg/L	0.050	**102**	90	110			
Arsenic		0.0502	mg/L	0.0050	**100**	90	110			
Barium		0.0513	mg/L	0.10	**103**	90	110			
Beryllium		0.0252	mg/L	0.0010	**101**	90	110			
Cadmium		0.0266	mg/L	0.0010	**106**	90	110			
Chromium		0.0510	mg/L	0.010	**102**	90	110			
Copper		0.0521	mg/L	0.010	**104**	90	110			
Lead		0.0502	mg/L	0.010	**100**	90	110			
Manganese		0.252	mg/L	0.010	**101**	90	110			
Mercury		0.00190	mg/L	0.0010	**95**	90	110			
Nickel		0.0513	mg/L	0.010	**103**	90	110			
Selenium		0.0501	mg/L	0.0050	**100**	90	110			
Silicon		0.490	mg/L	0.10	**98**	90	110			
Silver		0.0260	mg/L	0.0050	**104**	90	110			
Thallium		0.0509	mg/L	0.10	**102**	90	110			
Uranium		0.0199	mg/L	0.0010	**99**	90	110			
Zinc		0.0511	mg/L	0.010	**102**	90	110			
Sample ID: ICSA-090423A	18	Interference Check Sample A								12/17/09 21:34
Aluminum		43.8	mg/L	0.10	**109**	70	130			
Antimony		0.000268	mg/L	0.050						
Arsenic		0.000182	mg/L	0.0050						
Barium		0.000356	mg/L	0.10						
Beryllium		ND	mg/L	0.0010						
Cadmium		0.000439	mg/L	0.0010						
Chromium		0.000544	mg/L	0.010						
Copper		0.00145	mg/L	0.010						

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_091217A		
Sample ID: ICSA-090423A	18	Interference Check Sample A								12/17/09 21:34
Lead		8.60E-05	mg/L	0.010						
Manganese		0.00246	mg/L	0.010						
Mercury		3.20E-05	mg/L	0.0010						
Nickel		0.00126	mg/L	0.010						
Selenium		9.80E-05	mg/L	0.0050						
Silicon		0.00267	mg/L	0.10		0	0			
Silver		0.000117	mg/L	0.0050						
Thallium		5.10E-05	mg/L	0.10						
Uranium		8.00E-06	mg/L	0.0010						
Zinc		0.00113	mg/L	0.010						
Sample ID: ICSAB-090423A,09010	18	Interference Check Sample AB								12/17/09 21:41
Aluminum		42.7	mg/L	0.10	**107**	70	130			
Antimony		0.000182	mg/L	0.050		0	0			
Arsenic		0.0113	mg/L	0.0050	**113**	70	130			
Barium		7.30E-05	mg/L	0.10		0	0			
Beryllium		2.00E-06	mg/L	0.0010		0	0			
Cadmium		0.0110	mg/L	0.0010	**110**	70	130			
Chromium		0.0226	mg/L	0.010	**113**	70	130			
Copper		0.0232	mg/L	0.010	**116**	70	130			
Lead		7.60E-05	mg/L	0.010		0	0			
Manganese		0.0244	mg/L	0.010	**122**	70	130			
Mercury		2.10E-05	mg/L	0.0010		0	0			
Nickel		0.0233	mg/L	0.010	**116**	70	130			
Selenium		0.0109	mg/L	0.0050	**109**	70	130			
Silicon		0.00276	mg/L	0.10		0	0			
Silver		0.0204	mg/L	0.0050	**102**	70	130			
Thallium		4.20E-05	mg/L	0.10		0	0			
Uranium		5.00E-06	mg/L	0.0010		0	0			
Zinc		0.0112	mg/L	0.010	**112**	70	130			
Method: E200.8										Batch: R59022
Sample ID: LRB	18	Method Blank				Run: ICPMS204-B_091217A				12/17/09 17:20
Aluminum		0.0001	mg/L	7E-05						
Antimony		ND	mg/L	3E-05						
Arsenic		ND	mg/L	2E-05						
Barium		4E-05	mg/L	3E-05						
Beryllium		ND	mg/L	1E-05						
Cadmium		ND	mg/L	1E-05						
Chromium		6E-05	mg/L	5E-05						
Copper		5E-05	mg/L	3E-05						
Lead		ND	mg/L	5E-06						
Manganese		5E-05	mg/L	2E-05						
Mercury		ND	mg/L	7E-06						

Qualifiers:

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QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8										Batch: R59022
Sample ID: LRB	18	Method Blank				Run: ICPMS204-B_091217A				12/17/09 17:20
Nickel		ND	mg/L	3E-05						
Selenium		ND	mg/L	3E-05						
Silicon		0.002	mg/L	0.0004						
Silver		8E-05	mg/L	2E-05						
Thallium		ND	mg/L	1E-05						
Uranium		ND	mg/L	1E-05						
Zinc		0.0009	mg/L	0.0001						
Sample ID: LFB	18	Laboratory Fortified Blank				Run: ICPMS204-B_091217A				12/17/09 17:27
Aluminum		0.0504	mg/L	0.10	100	85	115			
Antimony		0.0491	mg/L	0.050	98	85	115			
Arsenic		0.0485	mg/L	0.0050	97	85	115			
Barium		0.0487	mg/L	0.10	97	85	115			
Beryllium		0.0510	mg/L	0.0010	102	85	115			
Cadmium		0.0487	mg/L	0.0010	97	85	115			
Chromium		0.0490	mg/L	0.010	98	85	115			
Copper		0.0485	mg/L	0.010	97	85	115			
Lead		0.0493	mg/L	0.010	99	85	115			
Manganese		0.0499	mg/L	0.010	100	85	115			
Mercury		0.000950	mg/L	0.0010	95	85	115			
Nickel		0.0486	mg/L	0.010	97	85	115			
Selenium		0.0497	mg/L	0.0050	99	85	115			
Silicon		0.202	mg/L	0.10	100	85	115			
Silver		0.0185	mg/L	0.0050	92	85	115			
Thallium		0.0494	mg/L	0.10	99	85	115			
Uranium		0.0503	mg/L	0.0010	101	85	115			
Zinc		0.0497	mg/L	0.010	97	85	115			
Sample ID: H09120173-001AMS	18	Sample Matrix Spike				Run: ICPMS204-B_091217A				12/17/09 19:27
Aluminum		0.0583	mg/L	0.10	103	70	130			
Antimony		0.0510	mg/L	0.0030	101	70	130			
Arsenic		0.0535	mg/L	0.0010	100	70	130			
Barium		0.0780	mg/L	0.10	98	70	130			
Beryllium		0.0523	mg/L	0.0010	105	70	130			
Cadmium		0.0491	mg/L	0.0010	98	70	130			
Chromium		0.0493	mg/L	0.010	97	70	130			
Copper		0.0506	mg/L	0.010	94	70	130			
Lead		0.0543	mg/L	0.0010	100	70	130			
Manganese		0.102	mg/L	0.010	98	70	130			
Mercury		0.000970	mg/L	0.00020	97	70	130			
Nickel		0.0478	mg/L	0.010	95	70	130			
Selenium		0.0532	mg/L	0.0050	106	70	130			
Silicon		11.0	mg/L	0.10		70	130			A
Silver		0.0176	mg/L	0.0050	88	70	130			

Qualifiers:

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ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R59022	
Sample ID: H09120173-001AMS	18	Sample Matrix Spike				Run: ICPMS204-B_091217A			12/17/09 19:27	
Thallium		0.0502	mg/L	0.0010	100	70	130			
Uranium		0.0743	mg/L	0.0010	102	70	130			
Zinc		0.160	mg/L	0.010	81	70	130			
Sample ID: H09120173-001AMSD	18	Sample Matrix Spike Duplicate				Run: ICPMS204-B_091217A			12/17/09 19:33	
Aluminum		0.0569	mg/L	0.10	100	70	130		20	
Antimony		0.0507	mg/L	0.0030	101	70	130	0.6	20	
Arsenic		0.0546	mg/L	0.0010	102	70	130	2	20	
Barium		0.0779	mg/L	0.10	98	70	130		20	
Beryllium		0.0522	mg/L	0.0010	104	70	130	0.4	20	
Cadmium		0.0486	mg/L	0.0010	97	70	130	1	20	
Chromium		0.0497	mg/L	0.010	98	70	130	0.9	20	
Copper		0.0509	mg/L	0.010	95	70	130	0.6	20	
Lead		0.0539	mg/L	0.0010	100	70	130	0.7	20	
Manganese		0.101	mg/L	0.010	96	70	130	0.9	20	
Mercury		0.000949	mg/L	0.00020	95	70	130	2.2	20	
Nickel		0.0479	mg/L	0.010	95	70	130	0.3	20	
Selenium		0.0531	mg/L	0.0050	106	70	130	0.2	20	
Silicon		10.8	mg/L	0.10		70	130	2.3	20	A
Silver		0.0177	mg/L	0.0050	88	70	130	0.2	20	
Thallium		0.0497	mg/L	0.0010	99	70	130	1.2	20	
Uranium		0.0747	mg/L	0.0010	102	70	130	0.5	20	
Zinc		0.159	mg/L	0.010	79	70	130	0.6	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

ENERGY LABORATORIES, INC. * 3161 E Lyndale (59604) * PO Box 5688 * Helena, MT 59601
Toll Free 877.472.0711 * 406.442.0711 * FAX 406.442.0712 * helena@enerylab.com

QA/QC Summary Report

Client: Genesis Inc.
Project: Troy Mine

Report Date: 01/07/10
Work Order: H09120170

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS204-B_091218A		
Sample ID: QCS-090602A,090609	2	Initial Calibration Verification Standard								12/18/09 11:45
Manganese		0.255	mg/L	0.010	**102**	90	110			
Silicon		0.480	mg/L	0.10	**96**	90	110			
Sample ID: ICSA-090423A	2	Interference Check Sample A								12/18/09 11:52
Manganese		0.00257	mg/L	0.010						
Silicon		0.00255	mg/L	0.10		0	0			
Sample ID: ICSAB-090423A,09010	2	Interference Check Sample AB								12/18/09 11:58
Manganese		0.0251	mg/L	0.010	**125**	70	130			
Silicon		0.00270	mg/L	0.10		0	0			
Method: E200.8										Batch: R59047
Sample ID: LRB	2	Method Blank				Run: ICPMS204-B_091218A				12/18/09 12:39
Manganese		6E-05	mg/L	2E-05						
Silicon		0.002	mg/L	0.0004						
Sample ID: LFB	2	Laboratory Fortified Blank				Run: ICPMS204-B_091218A				12/18/09 12:46
Manganese		0.0500	mg/L	0.010	**100**	85	115			
Silicon		0.200	mg/L	0.10	**99**	85	115			
Sample ID: H09120175-001BMS	2	Sample Matrix Spike				Run: ICPMS204-B_091218A				12/18/09 13:12
Manganese		1.30	mg/L	0.010		70	130			A
Silicon		11.9	mg/L	0.10		70	130			A
Sample ID: H09120175-001BMSD	2	Sample Matrix Spike Duplicate				Run: ICPMS204-B_091218A				12/18/09 13:19
Manganese		1.29	mg/L	0.010		70	130	**0.4**	20	A
Silicon		12.2	mg/L	0.10		70	130	**2.3**	20	A

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

ENERGY LABORATORIES, INC. • P.O. Box 3658 • 3161 East Lyndale Ave. • Helena, MT 59604
877-472-0711 • 406-442-0711 • 406-442-0712 fax • helena@energylab.com

Energy Laboratories Inc
Workorder Receipt Checklist

H09120170

Genesis Inc Troy Mine

Login completed by: Tracy L. Lorash
Reviewed by: BL2000\wjohnson
Reviewed Date: 12/21/2009 9:20:08 AM

Date and Time Received: 12/17/2009 9:48 AM
Received by: rlt
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☑	No ☐	
Container/Temp Blank temperature:	1.6°C On Ice		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☑	Not Applicable ☐

Contact and Corrective Action Comments:

All dissolved metals/hardness/SAR samples filtered and preserved w/ 1ml. HNO3 in lab. Ferric Iron sample poured off and preserved in lab w/ 1ml. HNO3. TL

ENERGY LABORATORIES

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name:	Project Name, PWS, Permit, Etc.	Sample Origin	EPA/State Compliance:
CDM	TROY MINE	State: MT	Yes ☐ No ☒

Report Mail Address:	Contact Name:	Phone/Fax:	Email:	Sampler: (Please Print)
50 W 14TH ST, # 200 HELENA, MT 59601	DUSTIN KLEMPEL	(406) 441-1405	KLEMPELDT@CDM.COM	DUSTIN KLEMPEL

Invoice Address:	Invoice Contact & Phone:	Purchase Order:	Quote/Bottle Order:
TROY MINE PO. BOX 1660 TROY, MT 59935	PAUL KUKAY (406) 295-5882 x221 PKUKAY@HOTMAIL.COM		—

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

- ☐ DW
- ☐ GSA
- ☐ POTW/WWTP
- ☐ State: _____
- ☐ Other: _____
- ☐ A2LA
- ☐ EDD/EDT (Electronic Data) Format: _____
- ☐ LEVEL IV
- ☐ NELAC

Contact ELI prior to **RUSH** sample submittal for charges and scheduling – See Instruction Page

Comments:

Shipped by: hand

Cooler ID(s):

Receipt Temp 1.6 °C

On Ice: (Yes) No

Custody Seal (Y) N

Bottles/Coolers B (C)

Intact (Y) N

Signature Match (Y) N

ANALYSIS REQUESTED

Number of Containers
Sample Type: A W S V B O
Air Water Soils/Solids Vegetation Bioassay Other

SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX	SEE ATTACHED	Normal Turnaround (TAT)	RUSH	Comments	LABORATORY USE ONLY
1 MW 95-4	12/16/09	10:20	W	X	X			H09120170
2 DECANT POND	12/16/09	11:10	W	X	X			
3 MINE WATER	12/16/09	13:10	W	X	X			
4								
5								
6								
7								
8								
9								
10								

Custody Record MUST be Signed

Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
DUSTIN KLEMPEL	12/17/09 09:48	Dust Klempel			
Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
Sample Disposal: Return to Client: _____ Lab Disposal: _____			Received by Laboratory: Roxanne Tubbs	Date/Time: 12.17.09 9:48	Signature:

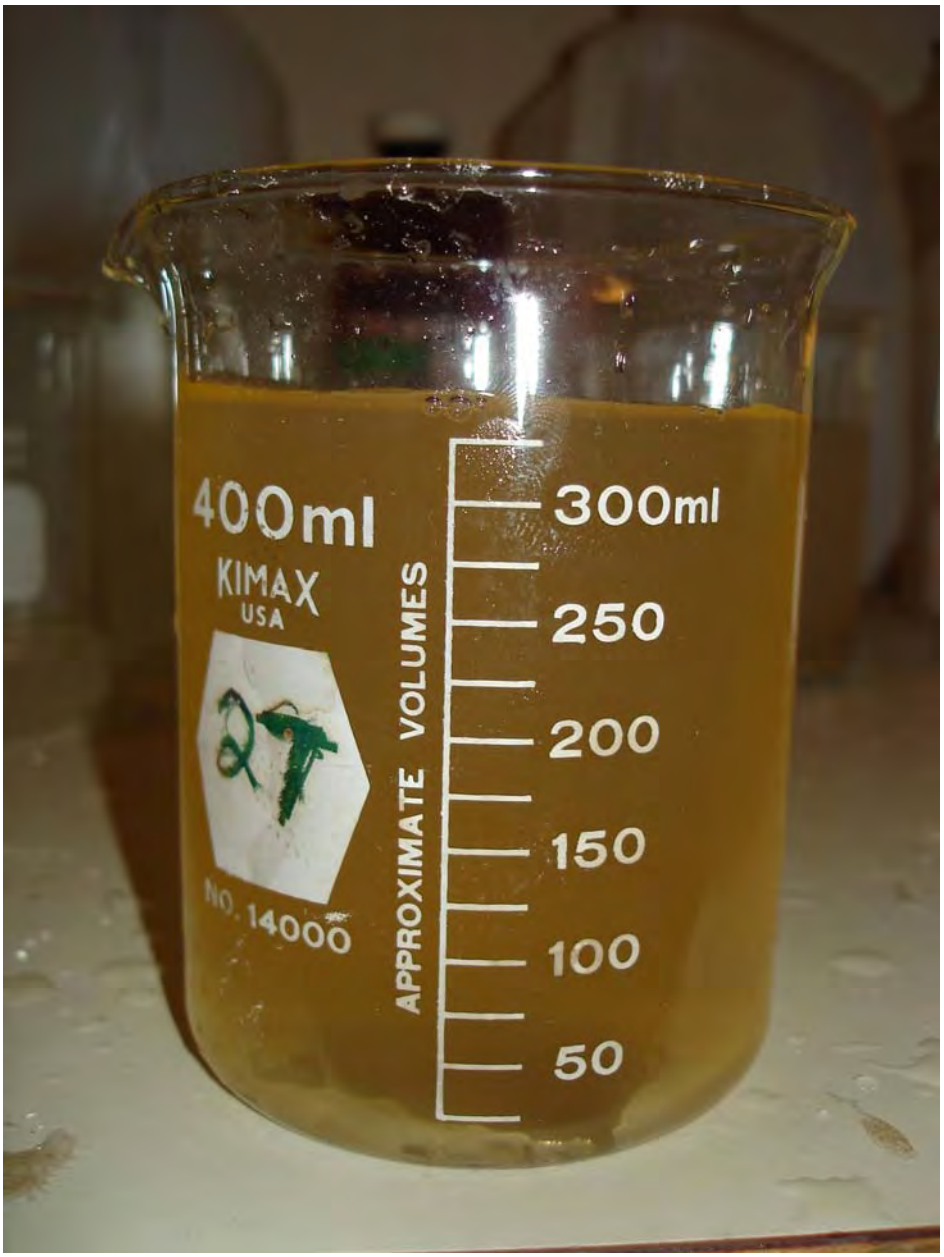
In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.
Visit our web site at www.energylab.com for additional information, downloadable fee schedule, forms, and links.

Attachment 2
Photographs

Monitoring Well MW95-4.

Jar Test Sample from MW95-4.

Mixed Jar Sample #5 (mixture of MW95-4 and Mine Water).



Test sample of MW95-4 water with peroxide added – to show presence of iron.

Test Jar #4 after reaction period. Bottle on left is unfiltered. Bottle on right is filtered and preserved.

Appendix E
Troy Mine Mill Site Conceptual Channel Design

50 West 14th Street, Suite 200
Helena, Montana 59601
tel: 406 441-1400
fax: 406 449-7725

Draft Memorandum

To: *Emily Corsi, Herb Rolfes – DEQ*
Bobbie Lacklen, John McKay - KNF

From: *Bill Bucher- CDM*

Date: *December 3, 2010*

Subject: *Troy Mine Mill Site Conceptual Channel Design*

CDM has prepared a design and cost estimate for a conceptual drainage channel design at the Troy Mine mill site to support the *Draft Environmental Assessment* currently being prepared for final reclamation of the mine. The mill pad and waste rock dump located just below the mine portal are built across a drainage that enters the site from the west. Currently water from this drainage is collected in a detention basin on the upslope side of the millsite and routed beneath the mill site through two culverts to the downslope side of the site where it enters Stanley Creek. The culverts are over 600 feet long and could not be maintained with any assurance in the long term. Under the Agency-Mitigated Alternative for the reclamation plan, these culverts will be plugged and the drainage channel reconstructed over or around the mill pad/waste rock dump.

The purpose of this memorandum is to present a conceptual design for the new channel and provide approximate reclamation costs for construction of the new channel. Maintenance of the new channel is designed to be minimal and should not extend beyond the first few years after construction.

Alternative Considered but not Selected

The most desirable solution for channel design is removal of the fill at the mill site patio and construction of a channel along the original natural alignment at the original grade. This solution would eliminate the difficulty of maintaining a stable channel on the face of the fill and allow for a construction of a naturally functioning channel, which could minimize long-term maintenance costs. However, rebuilding the original channel for the larger drainage will require removing a large portion of the mill site fill. It will also require relocating the access road and buried pipeline that are currently at the mill site.

Two scenarios were investigated to determine the feasibility of establishing a more natural channel gradient across the site. In the first scenario, the existing twin culverts would be

plugged and the surrounding depression filled. The channel would cross the filled depression and follow an approximate 4H:1V grade to the toe of the mill site fill slope at the location of the original channel. For estimation purposes, it is assumed that the bottom width of the cut would be 24 feet to accommodate the new channel, and the side slopes of the cut would rise at 2H:1V. An AutoCAD drawing of the required cut is attached as Figure 1. The volume of cut would be 71,000 cy. The excavated material would be transported to the relatively flat portion of the mill site, where it would be placed in lifts and compacted to form a fill at a slope no greater than 2H:1V.

A second scenario would plug the twin culverts but begin excavation approximately at the top of the culverts. The channel would be excavated at a slightly lesser gradient because it is starting at a lower elevation, and would terminate at the some point in the original channel. This layout results in about 110,000 cy of excavation. Although this channel is presumably near the original channel grade, it may not replicate the original channel because we do not know the alignment of the original channel.

If we assume the excavation can be accomplished for about $4 per cubic yard, the cost of excavation would be in the range of $280,000 to $440,000. This cost would be in addition to costs for building the new channel and revegetating the fresh cut slopes. Because of the greatly increased cost of this alternative compared to the costs of the options discussed below, this alternative was not pursued further.

Selected Alternative

Two options for the selected alternative were considered for evaluation as shown in the attached Figure 2. Both options originate from the end of the natural channel above the current detention basin, which will be backfilled during reclamation. Option 1 routes the drainage in an easterly direction across the top of the reclaimed mill pad/waste rock dump, down the face of the dump and into an energy dissipation basin before discharging to the original channel and Stanley Creek. These options are shown on the attached layout for the mill site.

Option 2 routes the water to the northeast on reclaimed ground until it reaches the north end of the mill pad/waste rock dump where it descends a steep slope. At the base of the steepest portion of the slope, an energy dissipation basin will reduce the velocity of the stream before it is routed through a constructed channel the remaining distance to Stanley Creek.

There is a minor drainage that enters the southern portion of the mill site that would also be routed across the mill patio to the road. Then it would be routed on the uphill (west) side of the road to the larger channel.. This would require shaping a small channel through the reclaimed area and lining it with appropriately sized rock. This design applies to Option 1 or Option 2. These costs are incidental compared to the costs for the main drainage and are not considered further in this memorandum.

Hydrology and Hydraulics

The design storm for permanent drainage channels at mine sites in Montana is the 100-year 24-hour storm. The Forest Service sizes culverts for the 100-year peak flow, which is the event that occurs with a probability of 1% in any given year. The 100-year flow was calculated using the USGS *Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998* (Parrett and Johnson, 2004). It was assumed that a burn could occur in the even-aged forest in this tributary drainage so a forest cover factor of 50% was used to represent 50% crown kill. The calculated 100-year flow under this condition is 33 cfs. An attachment provides documentation of the calculation.

Hydraulic calculations were performed using the Bathurst resistance calculation method as described in the *Stormwater Collection Systems Design Handbook* (Mays, 2001, Section 16.5). This iterative method determines the rock size necessary to prevent movement of the rock with a selected factor of safety. A typical industry standard factor of safety of 1.3 was selected for this calculation. This method is specifically meant for steep (greater than 10%) channel slopes where Manning's equation is not valid. Calculations show that a channel with a bottom width of 3 feet and side slopes of 2H:1V will be more than adequate to accommodate the calculated peak flow. The attached sketch shows the typical cross-sections for gentler and steeper portions of the channel.

For the portions of the channel with a slope of less than 10%, a rock size of d_{50} = 16 inches was calculated. For the steeper portions of the channels (77% for Option 1 and 50% for Option 2) a d_{50} = 5.6 feet is required. The latter gradation will range from a d_{10} of 2.8 feet to a d_{90} of 7 feet. Excel spreadsheet calculations are attached.

Conceptual Design

The channel options were designed as rock-lined channels using guidance from the USACE manual *Hydraulic Design of Flood Control Channels* (ASCE, 1995). The design includes a 9-inch thick filter bed of d_{50} = 6 inches beneath the riprap. Below this will be 1-inch minus bedding to protect the liner to be constructed where the channel crosses the mill patio. The liner will prevent infiltration of water into the mill fill. This liner could be constructed of HDPE, geosynthetic clay liner (GCL), or clay. Bedding material may need to be placed below the liner as well to provide a suitable surface for installation.

On the steep portion of the channel, installation of a liner will not be feasible. Riprap should be underlain by rock filter layers that prevent scour of the underlying material. It may be that appropriate sized material is already in place in this portion of the mill site, and it will not be necessary to place filter layers in that case.

The design includes a four foot culvert for passage of the drainage beneath the realigned and reconstructed road. A four foot culvert is oversized for the design flow and slope but is preferred to smaller sizes because of its ability to pass debris more readily.

The energy dissipation basin at the base of the steep slopes is intended to reduce velocities before a milder channel routes the discharge to Stanley Creek. The final design of this basin is recommended to be in accordance with US Department of Transportation (USDOT) guidelines (USDOT, 1975) for energy dissipaters. For purposes of this conceptual design, it is assumed that a basin 30 feet wide and 50 feet long will be more than adequate to dissipate energy from the design storm. The rock size for the basin is assumed to have a d_{50} of 16 inches but this may need to be adjusted during final design.

Although this channel has been designed for cost estimating purposes as a riprap channel, modifications can be made to provide a more natural appearance and function, especially in the gentler reaches. Woody debris can be incorporated between the rocks, rocks can be arranged to create step pools, and shrubs and trees can be planted between rocks on the banks. However, the framework of large rock sizes is still needed throughout the channel to provide stability under high flows. Addition of these items will increase installation time but should not significantly affect material costs relative to the high cost of the rock.

Both options present construction problems with using large rock on steep slopes. The 2H:1V slope of Option 2 is tractable with conventional equipment. Placement of large rock on the angle of repose slope of Option 1 will be more difficult. Equipment tethered from above may be able to shape the channel and place the required large rock. If sufficiently large rock is already present in the face of the dump, it may not be necessary to place rock here, making this option more attractive. However, without incising a channel in the face with equipment there will be no certainty that the discharge will be funneled to the energy dissipation basin.

Cost Estimate

A cost estimate for each option was prepared and these are attached to this memorandum. The largest and most uncertain cost is the cost of providing and placing rock. It is assumed that the d_{50} = 16-inch and d_{50} = 6-inch gradations can be found in the waste rock dump or other nearby areas and a cost of $30/cy will be sufficient for collection and placement of these materials. However, the d_{50} = 5-foot plus rock may need to be imported from a greater distance. A cost of $60/cy has been used for this rock assuming it can be found within 30 miles.

Other elements accounted for in the cost estimates are mobilization, erosion control, clearing and grubbing of timbered areas, installation of a culvert, and construction of an access road from the existing access road to construct the energy dissipater. Construction costs include a 15% contingency. Engineering design and oversight costs are estimated at 20% of construction costs. The total cost estimate for Option 1 is about $238,000 and the estimated total cost of Option 2 is $290,000. The attached cost sheets present breakdowns of the estimated costs of the two options.

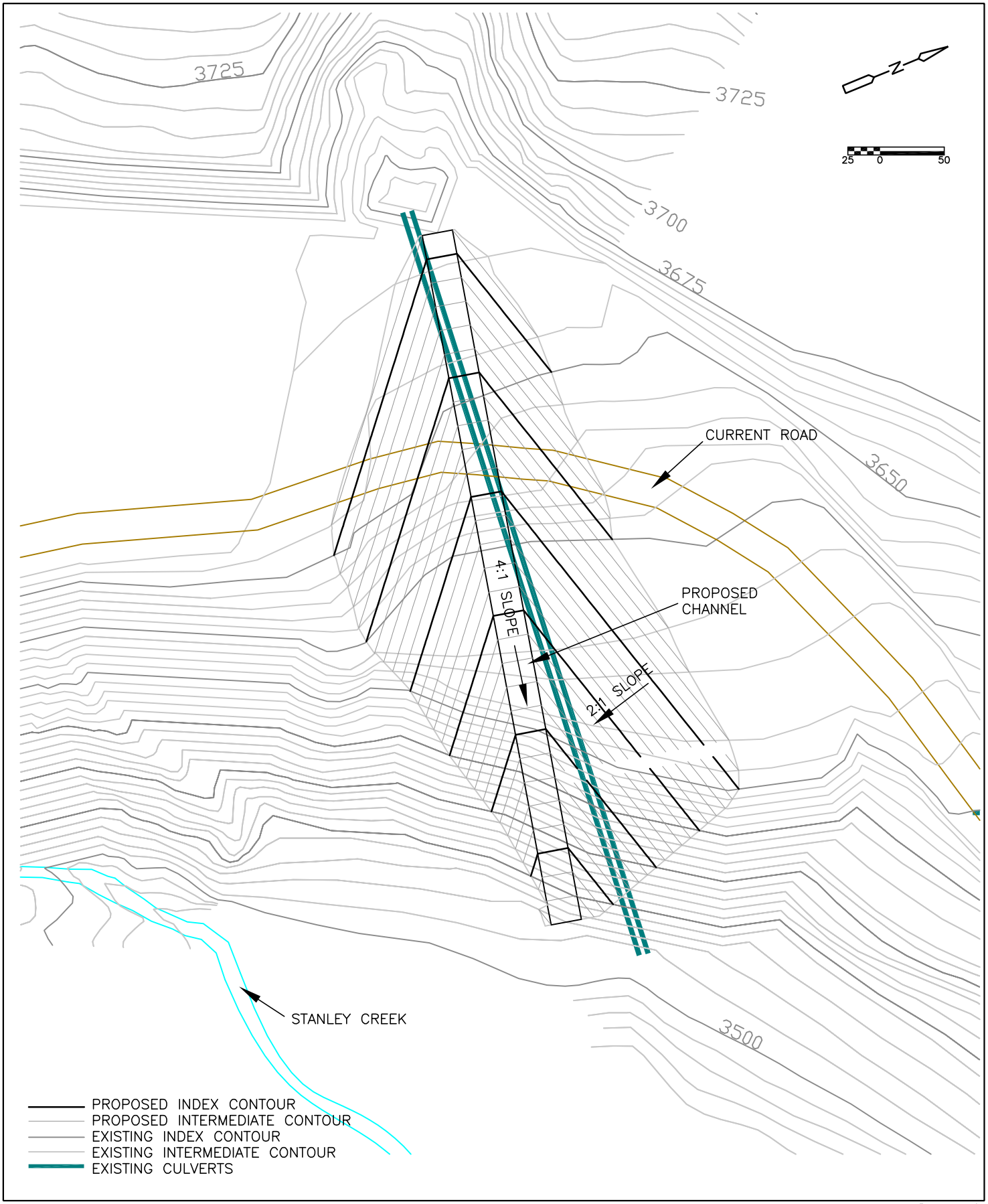
References

American Society of Civil Engineers, 1995. Hydraulic Design of Flood Control Channels. Technical Engineering and Design Guides as Adapted from the US Army Corps of Engineers, No. 10. New York, N. Y.

Mays, L., 2001. Stormwater Collection Systems Design Handbook.

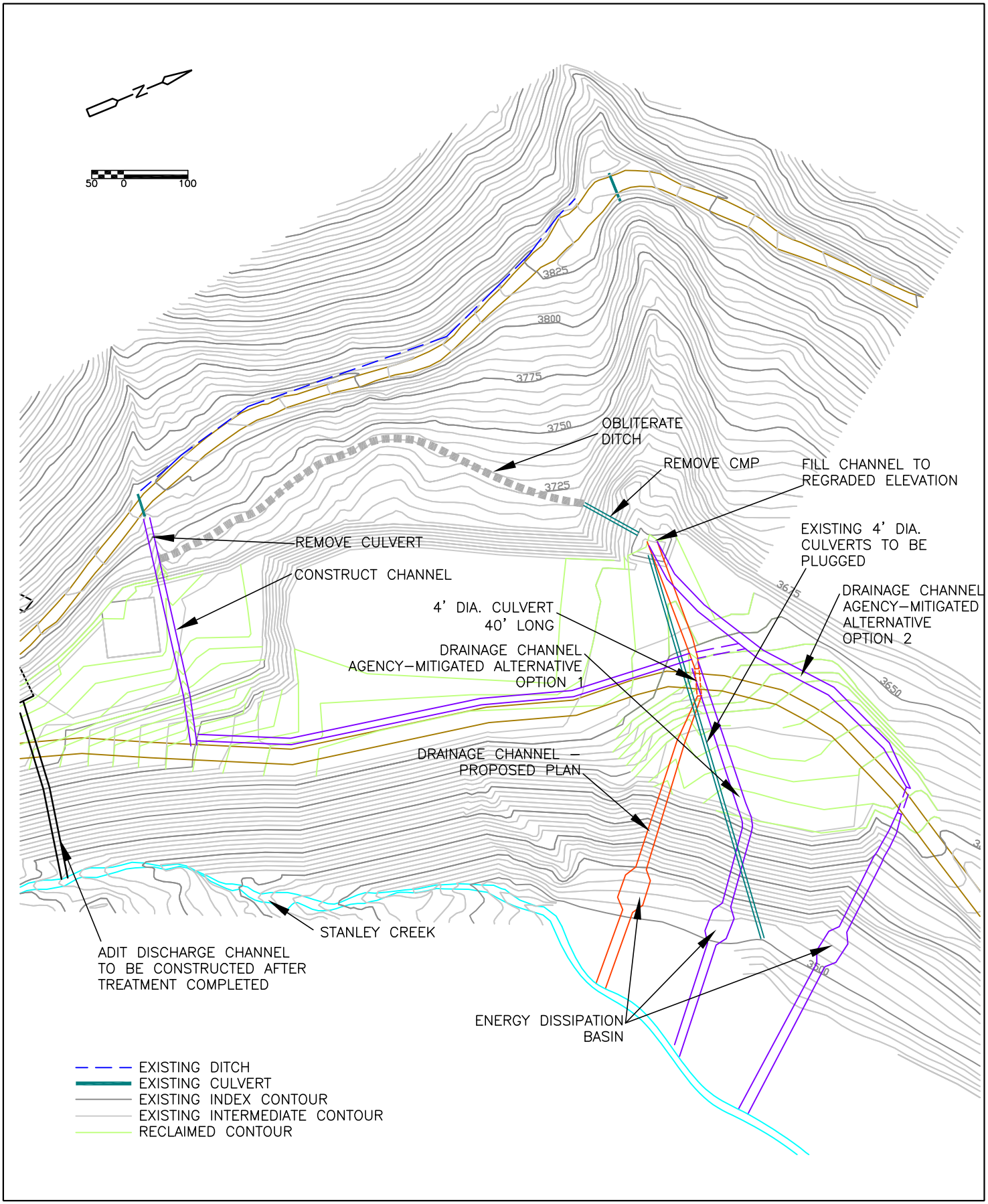
Parrett, C. and D.LR. Johnson, 2004. Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998. US Geological Survey Water-Resources Investigations Report 03-4308, Helena MT. February 2004.

US Department of Transportation, 1975. Hydraulic Design of Energy Dissipators for Culverts and Cahnnels. Hydraulic Engineering Circular No. 14. June 1975.



K:\Troy Mine\DWG\CSTP001.dwg SAVED:12/3/10 PRINTED:12/3/10 BY:KOTSONJF

FIGURE 1
Excavation for 4:1 Channel Slope
Troy Mine Waterline Conceptual
Channel Design



K:\Troy Mine\DWG\Channel Discharge Pipelines.dwg SAVED12/2/10 PRINTED12/3/10 BY:KDTSONJF

FIGURE 2
Channel Options
Troy Mine Conceptual
Channel Design

CDM

CLIENT	MDEQ	JOB NO.		COMPUTED BY	WHB
PROJECT	Troy Mine EA	DATE CHECKED		DATE	12/1/2010
DETAIL	Peak Flow Calc. Trib to Stanley Cr.	CHECKED BY		PAGE NO.	1 of 1

Determine peak flow of 100 year event at mill site drainage. Use WRIR 03-4308 (Parrett & Johnson, 2004) to calculate 100-yr flow.

Drainage Area = 0.179 sq. mi (USGS topo)
Ave Annual precip = 24" (Troy average precip)
Forest cover = 50% Burned condition with 50% crown kill.

Use West Region Equation

$$Q_{100} = 18.7\, A^{0.812}\, P^{1.06}\, (F+1)^{-0.664}$$

$$Q_{100} = 18.7 \times (0.179)^{0.812}\, (24)^{1.06}\, (51)^{-0.664}$$

$$Q_{100} = 33 \text{ cfs.}$$

Steep Slope Riprap Design
Ref: Stormwater Collection Systems Design Handbook, Larry Mays, 2001, Section 16.5
Troy - Mine, Millpad Channel, 10% slope
Target Flow = 33 cfs

Channel Dimensions

Bottom Width(ft) =	3.28	
Bottom Width(m) =	1	
Sideslopes =	2	:1(H:V)
Slope (m/m) =	0.1	
Length (ft) =	581	
Length (m) =	177	

Trial Lining

D90 (ft) =	1.64
D90 (m) =	0.5
D50 (ft) =	1.31
D50 (m) =	0.4
D10 (ft) =	0.66
D10 (m) =	0.2

Range of Depth to be Evaluated

Least Depth (m) =	0.1
Maximum Depth (m)=	2
Increment (m) =	0.02

Angles

Side Slope, degrees	26.57
Bed Slope, degrees	5.74
Riprap Angle of Repose, degrees (Get from Charts)	43
Factor of Safety	1.3

Hydraulic Calculations

Depth (ft)	Depth (m)	Area (sf)	Area (sm)	Wetted Perimeter (ft)	Wetted Perimeter (m)	Top Width (ft)	Top Width (m)	Hydraulic Radius (ft)	Hydraulic Radius (m)
0.328	0.100	1.292	0.120	4.748	1.447	4.593	1.4	0.272	0.083
0.394	0.120	1.602	0.149	5.042	1.537	4.856	1.48	0.318	0.097
0.459	0.140	1.929	0.179	5.335	1.626	5.118	1.56	0.362	0.110
0.525	0.160	2.273	0.211	5.628	1.716	5.381	1.64	0.404	0.123
0.591	0.180	2.635	0.245	5.922	1.805	5.643	1.72	0.445	0.136
0.656	0.200	3.014	0.280	6.215	1.894	5.906	1.8	0.485	0.148
0.722	0.220	3.410	0.317	6.509	1.984	6.168	1.88	0.524	0.160
0.787	0.240	3.823	0.355	6.802	2.073	6.430	1.96	0.562	0.171
0.853	0.260	4.254	0.395	7.096	2.163	6.693	2.04	0.600	0.183
0.919	0.280	4.702	0.437	7.389	2.252	6.955	2.12	0.636	0.194
0.984	0.300	5.167	0.480	7.683	2.342	7.218	2.2	0.673	0.205
1.050	0.320	5.649	0.525	7.976	2.431	7.480	2.28	0.708	0.216
1.115	0.340	6.148	0.571	8.269	2.521	7.743	2.36	0.744	0.227
1.181	0.360	6.665	0.619	8.563	2.610	8.005	2.44	0.778	0.237
1.247	0.380	7.199	0.669	8.856	2.699	8.268	2.52	0.813	0.248
1.312	0.400	7.750	0.720	9.150	2.789	8.530	2.6	0.847	0.258
1.378	0.420	8.318	0.773	9.443	2.878	8.793	2.68	0.881	0.268
1.444	0.440	8.904	0.827	9.737	2.968	9.055	2.76	0.914	0.279
1.509	0.460	9.507	0.883	10.030	3.057	9.318	2.84	0.948	0.289
1.575	0.480	10.127	0.941	10.324	3.147	9.580	2.92	0.981	0.299
1.640	0.500	10.764	1.000	10.617	3.236	9.843	3	1.014	0.309
1.706	0.520	11.418	1.061	10.910	3.326	10.105	3.08	1.047	0.319
1.772	0.540	12.090	1.123	11.204	3.415	10.367	3.16	1.079	0.329
1.837	0.560	12.779	1.187	11.497	3.504	10.630	3.24	1.111	0.339
1.903	0.580	13.485	1.253	11.791	3.594	10.892	3.32	1.144	0.349
1.969	0.600	14.208	1.320	12.084	3.683	11.155	3.4	1.176	0.358
2.034	0.620	14.949	1.389	12.378	3.773	11.417	3.48	1.208	0.368
2.100	0.640	15.707	1.459	12.671	3.862	11.680	3.56	1.240	0.378
2.165	0.660	16.482	1.531	12.965	3.952	11.942	3.64	1.271	0.387

Note: Gradation calculation (D90 and D10) based on USFS Specs. for Roads and Bridges

Bathurst Resistance Calculations

Depth (ft)	Depth (m)	b	c1	f(FR)	c2	f(REG)	f(CG)	V*	Sum of f (functions)	n	V/V*	Velocity (V) m/sec	Froude Number	Correction for slope 0.98 Flow, Q m^3/sec	Flow, Q ft^3/sec	To N/m^2
0.33	0.1	0.180	0.624	1.319 *v^c1	1.745	3.233	0.602	0.313	2.568	0.082	2.650	0.830	0.838	0.100	3.5	80.9
0.39	0.12	0.199	0.580	1.220 *v^c1	1.944	3.700	0.582	0.343	2.627	0.082	2.722	0.934	0.861	0.139	4.9	94.5
0.46	0.14	0.215	0.545	1.153 *v^c1	2.118	4.137	0.565	0.371	2.696	0.082	2.805	1.040	0.887	0.186	6.6	107.6
0.52	0.16	0.231	0.515	1.105 *v^c1	2.273	4.552	0.550	0.396	2.770	0.081	2.893	1.146	0.915	0.242	8.5	120.2
0.59	0.18	0.244	0.490	1.070 *v^c1	2.413	4.946	0.538	0.420	2.846	0.080	2.983	1.253	0.943	0.307	10.8	132.4
0.66	0.2	0.256	0.469	1.042 *v^c1	2.540	5.324	0.527	0.443	2.922	0.079	3.073	1.361	0.972	0.381	13.4	144.3
0.72	0.22	0.268	0.450	1.020 *v^c1	2.656	5.687	0.517	0.465	2.998	0.078	3.162	1.469	1.000	0.465	16.4	155.9
0.79	0.24	0.278	0.433	1.003 *v^c1	2.763	6.039	0.508	0.485	3.073	0.077	3.250	1.577	1.028	0.560	19.8	167.2
0.85	0.26	0.288	0.419	0.988 *v^c1	2.862	6.379	0.499	0.505	3.147	0.076	3.337	1.685	1.055	0.666	23.5	178.4
0.92	0.28	0.297	0.405	0.976 *v^c1	2.954	6.711	0.491	0.524	3.219	0.075	3.422	1.794	1.082	0.783	27.6	189.3
0.98	0.3	0.306	0.393	0.966 *v^c1	3.040	7.034	0.484	0.542	3.290	0.075	3.506	1.902	1.109	0.913	32.2	200.1
1.05	0.32	0.314	0.381	0.958 *v^c1	3.122	7.350	0.477	0.560	3.360	0.074	3.588	2.010	1.135	1.055	37.2	210.7
1.12	0.34	0.321	0.371	0.950 *v^c1	3.198	7.660	0.471	0.578	3.429	0.073	3.669	2.119	1.160	1.210	42.7	221.2
1.18	0.36	0.328	0.361	0.944 *v^c1	3.271	7.963	0.465	0.594	3.496	0.072	3.748	2.227	1.185	1.379	48.7	231.6
1.25	0.38	0.335	0.352	0.938 *v^c1	3.341	8.262	0.459	0.611	3.562	0.071	3.825	2.335	1.210	1.562	55.1	241.8
1.31	0.4	0.342	0.344	0.934 *v^c1	3.407	8.556	0.454	0.626	3.627	0.070	3.901	2.444	1.234	1.760	62.1	252.0
1.38	0.42	0.348	0.336	0.929 *v^c1	3.470	8.846	0.449	0.642	3.690	0.069	3.976	2.552	1.257	1.972	69.6	262.1
1.44	0.44	0.354	0.329	0.926 *v^c1	3.531	9.132	0.444	0.657	3.753	0.069	4.050	2.661	1.281	2.201	77.7	272.1
1.51	0.46	0.360	0.322	0.922 *v^c1	3.589	9.415	0.439	0.672	3.815	0.068	4.122	2.769	1.303	2.446	86.3	282.0
1.57	0.48	0.366	0.315	0.919 *v^c1	3.646	9.694	0.435	0.686	3.875	0.067	4.193	2.877	1.326	2.707	95.5	291.8
1.64	0.5	0.371	0.309	0.917 *v^c1	3.700	9.971	0.430	0.700	3.935	0.067	4.263	2.986	1.348	2.986	105.4	301.6
1.71	0.52	0.376	0.303	0.915 *v^c1	3.753	10.245	0.426	0.714	3.993	0.066	4.332	3.094	1.370	3.282	115.8	311.4
1.77	0.54	0.381	0.297	0.913 *v^c1	3.804	10.516	0.422	0.728	4.051	0.065	4.400	3.203	1.391	3.597	126.9	321.0

Maximum Boundary Shear Stresses

Depth (ft)	d (m)	B/R	Kbs	Kss	Fsf	T bed N/m^2	T bank N/m^2	Stresses Allowable? Bed	Bank
0.33	0.1	12.060	1.176	0.923	0.892	95.2	84.9	OK	OK
0.39	0.12	10.327	1.201	0.942	0.895	113.5	101.6	OK	OK
0.46	0.14	9.074	1.223	0.960	0.898	131.6	118.2	OK	OK
0.52	0.16	8.123	1.244	0.977	0.901	149.5	134.7	OK	OK
0.59	0.18	7.373	1.264	0.992	0.904	167.3	151.3	OK	OK
0.66	0.2	6.766	1.282	1.006	0.907	185.0	167.8	OK	OK
0.72	0.22	6.262	1.299	1.020	0.910	202.5	184.3	OK	OK
0.79	0.24	5.837	1.315	1.033	0.913	220.0	200.8	OK	OK
0.85	0.26	5.473	1.331	1.045	0.915	237.4	217.3	OK	OK
0.92	0.28	5.156	1.345	1.056	0.918	254.7	233.8	OK	OK
0.98	0.3	4.878	1.359	1.067	0.920	272.0	250.3	OK	OK
1.05	0.32	4.632	1.373	1.078	0.923	289.2	266.9	OK	
1.12	0.34	4.413	1.386	1.088	0.925	306.5	283.4	OK	
1.18	0.36	4.215	1.398	1.097	0.927	323.7	300.0	OK	
1.25	0.38	4.036	1.410	1.106	0.929	340.9	316.7	OK	
1.31	0.4	3.873	1.421	1.115	0.931	358.1	333.3	OK	
1.38	0.42	3.725	1.432	1.124	0.933	375.2	350.1	OK	
1.44	0.44	3.588	1.442	1.132	0.935	392.4	366.8	OK	
1.51	0.46	3.461	1.453	1.140	0.936	409.6	383.6	OK	
1.57	0.48	3.345	1.463	1.148	0.938	426.8	400.4	OK	
1.64	0.5	3.236	1.472	1.156	0.940	444.0	417.3	OK	
1.71	0.52	3.135	1.481	1.163	0.941	461.3	434.2	OK	
1.77	0.54	3.040	1.490	1.170	0.943	478.5	451.2		

Where C is = 0.785

z	C
1.5	0.76
2	0.785
3	0.85
4	0.935
6	0.97

Permissible Shear Stresses

D50 = (m)	Tc = (N/m^2)	SF =	Cz =	Cw=	Cr=	Tpbed = N/m^2
0.4	600	1.3	0.89	1	0.54	461.54

Depth (ft)	d	E	Ab	Cl	Cb	Ca	Al (estimated)	Tp_bank N/m^2
0.33	0.1	6.78	0.15	2.01	1.00	0.42	0	250.8
0.39	0.12	5.67	0.18	2.01	1.00	0.42	0	250.9
0.46	0.14	4.87	0.21	2.01	1.00	0.42	0	251.0
0.52	0.16	4.27	0.23	2.01	1.00	0.42	0	251.2
0.59	0.18	3.80	0.26	2.01	1.00	0.42	0	251.3
0.66	0.2	3.43	0.29	2.01	1.00	0.42	0	251.4
0.72	0.22	3.12	0.32	2.01	1.00	0.42	0	251.5
0.79	0.24	2.87	0.35	2.01	1.00	0.42	0	251.7
0.85	0.26	2.65	0.38	2.01	1.00	0.42	0	251.8
0.92	0.28	2.46	0.41	2.01	1.00	0.42	0	251.9
0.98	0.3	2.30	0.43	2.02	1.00	0.42	0	252.0
1.05	0.32	2.16	0.46	2.02	1.00	0.42	0	252.2
1.12	0.34	2.03	0.49	2.02	1.00	0.42	0	252.3
1.18	0.36	1.92	0.52	2.02	1.00	0.42	0	252.4
1.25	0.38	1.82	0.55	2.02	1.00	0.42	0	252.6
1.31	0.4	1.73	0.58	2.02	1.00	0.42	0	252.7
1.38	0.42	1.64	0.61	2.02	1.00	0.42	0	252.8
1.44	0.44	1.57	0.64	2.02	1.00	0.42	0	253.0
1.51	0.46	1.50	0.67	2.02	1.00	0.42	0	253.1
1.57	0.48	1.44	0.70	2.02	1.00	0.42	0	253.2
1.64	0.5	1.38	0.73	2.03	1.00	0.42	0	253.3
1.71	0.52	1.33	0.75	2.03	1.00	0.42	0	253.5
1.77	0.54	1.28	0.78	2.03	1.00	0.42	0	253.6

Steep Slope Riprap Design
Ref: Stormwater Collection Systems Design Handbook, Larry Mays, 2001, Section 16.5
Troy - Mine, Millpad Channel, 77% slope
Target Flow = 33 cfs

Channel Dimensions

Bottom Width(ft) =	2.99	
Bottom Width(m) =	0.91	
Sideslopes =	2	:1(H:V)
Slope (m/m) =	0.77	
Length (ft) =	200	
Length (m) =	61	

Trial Lining

D90 (ft) =	6.97
D90 (m) =	2.125
D50 (ft) =	5.58
D50 (m) =	1.7
D10 (ft) =	2.79
D10 (m) =	0.85

Range of Depth to be Evaluated

Least Depth (m) =	0.1
Maximum Depth (m)=	2
Increment (m) =	0.02

Angles

Side Slope, degrees	26.57
Bed Slope, degrees	50.35
Riprap Angle of Repose, degrees (Get from Charts)	43
Factor of Safety	1.3

Hydraulic Calculations

Depth (ft)	Depth (m)	Area (sf)	Area (sm)	Wetted Perimeter (ft)	Wetted Perimeter (m)	Top Width (ft)	Top Width (m)	Hydraulic Radius (ft)	Hydraulic Radius (m)
0.328	0.100	1.195	0.111	4.453	1.357	4.298	1.31	0.268	0.082
0.394	0.120	1.485	0.138	4.746	1.447	4.560	1.39	0.313	0.095
0.459	0.140	1.793	0.167	5.040	1.536	4.823	1.47	0.356	0.108
0.525	0.160	2.118	0.197	5.333	1.626	5.085	1.55	0.397	0.121
0.591	0.180	2.461	0.229	5.627	1.715	5.348	1.63	0.437	0.133
0.656	0.200	2.820	0.262	5.920	1.804	5.610	1.71	0.476	0.145
0.722	0.220	3.197	0.297	6.213	1.894	5.873	1.79	0.515	0.157
0.787	0.240	3.591	0.334	6.507	1.983	6.135	1.87	0.552	0.168
0.853	0.260	4.002	0.372	6.800	2.073	6.398	1.95	0.588	0.179
0.919	0.280	4.430	0.412	7.094	2.162	6.660	2.03	0.625	0.190
0.984	0.300	4.876	0.453	7.387	2.252	6.923	2.11	0.660	0.201
1.050	0.320	5.339	0.496	7.681	2.341	7.185	2.19	0.695	0.212
1.115	0.340	5.819	0.541	7.974	2.431	7.448	2.27	0.730	0.222
1.181	0.360	6.316	0.587	8.268	2.520	7.710	2.35	0.764	0.233
1.247	0.380	6.831	0.635	8.561	2.609	7.972	2.43	0.798	0.243
1.312	0.400	7.363	0.684	8.855	2.699	8.235	2.51	0.831	0.253
1.378	0.420	7.911	0.735	9.148	2.788	8.497	2.59	0.865	0.264
1.444	0.440	8.478	0.788	9.441	2.878	8.760	2.67	0.898	0.274
1.509	0.460	9.061	0.842	9.735	2.967	9.022	2.75	0.931	0.284
1.575	0.480	9.662	0.898	10.028	3.057	9.285	2.83	0.963	0.294
1.640	0.500	10.280	0.955	10.322	3.146	9.547	2.91	0.996	0.304
1.706	0.520	10.915	1.014	10.615	3.236	9.810	2.99	1.028	0.313
1.772	0.540	11.567	1.075	10.909	3.325	10.072	3.07	1.060	0.323
1.837	0.560	12.236	1.137	11.202	3.414	10.335	3.15	1.092	0.333
1.903	0.580	12.923	1.201	11.496	3.504	10.597	3.23	1.124	0.343
1.969	0.600	13.627	1.266	11.789	3.593	10.860	3.31	1.156	0.352
2.034	0.620	14.348	1.333	12.082	3.683	11.122	3.39	1.188	0.362
2.100	0.640	15.087	1.402	12.376	3.772	11.385	3.47	1.219	0.372
2.165	0.660	15.842	1.472	12.669	3.862	11.647	3.55	1.250	0.381

Note: Gradation calculation (D90 and D10) based on USFS Specs. for Roads and Bridges

Bathurst Resistance Calculations

Depth (ft)	Depth (m)	b	c1	f(FR)	c2	f(REG)	f(CG)	V*	Sum of f (functions)	n	V/V*	Velocity (V) m/sec	Froude Number	Correction for slope 0.98 Flow, Q m^3/sec	Flow, Q ft^3/sec	To N/m^2
0.33	0.1	0.109	0.842	2.222 *v^c1	1.478	1.300	0.740	0.869	2.138	0.098	2.210	1.921	1.940	0.213	7.5	394.2
0.39	0.12	0.120	0.800	1.972 *v^c1	1.605	1.454	0.726	0.952	2.081	0.104	2.162	2.058	1.897	0.284	10.0	459.8
0.46	0.14	0.130	0.765	1.803 *v^c1	1.714	1.596	0.713	1.028	2.053	0.107	2.142	2.203	1.880	0.367	13.0	522.7
0.52	0.16	0.138	0.737	1.681 *v^c1	1.809	1.728	0.703	1.099	2.041	0.110	2.138	2.351	1.877	0.463	16.3	583.5
0.59	0.18	0.146	0.713	1.588 *v^c1	1.891	1.853	0.693	1.166	2.040	0.112	2.145	2.501	1.882	0.572	20.2	642.4
0.66	0.2	0.153	0.692	1.516 *v^c1	1.965	1.970	0.685	1.229	2.046	0.113	2.158	2.652	1.894	0.695	24.5	699.8
0.72	0.22	0.160	0.674	1.458 *v^c1	2.030	2.082	0.677	1.289	2.056	0.114	2.175	2.804	1.909	0.833	29.4	755.8
0.79	0.24	0.166	0.658	1.410 *v^c1	2.090	2.190	0.670	1.346	2.069	0.115	2.195	2.956	1.926	0.986	34.8	810.7
0.85	0.26	0.172	0.643	1.369 *v^c1	2.144	2.293	0.664	1.401	2.085	0.115	2.218	3.108	1.946	1.155	40.8	864.5
0.92	0.28	0.177	0.630	1.335 *v^c1	2.193	2.393	0.658	1.454	2.101	0.115	2.241	3.259	1.966	1.341	47.3	917.5
0.98	0.3	0.182	0.618	1.305 *v^c1	2.239	2.490	0.652	1.505	2.119	0.115	2.265	3.410	1.988	1.545	54.5	969.6
1.05	0.32	0.187	0.607	1.279 *v^c1	2.281	2.584	0.647	1.555	2.138	0.115	2.290	3.561	2.010	1.766	62.3	1021.1
1.12	0.34	0.191	0.597	1.256 *v^c1	2.321	2.676	0.642	1.603	2.157	0.115	2.316	3.711	2.032	2.006	70.8	1072.0
1.18	0.36	0.195	0.588	1.236 *v^c1	2.358	2.765	0.637	1.649	2.177	0.115	2.341	3.860	2.054	2.265	79.9	1122.3
1.25	0.38	0.199	0.579	1.218 *v^c1	2.393	2.853	0.632	1.694	2.197	0.115	2.367	4.010	2.077	2.545	89.8	1172.1
1.31	0.4	0.203	0.571	1.202 *v^c1	2.426	2.939	0.628	1.738	2.217	0.115	2.392	4.158	2.099	2.844	100.4	1221.5
1.38	0.42	0.207	0.563	1.187 *v^c1	2.457	3.023	0.624	1.781	2.237	0.114	2.418	4.306	2.122	3.165	111.7	1270.5
1.44	0.44	0.210	0.556	1.173 *v^c1	2.487	3.106	0.620	1.823	2.257	0.114	2.443	4.454	2.144	3.508	123.8	1319.1
1.51	0.46	0.213	0.549	1.160 *v^c1	2.515	3.187	0.616	1.864	2.278	0.114	2.469	4.601	2.166	3.874	136.7	1367.3
1.57	0.48	0.217	0.542	1.149 *v^c1	2.543	3.267	0.612	1.904	2.298	0.113	2.494	4.748	2.188	4.262	150.4	1415.3
1.64	0.5	0.220	0.536	1.138 *v^c1	2.569	3.346	0.608	1.943	2.318	0.113	2.519	4.895	2.210	4.674	165.0	1463.0
1.71	0.52	0.223	0.530	1.129 *v^c1	2.594	3.424	0.605	1.982	2.338	0.113	2.543	5.041	2.232	5.111	180.4	1510.4
1.77	0.54	0.226	0.524	1.119 *v^c1	2.618	3.501	0.601	2.020	2.357	0.112	2.568	5.186	2.253	5.573	196.7	1557.7

Maximum Boundary Shear Stresses

Depth (ft)	d (m)	B/R	Kbs	Kss	Fsf	T bed N/m^2	T bank N/m^2	Stresses Allowable? Bed	Bank
0.33	0.1	11.127	1.188	0.933	0.976	468.4	457.2	OK	OK
0.39	0.12	9.540	1.214	0.953	0.974	558.2	543.7	OK	OK
0.46	0.14	8.390	1.238	0.972	0.973	647.1	629.6	OK	OK
0.52	0.16	7.516	1.260	0.989	0.973	735.1	715.1	OK	OK
0.59	0.18	6.827	1.280	1.005	0.973	822.4	800.3	OK	OK
0.66	0.2	6.267	1.299	1.020	0.974	909.1	885.2	OK	OK
0.72	0.22	5.803	1.317	1.034	0.975	995.3	970.0	OK	OK
0.79	0.24	5.410	1.334	1.047	0.975	1081.1	1054.6	OK	OK
0.85	0.26	5.073	1.350	1.059	0.976	1166.7	1139.2	OK	
0.92	0.28	4.780	1.365	1.071	0.978	1252.0	1223.9	OK	
0.98	0.3	4.523	1.379	1.082	0.979	1337.1	1308.5	OK	
1.05	0.32	4.295	1.393	1.093	0.980	1422.1	1393.3	OK	
1.12	0.34	4.091	1.406	1.104	0.981	1507.0	1478.1	OK	
1.18	0.36	3.908	1.418	1.113	0.982	1591.9	1563.1	OK	
1.25	0.38	3.742	1.431	1.123	0.983	1676.8	1648.2	OK	
1.31	0.4	3.591	1.442	1.132	0.984	1761.6	1733.6	OK	
1.38	0.42	3.452	1.453	1.141	0.985	1846.5	1819.1	OK	
1.44	0.44	3.325	1.464	1.149	0.986	1931.4	1904.7	OK	
1.51	0.46	3.208	1.475	1.158	0.987	2016.4	1990.6		
1.57	0.48	3.099	1.485	1.166	0.988	2101.5	2076.8		
1.64	0.5	2.998	1.495	1.173	0.989	2186.7	2163.1		
1.71	0.52	2.904	1.504	1.181	0.990	2271.9	2249.6		
1.77	0.54	2.816	1.513	1.188	0.991	2357.3	2336.4		

Where C is = 0.785

z	C
1.5	0.76
2	0.785
3	0.85
4	0.935
6	0.97

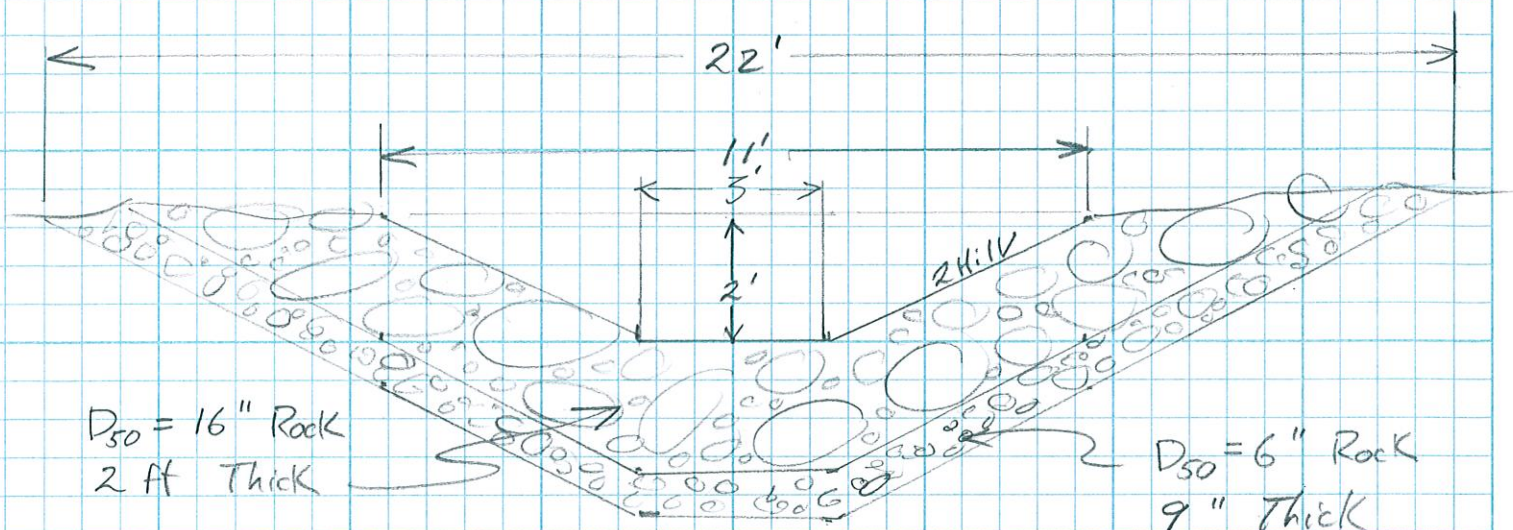
Permissible Shear Stresses

D50 = (m)	Tc = (N/m^2)	SF =	Cz =	Cw=	Cr=	Tpbed = N/m^2
1.7	2550	1.3	0.89	1	0.54	1961.54

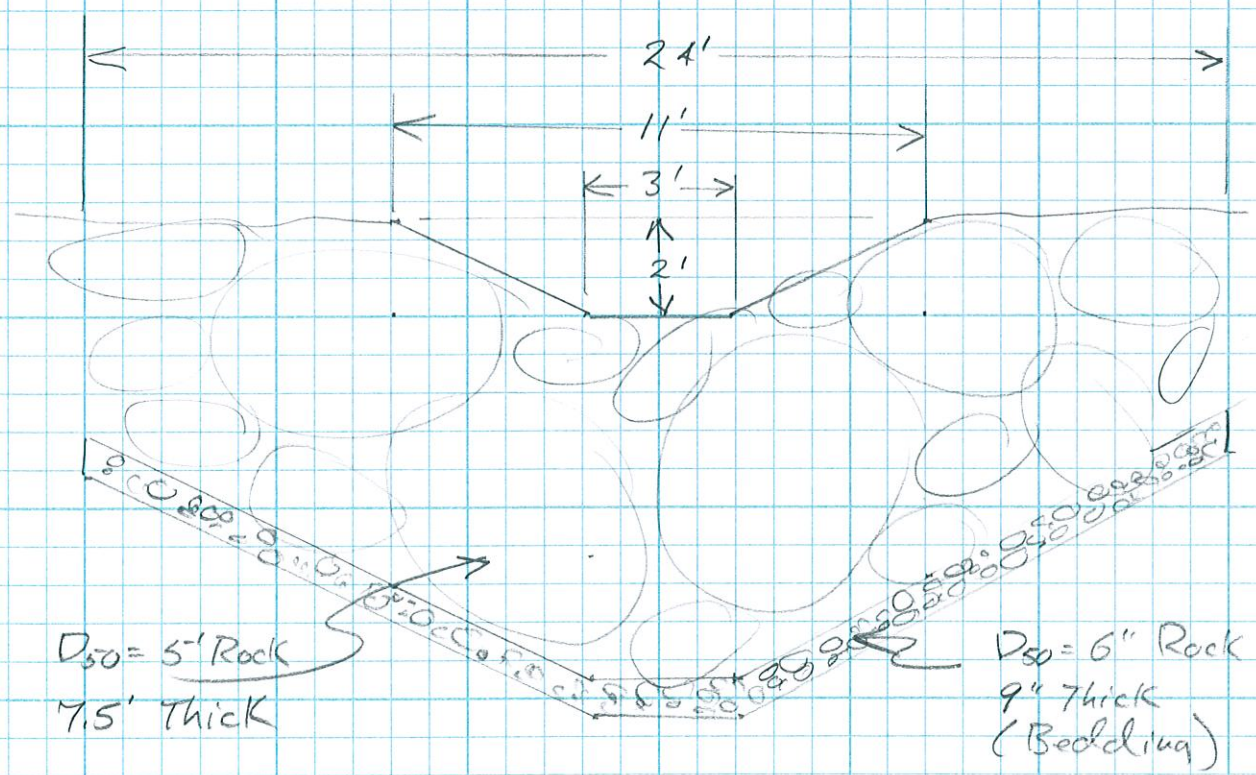
Depth (ft)	d	E	Ab	Cl	Cb	Ca	Al (estimated)	Tp_bank N/m^2
0.33	0.1	5.35	0.19	2.01	1.00	0.42	0	1066.5
0.39	0.12	4.50	0.22	2.01	1.00	0.42	0	1067.2
0.46	0.14	3.88	0.26	2.01	1.00	0.42	0	1067.9
0.52	0.16	3.42	0.29	2.01	1.00	0.42	0	1068.5
0.59	0.18	3.06	0.33	2.01	1.00	0.42	0	1069.2
0.66	0.2	2.76	0.36	2.01	1.00	0.42	0	1069.8
0.72	0.22	2.52	0.40	2.01	1.00	0.42	0	1070.5
0.79	0.24	2.32	0.43	2.02	1.00	0.42	0	1071.1
0.85	0.26	2.15	0.47	2.02	1.00	0.42	0	1071.8
0.92	0.28	2.00	0.50	2.02	1.00	0.42	0	1072.4
0.98	0.3	1.87	0.53	2.02	1.00	0.42	0	1073.1
1.05	0.32	1.76	0.57	2.02	1.00	0.42	0	1073.8
1.12	0.34	1.65	0.60	2.02	1.00	0.42	0	1074.4
1.18	0.36	1.56	0.64	2.02	1.00	0.42	0	1075.1
1.25	0.38	1.48	0.67	2.02	1.00	0.42	0	1075.7
1.31	0.4	1.41	0.71	2.02	1.00	0.42	0	1076.4
1.38	0.42	1.34	0.74	2.03	1.00	0.42	0	1077.1
1.44	0.44	1.28	0.78	2.03	1.00	0.42	0	1077.7
1.51	0.46	1.23	0.81	2.03	1.00	0.42	0	1078.4
1.57	0.48	1.18	0.85	2.03	1.00	0.42	0	1079.1
1.64	0.5	1.13	0.88	2.03	1.00	0.42	0	1079.8
1.71	0.52	1.09	0.92	2.03	1.00	0.42	0	1080.4
1.77	0.54	1.05	0.96	2.03	1.00	0.42	0	1081.1

CDM

CLIENT	MDEQ	JOB NO.		COMPUTED BY	WHB
PROJECT	Troy Mine EA	DATE CHECKED		DATE	6/17/2010
DETAIL	Millsite Channel Sections	CHECKED BY		PAGE NO.	



10% Slope Channel Section
1" = 3'



1.3:1 to 2:1 Channel Section
1" = 4'

TROY MINE RECLAMATION
MILLSITE CHANNEL COST
December 2, 2010

OPTION 1

Item			Quanity		Unit Cost	Cost	
Mobilization @ 10%						$15,681	
Erosion control @ 5%						$7,467	
Clear and Grub (wooded areas)			1	AC	4000	$4,000	
Access Road			700	LF	16	$11,200	USDA FS Cost Estimating Guide for Road Construction
Channel	length (ft)	section (ft ^{2})					
D_{50} = 16" Rock	650	30	722	CY	$30.00	$21,667	
D_{50} = 5' Rock	150	180	1000	CY	$60.00	$60,000	
D_{50} = 6" Rock	800	18	533	CY	$30.00	$16,000	
Energy Dissipation Basin							
D_{50} = 16" Rock	30	46	51	CY	$30.00	$1,533	
D_{50} = 6" Rock	30	23	26	CY	$30.00	$767	
Liner							
HDPE			1200	SY	$15.00	$18,000	
Bedding			400	CY	$20.00	$8,000	
Culvert							
4' Dia. CMP			40	LF	$143.00	$5,720	Means 33 41 13 40 2200
Excavation, Backfill, Compaction			40	LF	$61.30	$2,452	Means 31 23 16 13 0500, 2020 and 31 23 23 23 7000
Construction contingency @ 15%						$25,873	
Total Construction Cost						**$198,359**	
Engineering @ 20%						$39,672	
Total Project Cost						**$238,031**	

TROY MINE RECLAMATION
MILLSITE CHANNEL COST
December 2, 2010

OPTION 2

Item			Quanity		Unit Cost	Cost	
Mobilization @ 10%						$19,086	
Erosion control @ 5%						$9,089	
Clear and Grub (wooded areas)			1	AC	4000	$4,000	
Access Road			400	LF	16	$6,400	USDA FS Cost Estimating Guide for Road Construction
Channel	length (ft)	section (ft ^{2})					
D_{50} = 16" Rock	870	30	967	CY	$30.00	$29,000	
D_{50} = 5' Rock	200	180	1333	CY	$60.00	$80,000	
D_{50} = 6" Rock	970	18	647	CY	$30.00	$19,400	
Energy Dissipation Basin							
D_{50} = 16" Rock	30	46	51	CY	$30.00	$1,533	
D_{50} = 6" Rock	30	23	26	CY	$30.00	$767	
Liner							
HDPE			1500	SY	$15.00	$22,500	
Bedding			500	CY	$20.00	$10,000	
Culvert							
4' Dia. CMP			40	LF	$143.00	$5,720	Means 33 41 13 40 2200
Excavation, Backfill, Compaction			40	LF	$61.30	$2,452	Means 31 23 16 13 0500, 2020 and 31 23 23 23 7000
Construction contingency @ 15%						$31,492	
Total Construction Cost						**$241,439**	
Engineering @ 20%						$48,288	
Total Project Cost						**$289,726**	

Appendix F
Troy Mine Area Surface Water Evaluation

Technical Memorandum

To: *Emily Corsi, Herb Rolfes – DEQ*
Bobbie Lacklen, John McKay – KNF

From: *Kent Whiting, Mark Hills, Bill Bucher – CDM Helena*

Date: *December 3, 2010*

Subject: *Troy Mine Area Surface Water Evaluation*

The purpose of this memorandum is to evaluate the potential for adverse effects to surface water, seeps and springs in the vicinity of the Troy mine workings after closure of the mine. After closure the groundwater entering the mine will be allowed to flood up to a level of 4,225 feet, where it will be routed through the Service and Conveyor adits and transported by pipeline to the tailings impoundment area. The current decant ponds at this location will be used to infiltrate the water. This water will be treated through attenuation of metals as it infiltrates through the underlying soils as described in *Troy Mine Copper Attenuation Study – Secondary Processes* (CDM, 2010a). Further descriptions of this system are presented in the *Mine Water Management Technical Memorandum* (CDM, 2010b) and the *Conceptual Design of New Water Line for Transport of Mine Water after Mine Closure* (CDM, 2010c).

The primary concern is that as the elevation of water in the mine workings increases, the increased head in the mine workings will force mine water through permeable pathways in the vicinity of the mine. Movement of untreated mine pool water through these pathways has the potential to cause contamination of existing surface water, seeps and springs and create new seeps or springs, which may discharge contaminated water. This evaluation investigates the relationship between surface water, seeps and springs and the mine workings using a hydrogeological approach with a geochemical perspective. In the hydrogeologic evaluation, the surface water expressions in the vicinity of the mine workings are related to the present and future water elevations, and the expected changes are described. In the geochemical evaluation, the present water quality of the surface water, seeps and springs is described and used to determine the potential connection between the surface water, springs and seeps and the flooded mine workings.

Hydrogeologic Evaluation

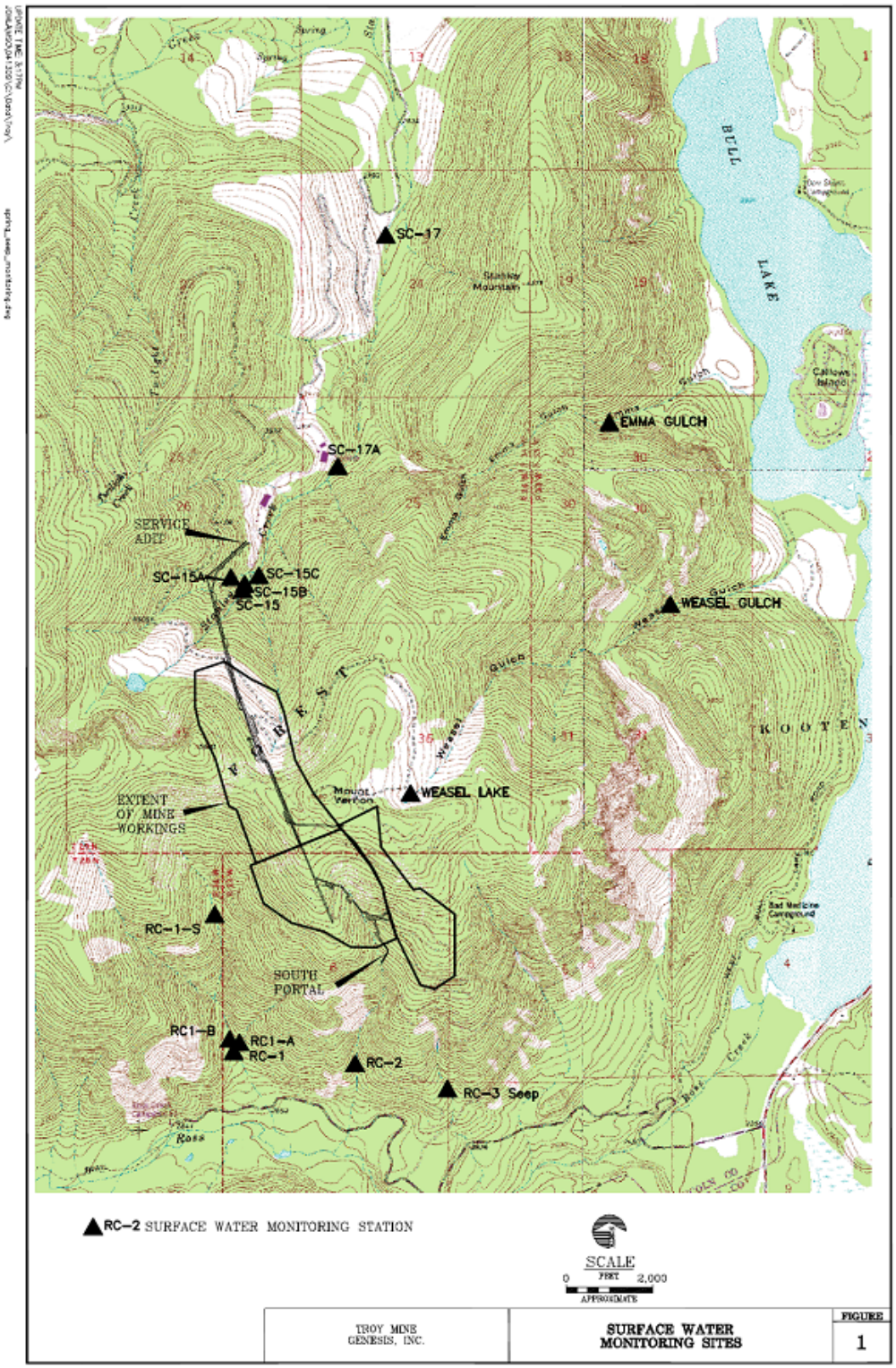
When the mine is closed, dewatering pumps will be shut-off and water will flood the workings. The physical and hydrologic features of the mine workings and terrain in the vicinity of the

Troy Mine were evaluated to assess changes that would occur in the hydrologic system. Data used in the evaluation were limited to the location, elevation, and distribution of identified springs and seeps near the Troy Mine, the current pumped mine water elevation in the mine workings, the expected flooded post-mine water elevation, and the local topography. Limited geologic and quantitative hydrologic data were available for this evaluation. For example, fracture systems are only well mapped within the ore body but not in the surrounding formations, and no wells were available outside the mine footprint to verify static water elevations in the surrounding area.

The general extent of the mine workings and the location of identified surface water sites in the vicinity of the Troy Mine are shown in **Figure 1**. The monitored surface water sites are located in low lying areas within the Stanley Creek drainage north of the mine and the Ross Creek drainage south of the mine. These surface water sites represent known points of groundwater discharge during the period of mine operation and dewatering. Hydrometrics (2009) reported two springs (RC-1-S and RC-3) in the Ross Creek drainage and apparent groundwater-supplied baseflow in two Ross Creek tributaries (RC-1 and RC-2). Hydrometrics also reported that expressions of groundwater exist in Stanley Creek within the defined stream channel. These springs appear to represent groundwater expression at elevations from 3,800 to 3,900 feet. The SC-15 sites (near the mine Service Adit) generally have flow even during late summer and fall. This discharge during the dry portion of the annual water cycle suggests that these springs are connected to an aquifer of significant extent.

To assess the potential impacts on groundwater discharge in the vicinity of the mine after closure, a series of cross-sections were drawn. Sections A-A' through E-E' intersect the mine workings and surface water monitoring sites. The cross-sections are attachments to this document. The plan view of the mine area is shown on each of the drawings to reference the respective sections. During mine operation, the active workings are dewatered to 4,050 feet above mean sea level (amsl). After mine closure, the maximum "flooded" groundwater elevation will be 4,225 feet amsl. The maximum flooded elevation is set by the base of the high point in the service adit that will remain open and serve to drain the mine workings. Following mine closure, elevation head within the mine workings will increase about 175 feet. The projected "flooded" water table (light blue line) relative to the current "pumped" water table (dark blue line) on the sections depicts the relative magnitude of shift that is anticipated for the surface water monitoring sites.

The cross-sections indicate the approximate stratigraphy and elevation of the geologic units. This information is most accurate in the immediate vicinity of the mine workings and is extrapolated in areas more distant from the mine workings. The geologic sections show that current and post-closure water levels are within the Revett formation. The Revett Formation consists of fractured quartzite and groundwater flow is through fractures. At the coarse scale of these cross-sections, fracture flow can be represented similarly to that of a porous medium, and groundwater elevations have been estimated based on this assumption.



Source: Genesis, Inc.

The evaluation of the hydrogeology of the area surrounding the mine workings indicates that the surface water measurement sites are typically far below the elevation of the mine workings. The monitoring sites in Stanley Creek are 250 feet below the elevation of the operational (pumped) water level in the mine, and the monitoring sites in Ross Creek drainage are at least 700 feet below the operational water level. The projected post-closure rise of water level would be relatively small compared to the hydraulic head difference between the operational (pumped) mine water level and most surface water measurement sites (see attachments). Using the principles of groundwater flow, it is expected that this head difference would decrease in an outward direction from the mine to no more than a few tens of feet in the vicinity of the monitoring sites. This would limit the potential for migration of water sources in the vicinity of these sites horizontally and vertically, as well as limit the potential increase inflow to a small percentage of current flow.

It is known that there are perennial surface water flows in the upper reaches of Stanley Creek. One small perennial stream originates above the elevation of the mine workings presumably from a local aquifer. The upper portions of this stream would not be affected by flooding of the mine because it originates above the maximum mine flooding elevation. However, other springs and seeps may become active at elevations below the final mine pool elevation after mine closure. These springs would most likely occur in the interval between the current pumping level of 4,050 feet and the final pool elevation of 4,225 feet, an interval of 175 feet. Whether these springs appear depends largely on whether faults that intercept the ground surface in this interval can transmit sufficient water to result in surface expressions. Although there is limited knowledge of surface faults in the perimeter around the mine workings, it is known that most faults within the mine workings tend to be vertically oriented. They therefore transmit groundwater primarily in the vertical direction, with horizontal flow being limited by their length and a lesser hydraulic gradient. Horizontal joints, fractures, and faults that could transmit water to the surface are not documented. This geological understanding suggests that the potential for development of new springs in the interval of the flooded mine workings is limited.

Geochemical Evaluation

The data available for surface water, springs and seeps analysis was spotty, both in terms of the collection frequency and the parameters analyzed. The data used in the analysis were collected from a number of sources, which were collected as needed for different reasons. A summary of the data includes:

- ASARCO, mostly pre-mining baseline data, 1977-1985 (Genesis Appendix E of March 2008 Annual Report)
- Forest Service Database, 1973-2005

- DEQ Field Inspection Reports, 1991-2009
- Genesis Springs and Seep Data, February 2009
- Miscellaneous ASARCO data, 1979-1985
- Supplemental spring sampling performed by DEQ in August 2010

The surface water data were compared to data for the mine pool, the decant pond, and the mine adit collected mainly by Genesis but also with some data collected by DEQ and CDM. A summary of the data used is provided in Table 1.

Table 1 – Summary of Sample Data for Used for the Geochemical Evaluation.

Diagram	Number of Samples	Date Range
TDS Box Plot	31	1973-2007
Ternary Diagram	13	1975-2010
Dissolved Copper Box Plot	5	2002-2006
Dissolved Iron Box Plot	5	2003-2004

Major Ions

Major ions, such as calcium, magnesium, sulfate, chloride, sodium, and potassium, can be used to evaluate the source of a groundwater. Often, groundwaters derived from distinct aquifers will have distinct major ion chemistry, both in terms of the total dissolved load (i.e. TDS) and in the ratios of one ion to another. A comparison of the TDS concentrations for the mine area surface water compared to other water sources is provided in **Figure 2** below.

The mine area springs and seeps and surface waters have low TDS values compared to the mining related waters (mine void, decant pond, service adit) and the groundwaters in the vicinity of the tailings impoundment (a.k.a. "Lake Creek GW"). Most of the TDS in the mine related waters and tailings impoundment area groundwaters is composed of calcium, magnesium, and bicarbonate, although there is a higher contribution of sodium and potassium in the decant pond water, which may reflect the addition of reagents during the flotation process. The higher TDS and the calcium-magnesium carbonate composition of these waters likely is the result of fairly long residence times of ground water in local rocks, such as dolostone or clastic sediments cemented by the mineral dolomite ($CaMg(CO_3)_2$). The surface waters and mine area seeps and springs are not calcium-magnesium bicarbonate waters and are low in dissolved solids, suggesting that the source of these waters is precipitation runoff and/or

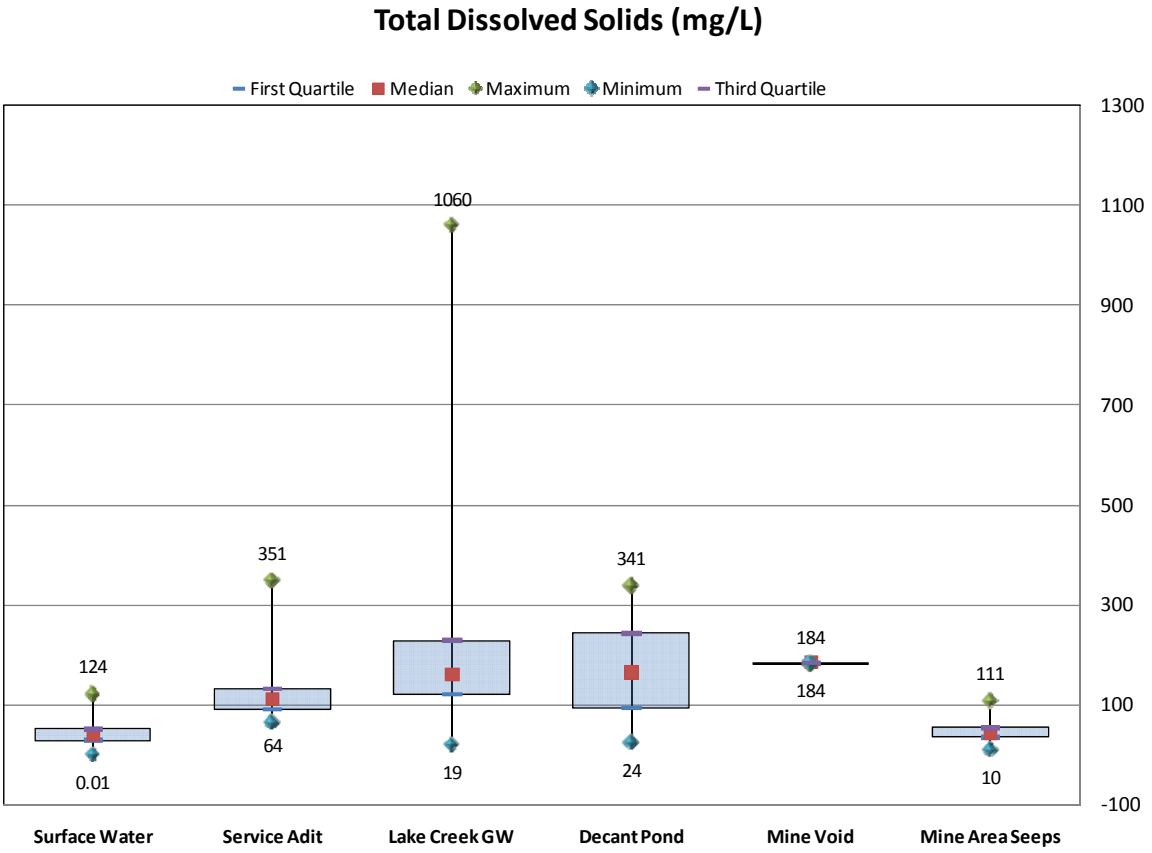


Figure 2 – Comparison of the TDS values for the mine area surface water (seeps) to other water types.

near-surface groundwater which has not had enough residence time or sufficient contact with dolomite-bearing aquifer materials.

Figure 3 is a ternary diagram showing the differences in the relative chemistry between the mine area surface water (as represented by a single sample collected within the Ross Creek drainage) and some of the mine-related waters. The triangular field on the bottom left is used to plot the positively-charged ions (calcium, magnesium, sodium, potassium), and the triangular field on the bottom right is used to plot the negatively-charged ions (chloride, sulfate, bicarbonate). The central diamond-shaped field reflects the whole chemistry composition of the water. In general, similar waters plot close to each other on a ternary diagram, while dissimilar waters plot at a distance from each other. The Ross Creek baseline data indicate a calcium-magnesium sulfate water, while the mine-related waters and springs in the vicinity are calcium-

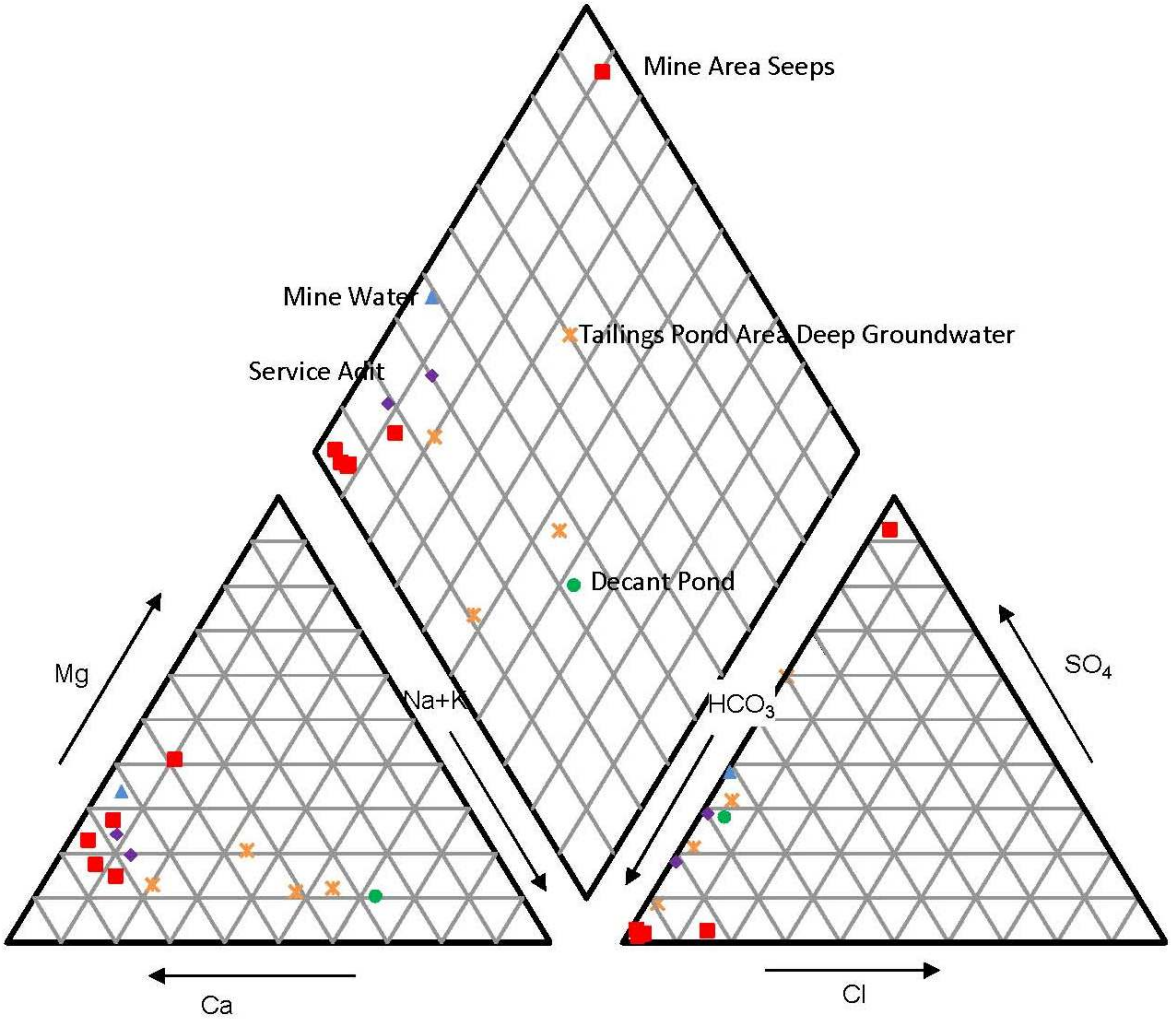


Figure 3 – Ternary diagram showing the ratios of the major ions for each water type.

magnesium carbonate waters with relatively lower magnesium ratios. A summary of the samples used for the diagram is shown in Table 2.

Figure 3 shows that Ross Creek surface water is very different from the mine-related waters. The difference in major ion ratios and TDS between the Ross Creek surface water and the other waters is a strong confirmation that the surface water in Ross Creek tributaries is not derived from the mine void.

Table 2 – Summary of Sample Data Used in Ternary Diagram

Sample ID	Date Collected	Type
Service Adit-D	5/12/09	Adit
Service Adit-P	5/12/09	
Decant Pond	5/14/2009	Decant Pond
Mine Water	12/16/2009	Mine Water
95-4	5/12/2009	Tailings Pond Area Deep Groundwater
95-5	5/12/2009	
95-8	6/12/2009	
MW-01-15	6/8/2009	
SC-15A	8/12/10	Mine Area Surface Water
SC-15C	8/12/10	
Ross Creek #11	8/12/10	
RC-1	8/12/10	
Ross Creek #10	8/12/10	
Ross Cr 74-10	5/20/75	

Metals

The metals data for mine area surface water is limited to dissolved and total recoverable concentrations of arsenic, antimony, copper, lead, iron, manganese, and zinc. Of these, few values above the analytical reporting limit were observed, namely total recoverable and dissolved copper, iron, and manganese, and dissolved zinc. In general, when detections were observed, the concentrations were low, as shown by the comparion of dissolved copper concentrations for each water type (**Figure 4**).

Dissolved zinc concentrations of 0.003 mg/L were reported for Ross Creek drainage sites RC-1 and RC-3 for samples collected in July 2006. Dissolved zinc concentrations within the mine void waters were higher, at 0.020 mg/L for the sample collected in December 2009. However, much of the other zinc data could not be compared to these two detections, as the reporting limit was too high (0.010 mg/L).

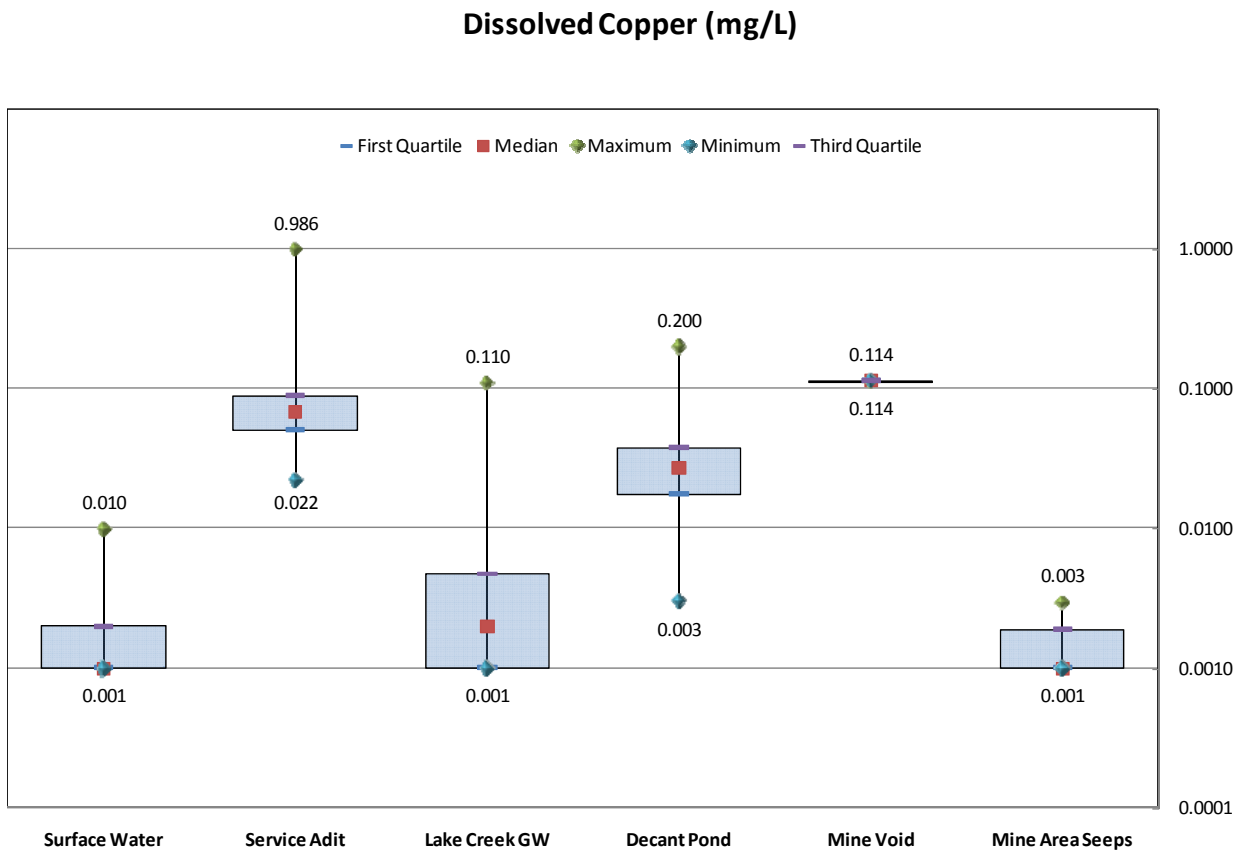


Figure 4 – Comparison of dissolved copper concentrations between the mine area surface water (seeps) and other waters on the site (note the logarithmic scale).

A comparison of the dissolved iron concentrations is shown in **Figure 5** below.

The highest dissolved iron concentrations (up to 69 mg/L) are associated with the deep groundwaters in the vicinity of the tailings impoundment. These waters have variable chemistry, as shown in the wide spread of the data points on the ternary diagram (Figure 3). The geochemical conditions are sometimes reducing, which results in high iron concentrations, while at other times are more oxidizing and have lower iron concentrations (see the *Troy Mine Copper Attenuation Study*, CDM, 2010, for more details). The wells completed in the Lake Creek Valley near the tailings impoundment ("MW" series) have shown erratic iron concentrations over time, which likely reflects a fluctuating redox gradient. The mine area surface waters generally have higher dissolved iron concentrations than the mine related waters, but not as high as the deep groundwaters in the vicinity of Lake Creek and the tailings impoundment.

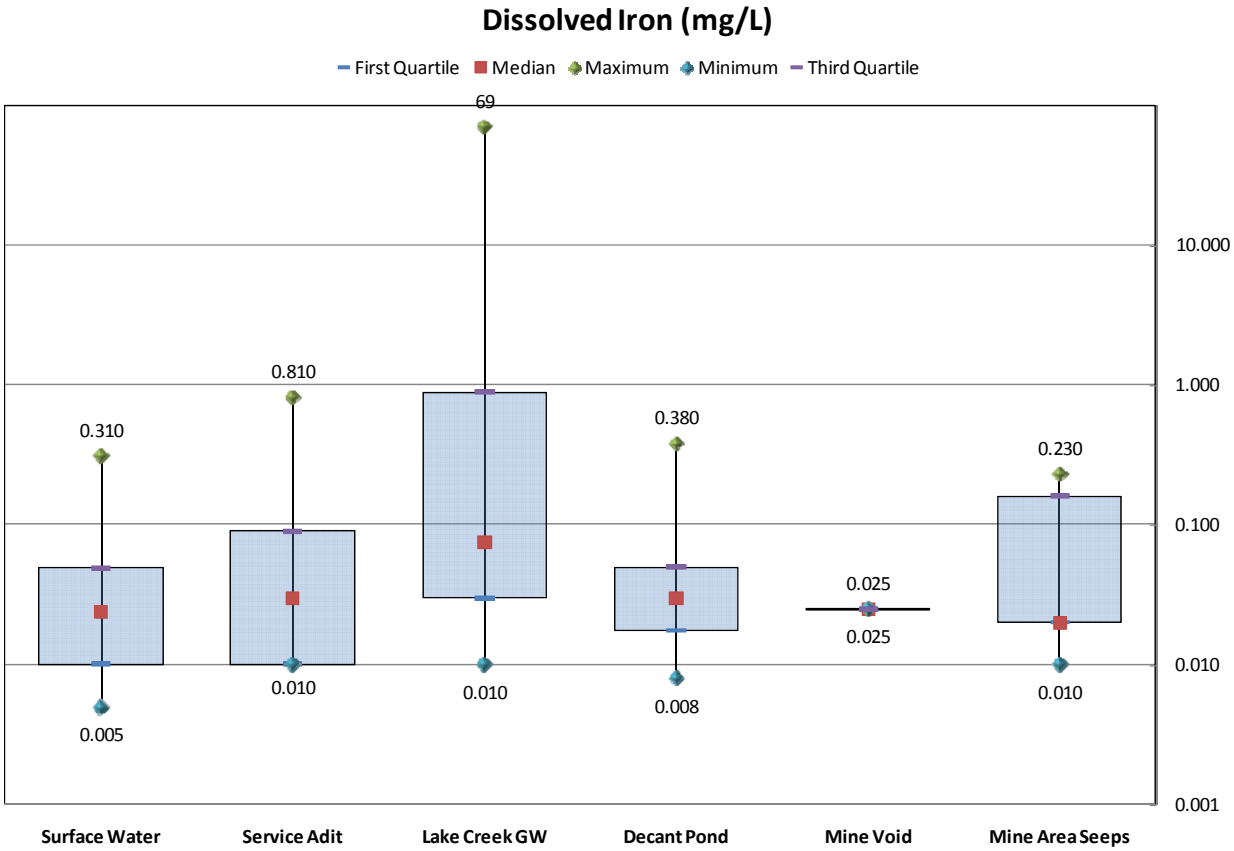


Figure 5 – Comparison of dissolved iron concentrations between the mine area surface water (seeps) and the other waters (note the logarithmic scale).

Post Closure Mine Water Quality

Following closure of the mine, the underground workings will be flooded up to the spillover point at the Service and Conveyor adits. Copper (Cu^{+2}) is released into water flooding the workings from the mineralized wall rocks by oxidation of the copper sulfide minerals present. The reaction requires an oxidant, such as dissolved oxygen (O_2) in order to occur. An example for the oxidation of chalcopyrite ($CuFeS_2$) is shown in equation 1.

$$CuFeS_2(s) + 4O_2(aq) \rightarrow Fe^{+2}(aq) + Cu^{+2}(aq) + 2SO_4^{-2}(aq) \qquad (1)$$

Under flooded conditions, the dissolved oxygen concentrations will be expected to decrease within the flooded portions of the workings, and the rate of oxidation of copper sulfide minerals should decrease as well. Skousen et al. (2006) in a study of several coal mines in the eastern United States over a 35 year period found that after the first few mine volumes of water pass through the system the water becomes much less acid or even net alkaline, and metals concentrations decrease. Although the Troy Mine is not acid producing, a similar beneficial

effect of flooding on metals concentrations is expected. The quality of the mine water is expected to improve or remain constant after closure.

Nitrate and ammonia concentrations would also decrease once blasting is discontinued. Nitrogen compounds in adit water result from incomplete detonations or from poor housekeeping (spilled explosives). Explosives typically contain nitrogen compounds, which are present in the mine water as ammonia, and once oxidized, as nitrate and/or nitrite. Once the initial mine water is flushed from the system (by discharge at the spillover point and transport to the decant ponds), nitrate and ammonia concentrations would decline. In fact, nitrate+nitrite and ammonia concentrations within the disused and partially flooded portions of the mine are significantly lower than for the decant pond water, and to some extent, the adit discharge as shown in Table 3.

Table 3 – Comparison of Nitrate and Ammonia Concentrations for the Active and Inactive Portions of the Mine.

Water	Sample Date	Ammonia Concentration (mg/L)	Nitrate+Nitrite Concentration (mg/L)
Mine Water (disused area)	12/16/09	0.39	7.4
Decant Pond	12/16/09	11.2	37.6
Decant Pond (Decant 1)	5/14/09	6	17.6
Decant Pond (Decant)	5/14/09	6	19.4
Decant Pond	6/9/09	4.4	14.5
Adit Pipe	5/12/09	2.33	7.99

The difference in the concentrations of ammonia and nitrite+nitrate is not as pronounced for the adit discharge as for the decant pond. However, the adit discharge is composed of drainage from both used and disused portions of the mine, and would be expected to have an intermediate concentration between the active and disused water quality. The decant pond water, which is derived from the mill circuit, would be expected to have the highest ammonia and nitrate+nitrite as the crushed ore bears fresh blasting residue.

Table 4 shows data for the decant ponds and the service adit before, during and after the mine shutdown from April 1993 to December 2004. For both the decant ponds and the Service Adit, there is a decrease in nitrate plus nitrate during mine shutdown, indicating that mine water quality improved for this parameter when operations ceased. Again, the effect is more pronounced in decant ponds water than service adit water although the mill was not operating in this period. A similar decrease in nitrite plus nitrate is expected after final closure of the mine.

Table 4 – Comparison of Average Nitrate plus Nitrite Concentrations (mg/L) before, during and after Mine Shutdown.

Water	Pre-Shutdown	Shutdown	Post Shutdown
Decant Pond	17.6	1.72	12.0
Service Adit	10.0	1.43	7.24

Conclusions

The evaluation of the hydrogeology of the area surrounding the mine workings shows that most identified springs are well below the elevation of the present (pumped) water level in the mine. The geochemical evaluation indicates that identified surface waters in the vicinity of the mine are not being impacted by mine water. The expected water level rise after mine closure is relatively small compared to the current head difference between the mine water level and most surface water expressions in the mine area. Using the principles of groundwater flow, it is expected that this head difference will decrease in an outward direction from the mine and become no more than tens of feet in the vicinity of the springs. Thus, the rate of discharge from the existing surface water expressions may increase to some degree due to the increased head, but the location and spatial distribution of the expressions is not expected to change appreciably after mine closure.

The evaluation of the major ions and metals within the mine area surface water and other mine waters reveals that the mine area surface waters are chemically distinct from the deep groundwater and mine related waters but quite similar to area surface waters. The data suggest that the source of mine area surface water is not from the mine void, but is likely derived from precipitation or freshly recharged near-surface aquifers. After the mine is flooded at closure, it is expected that mine water will improve in quality as oxidation is reduced in the flooded portions of the mine void and concentrations of metals and nitrogen compounds decrease. Therefore, any effects of mine water that may reach surface water expressions are expected to be reduced after mine flooding.

References

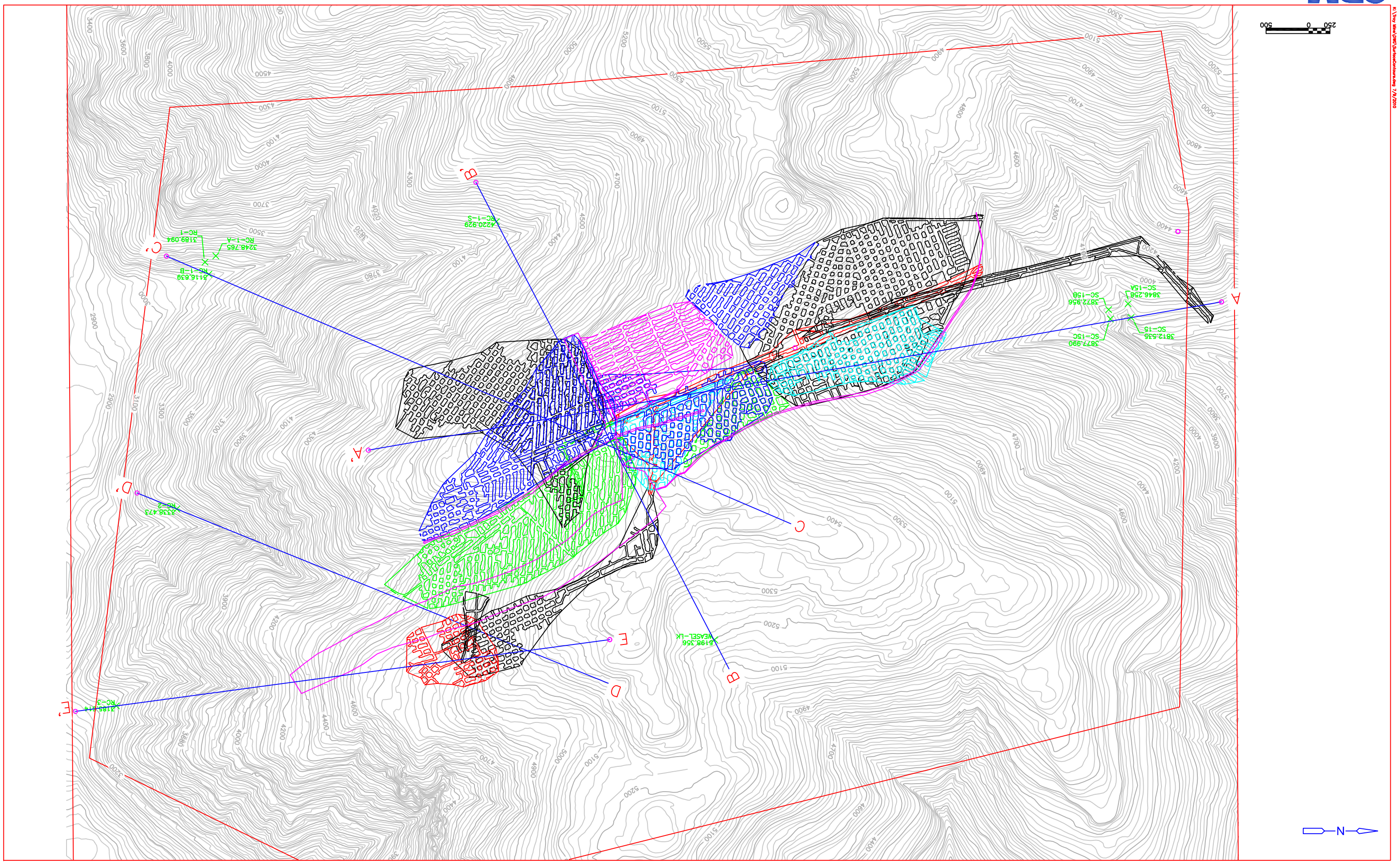
CDM. 2010a. *Troy Mine Copper Attenuation Study – Secondary Processes*. Prepared for DEQ by CDM, Inc. July 2010.

CDM, 2010b. Mine Water Management Analysis – Troy Mine. Technical Memorandum prepared for Montana Department of Environmental Quality and USDA Forest Service, Kootenai National Forest dated December 3, 2010.

CDM, 2010c. Conceptual Design of New Water Line for Transport of Mine Water after Mine Closure. Technical Memorandum prepared for Montana Department of Environmental Quality and USDA Forest Service, Kootenai National Forest dated December 3, 2010.

Hydrometrics, 2009. Memorandum from Juliann L. Clum to Doug Parker regarding Troy Mine Seep/Spring Flow Data Compilation Procedures. Hydrometrics, Inc., Helena, Montana. April 8, 2009.

Skousen, J., L. McDonald, B. Mack, and J. Demchak, 2006. Water quality from above-drainage underground mines over a 35-year period. *Proceedings of the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis, MO*.



OVERALL SITE PLAN

CDM

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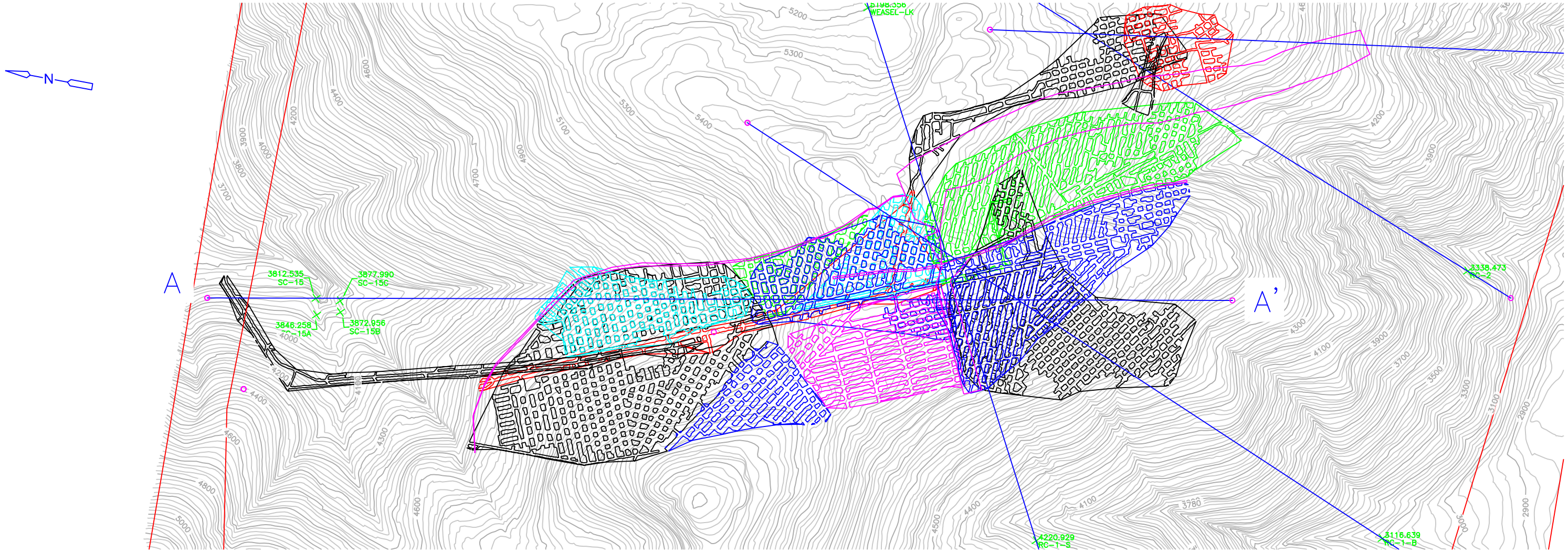
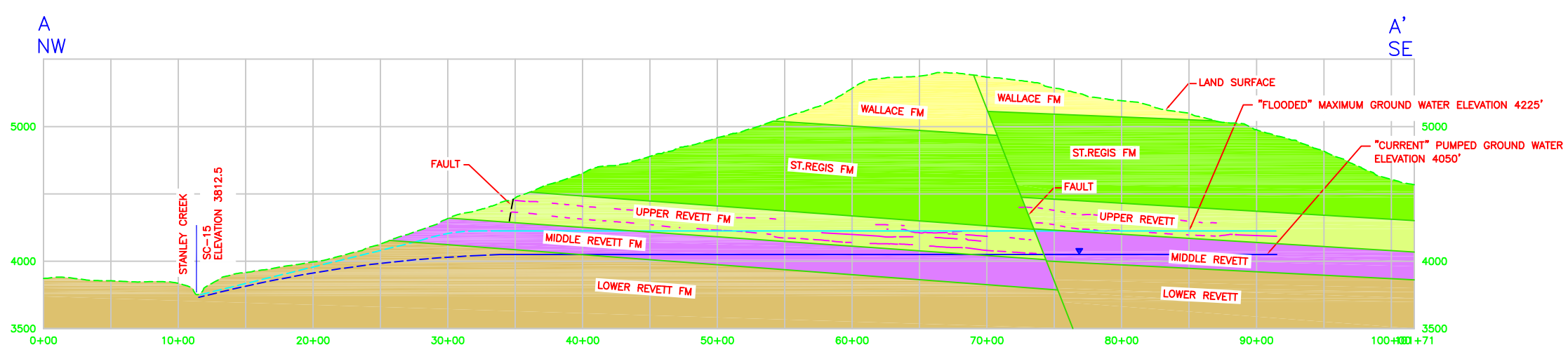


NOTES:
1. THE GEOLOGICAL CROSS-SECTIONS AND WATER LEVELS ARE BASED ON AVAILABLE DATA. THESE SECTIONS PRESENT SIMPLIFIED CONCEPTUAL INTERPRETATIONS OF THIS DATA.
2. FLOODED GROUNDWATER ELEVATION CONTROLLED BY HIGH POINT OF SERVICE ADIT.



LEGEND

- LAND SURFACE
- TOP OF MINE WORKINGS
- CURRENT PUMPED ELEVATION
- MAXIMUM FLOODED ELEVATION
- FAULTS

250 0 500

SECTION A

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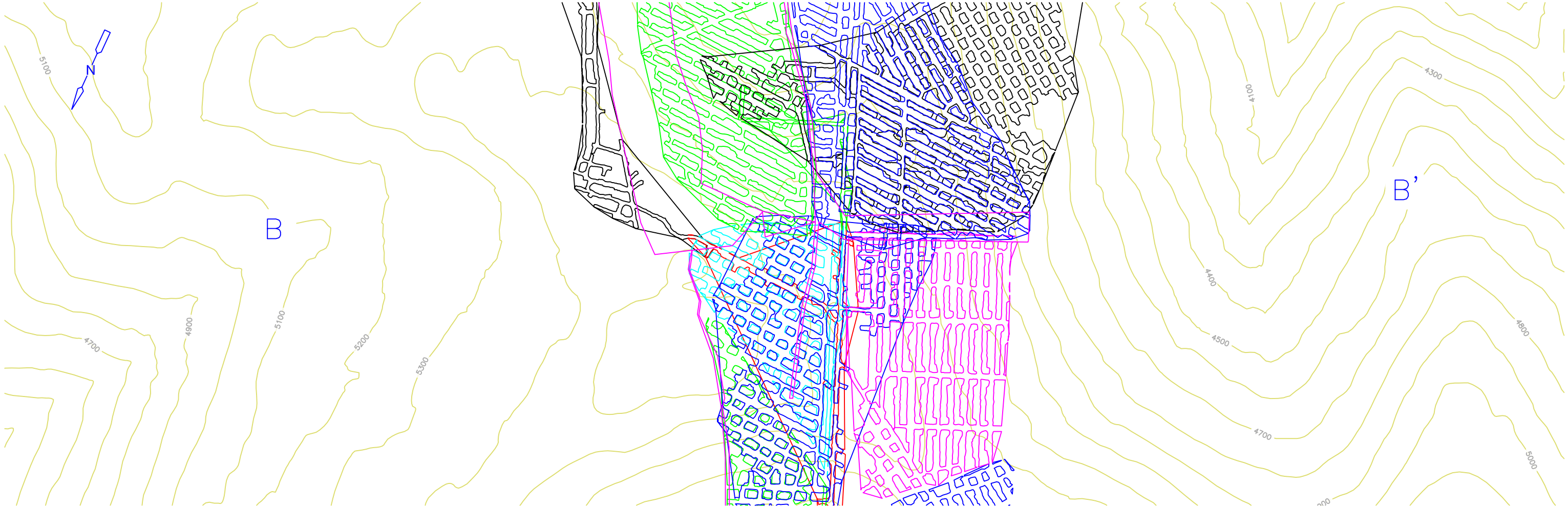

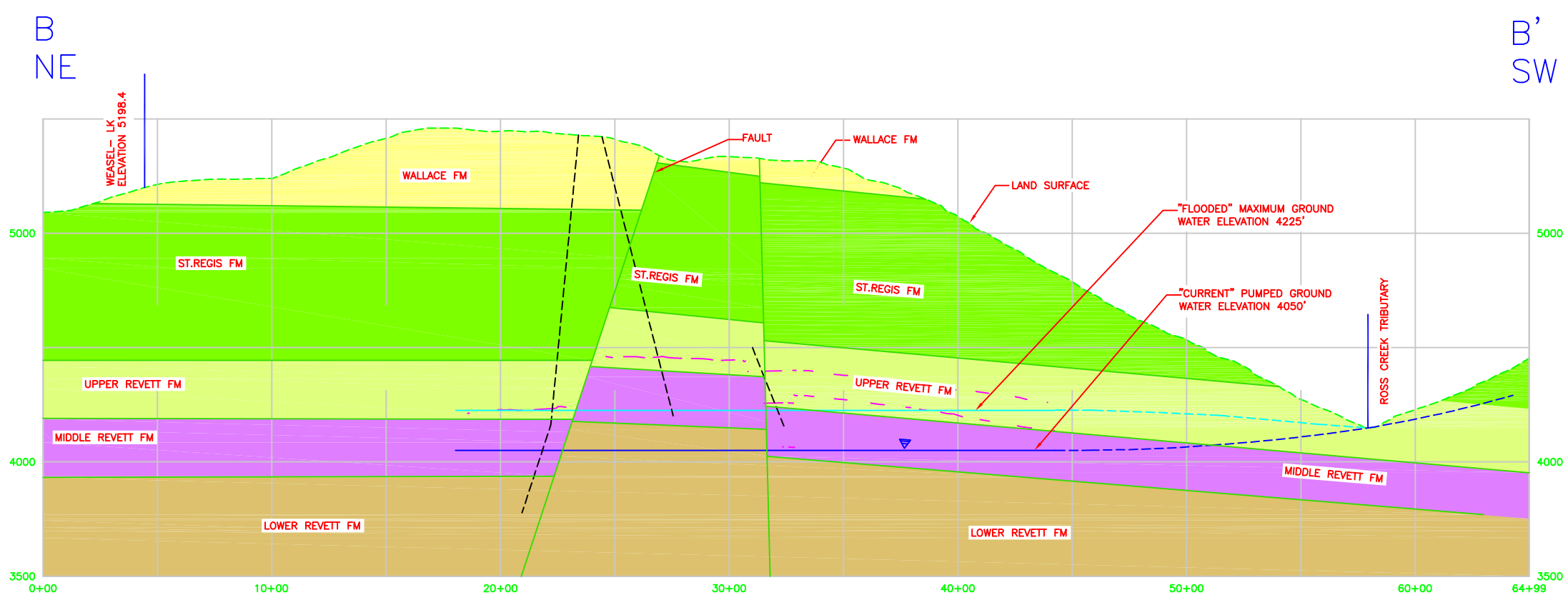

LEGEND

- LAND SURFACE
- TOP OF MINE WORKINGS
- CURRENT PUMPED ELEVATION
- MAXIMUM FLOODED ELEVATION
- FAULTS

NOTES:
1. THE GEOLOGICAL CROSS-SECTIONS AND WATER LEVELS ARE BASED ON AVAILABLE DATA. THESE SECTIONS PRESENT SIMPLIFIED CONCEPTUAL INTERPRETATIONS OF THIS DATA.
2. FLOODED GROUNDWATER ELEVATION CONTROLLED BY HIGH POINT OF SERVICE ADIT.

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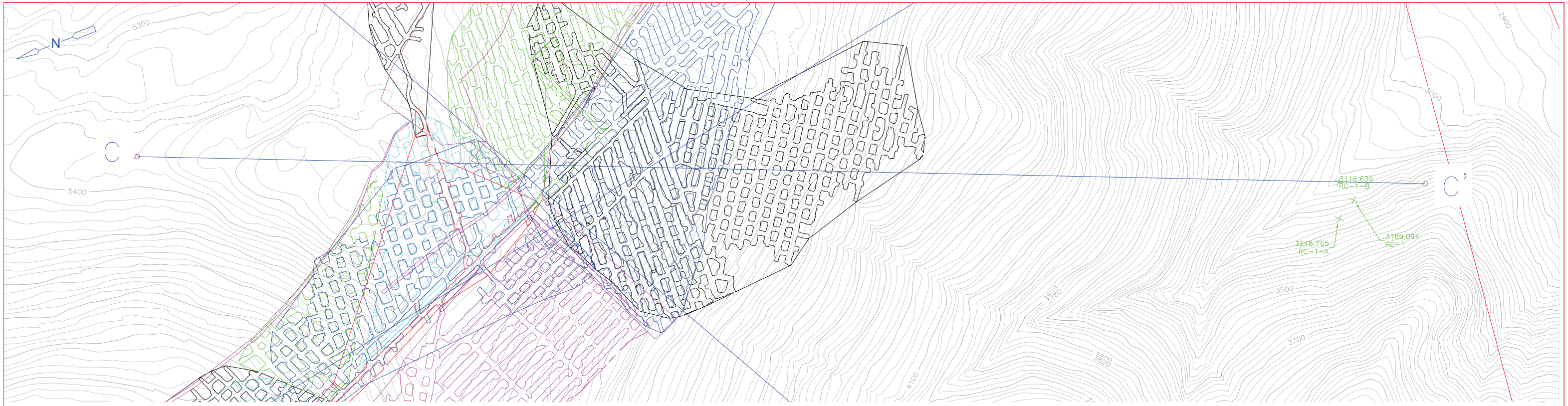
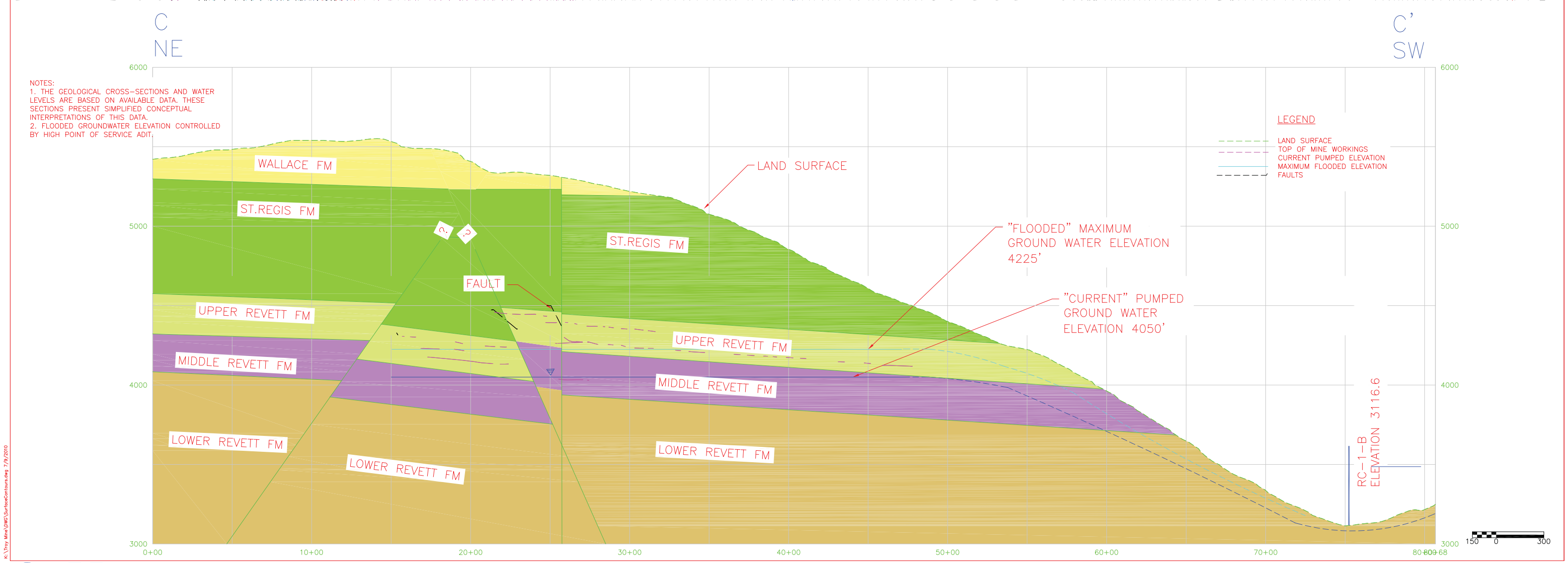
SECTION B





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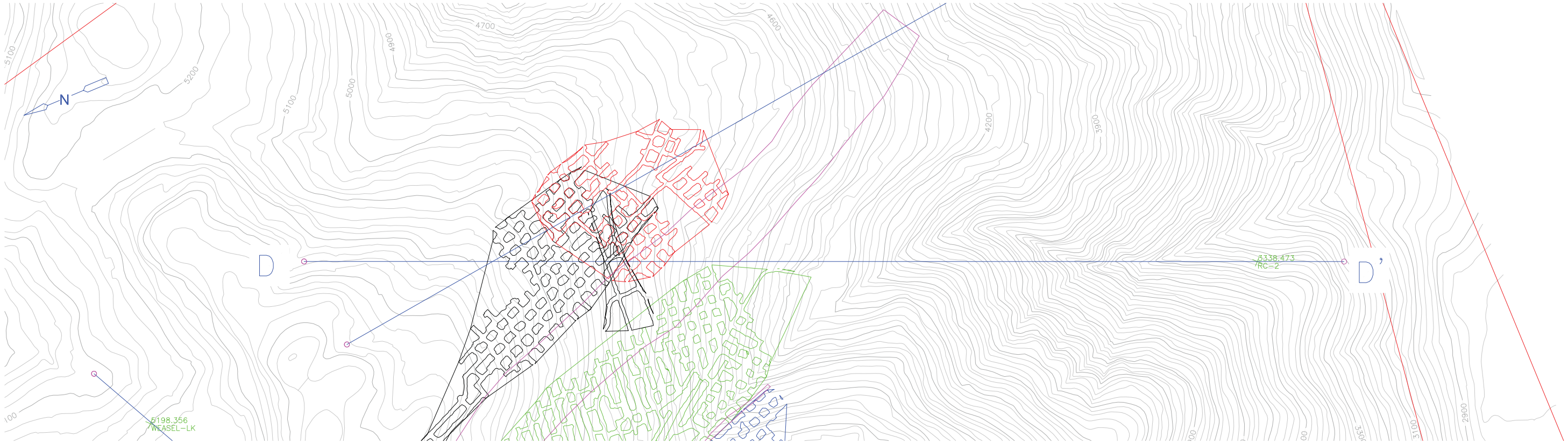
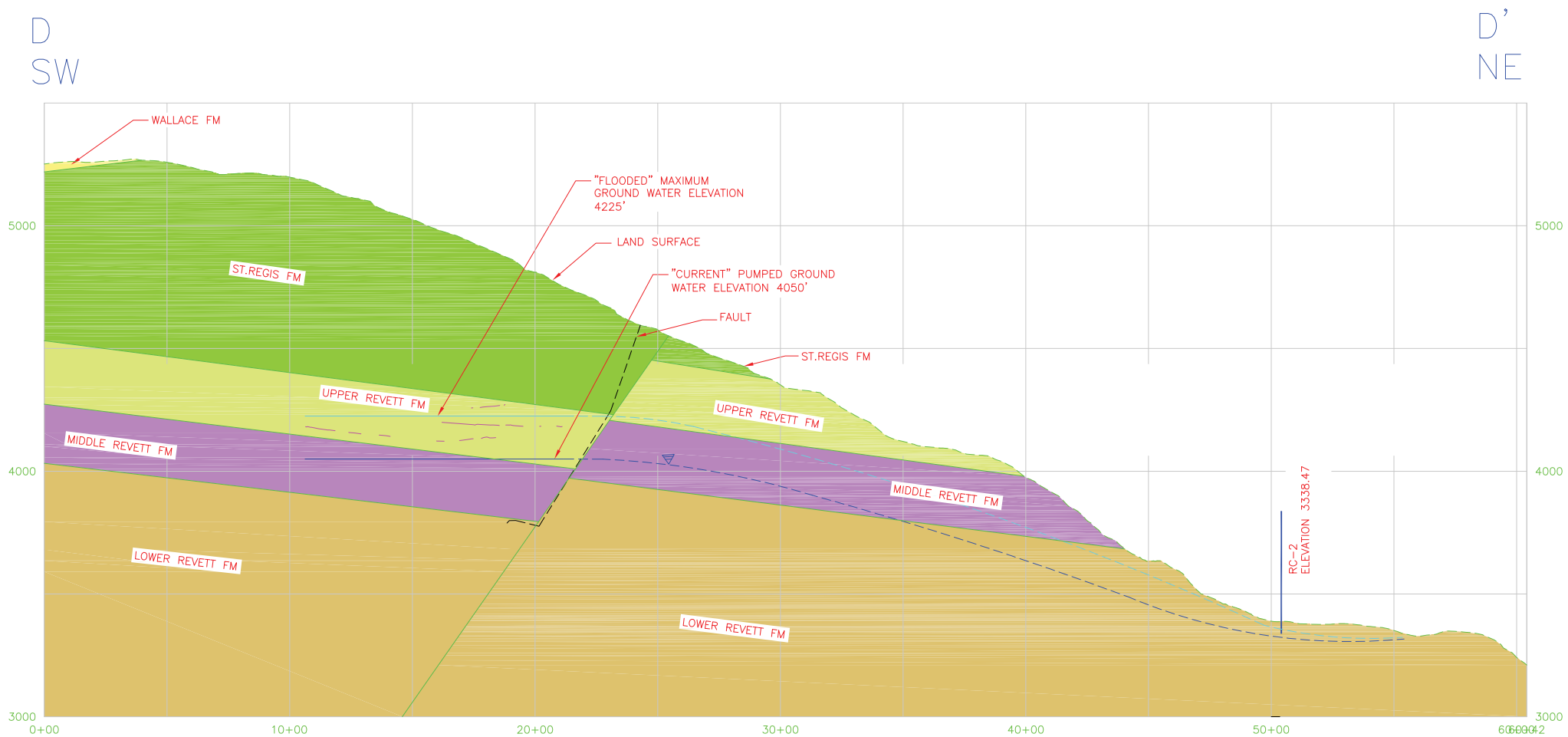
SECTION C





LEGEND

- LAND SURFACE
- TOP OF MINE WORKINGS
- CURRENT PUMPED ELEVATION
- MAXIMUM FLOODED ELEVATION
- FAULTS

NOTES:
1. THE GEOLOGICAL CROSS-SECTIONS AND WATER LEVELS ARE BASED ON AVAILABLE DATA. THESE SECTIONS PRESENT SIMPLIFIED CONCEPTUAL INTERPRETATIONS OF THIS DATA.
2. FLOODED GROUNDWATER ELEVATION CONTROLLED BY HIGH POINT OF SERVICE ADIT.

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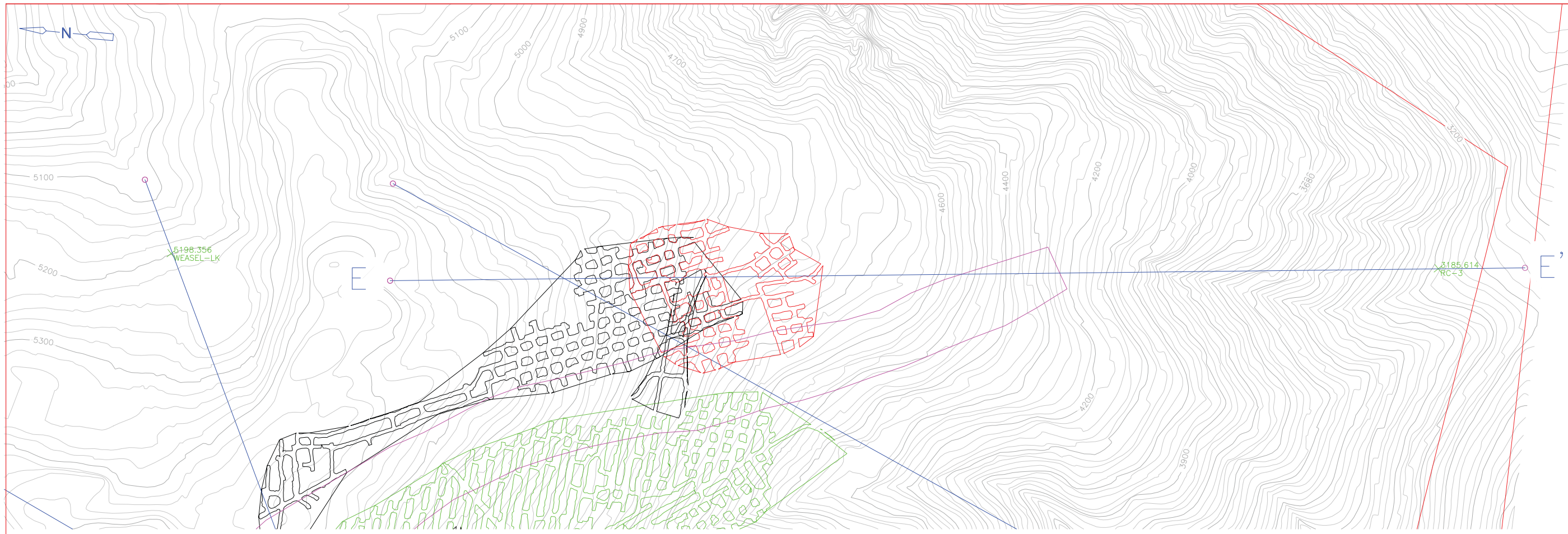
SECTION D



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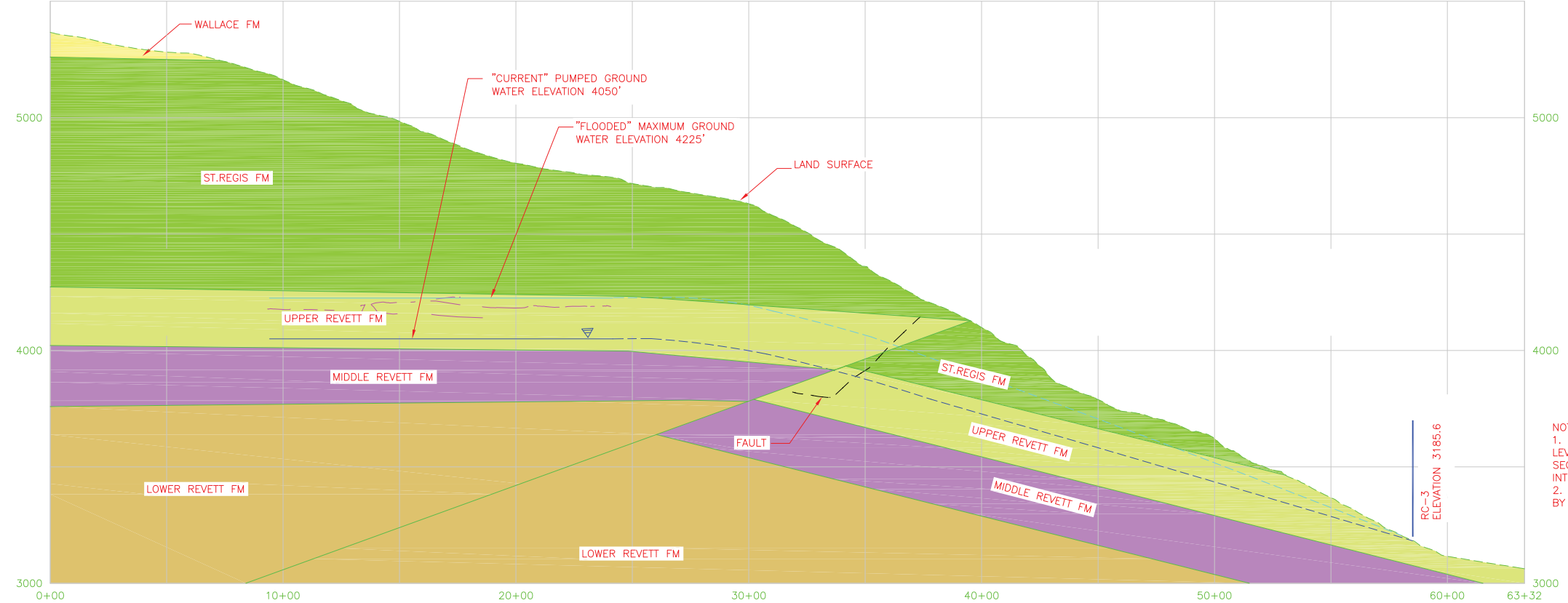

LEGEND

- LAND SURFACE
- TOP OF MINE WORKINGS
- CURRENT PUMPED ELEVATION
- MAXIMUM FLOODED ELEVATION
- FAULTS

NOTES:
1. THE GEOLOGICAL CROSS-SECTIONS AND WATER LEVELS ARE BASED ON AVAILABLE DATA. THESE SECTIONS PRESENT SIMPLIFIED CONCEPTUAL INTERPRETATIONS OF THIS DATA.
2. FLOODED GROUNDWATER ELEVATION CONTROLLED BY HIGH POINT OF SERVICE ADIT.

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SECTION E

Appendix G
Troy Mine Conceptual Design of New Water Line for Transport of Mine Water after Mine Closure

50 West 14th Street, Suite 200
Helena, Montana 59601
tel: 406 441-1400
fax: 406 449-7725

Technical Memorandum

To: *Emily Corsi, Herb Rolfes – DEQ*
Bobbie Lacklen, John McKay - KNF

From: *Darrel Stordahl, P.E., Bill Bucher, P.E., Terry Cowan, P.E. - CDM*

Date: *December 3, 2010*

Subject: *Conceptual Design of New Water Line for Transport of Mine Water after Mine Closure – Troy Mine*

CDM has been retained by the Montana Department of Environmental Quality (DEQ) and the Kootenai National Forest (KNF) to prepare a conceptual design and cost estimate for a new pipeline and capture system at the Troy Mine. The pipeline will transport mine pool discharge through the service and conveyor adits to the infiltration pond located at the tailings impoundment via a new, buried pipeline. The purpose of this memorandum is to present the conceptual design and cost estimate to be used in decision making by the agencies.

The Troy Mine is an underground copper and silver mine located south of the town of Troy in Lincoln County, MT. ASARCO began operating the mine in 1982 and halted production in 1993 due to low metals prices. The mine was sold to Revett Silver Company and production resumed under Genesis, a subsidiary of Revett, in 2005. In 2006, Genesis submitted a Revised Reclamation Plan, for which an Environmental Assessment (EA) must be completed. In support of the EA, this memorandum analyzes a closure water management alternative presented in the EA.

Mine Discharge Data

It has been shown in the *Revised Mine Water Management Analysis – Troy Mine* and *Mine Water Balance Analysis – Troy Mine* Technical Memoranda (CDM, 2010a and CDM, 2010b) that the Troy Mine is expected to discharge mine pool water through the service and conveyor adits after closure. The *Revised Mine Water Management Analysis* memorandum estimates the maximum water discharge to be 6.9 cubic feet per second (cfs), and this rate is used in this memorandum for the conceptual design of the new closure water line. The discharge estimation is based on a limited amount of available data. However, it is consistent with observed maximum discharges measured by the mine over the period of operation. This

memorandum includes a backup system for the proposed design that should handle any reasonably foreseeable discharges.

Water Line Conceptual Design and Calculations

The water line was designed to follow the existing tailings/slurry pipes, approximate the land gradient, and have the hydraulic capacity to handle all of the estimated peak discharge of 6.9 cfs under gravity flow (no pressure flow). The land gradient is rather steep near the adit openings and flattens as it approaches the tailings impoundment. The upper quarter of the pipe run has slopes around 12%, the next quarter close to 3.5%, and the bottom half has slopes approximately 1.0% down to 0.3%. With the wide range of slopes, and their corresponding pipe capacities, multiple pipe sizes were used in the design to provide a cost savings. See the *Cost Estimate and Assumptions* portion of this report for a list of pipe sizes, lengths, and costs. The static capacity of the water line is about 250,000 cubic feet when full (see attached calculation sheet). This is the maximum amount of water that could drain from the pipeline should a break occur at the lowest point in the line. This amount could be reduced with the addition of automatically controlled valves along the length of the pipeline, but this design feature is not incorporated in this design.

Smooth HDPE was chosen as the pipe material for this conceptual design. The smooth interior of HDPE provides hydraulic efficiency, has a long service life (estimated at 75 years), is virtually chemically inert, is easy to install, is watertight, and provides an overall cost savings. Other materials such as iron, steel and concrete would not provide the equivalent performance at as low a cost.

FlowMaster software was used in the hydraulic calculations. Pipe lengths and slopes were estimated from *Exhibit A, Troy Mine Facilities Current Status* of Genesis' March 2006 *Troy Mine Revised Reclamation Plan*. FlowMaster calculations and a topographic map are shown in attached Appendix A.

Systems Control and Data Acquisition

Supervisory Control and Data Acquisition (SCADA) is included as part of the new water line. The SCADA can detect variability of flow in the pipe system and if a leak is present it will alert the proper personnel and divert mine adit discharge into the existing 10-12" tailings reclaim water line.

Leakage or breakage in the nearly six-mile pipe can be determined by using two flow meters, one placed close to the mine adit and the other placed close to the discharge end. The SCADA system would compare the two flow rates, with a time delay allotted to compensate for the length of pipe between the flowmeters. The flow rates should correspond within a small percentage range. If a leak or pipeline break occurs, the flow rate at the discharge would not correspond to the flow rate at the intake. The SCADA system alarm will be

activated, and a valve would reroute the water to another pipe. The existing pipe would be taken out of commission until repairs were made.

The flow meters would be powered using a solar-powered panel-mounted system with battery backup. The flow meter at the infiltration pond will transmit its flow rate to a compact programmable logic controller (PLC) located inside the solar power panel. The PLC will forward the flow rate by Ethernet radio to another compact PLC located in a panel close to the mine portal. The values will be compared, and, if the difference is outside a predetermined range, the PLC will close the pipe valve and reroute flow to the existing reclaim water line. The SCADA system will notify appropriate personnel of an alarm situation.

The existing reclaim water line will be used as a backup system. It is assumed that the existing reclaim water line consists of a 10″ steel pipe on the upper, steeper section of the pipe run and a 12″ steel pipe on the lower, flatter run. Assuming the pipeline follows the land gradient, it is estimated that the reclaim water line will handle approximately half of the estimated maximum of 6.9 cfs under gravity flow conditions. It is likely that the reclaim water line could handle the full estimated maximum flow if it is retrofitted with appropriate vacuum relief and pressure relief valves.

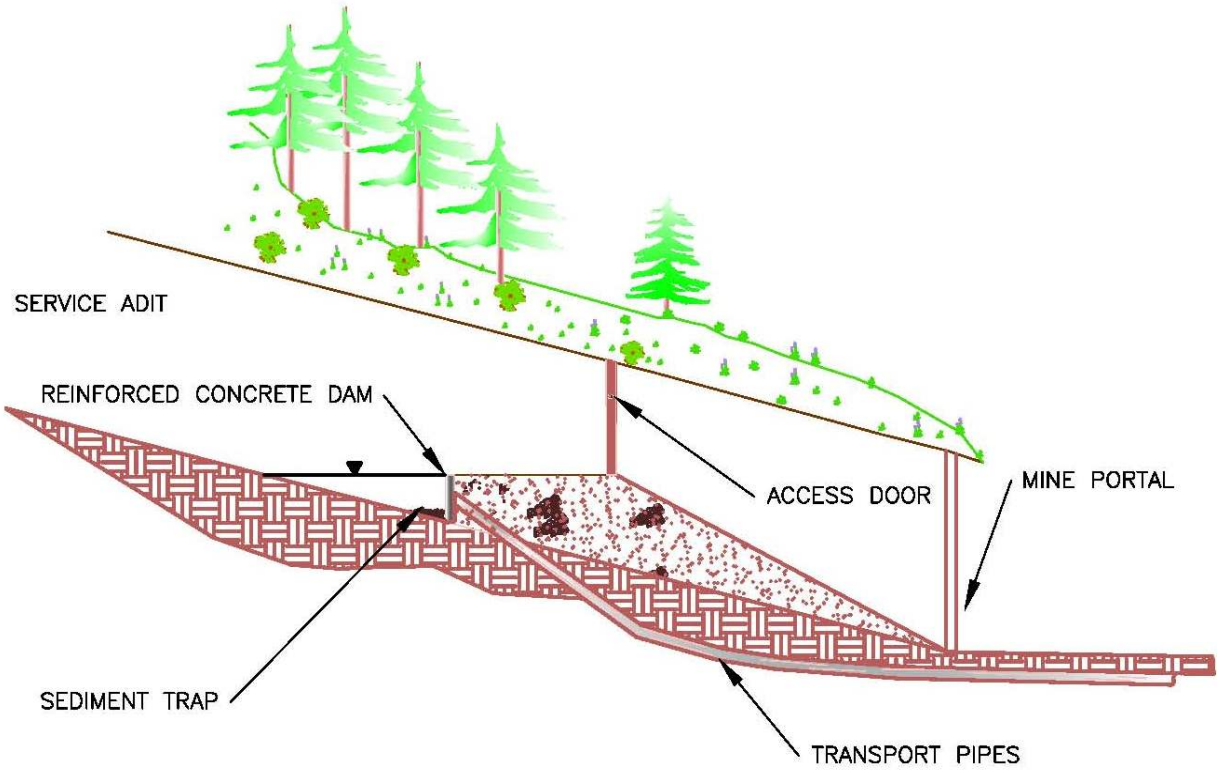
Mine Water Capture

Systems to capture the mine water and deliver it into the transport lines are needed at the service and conveyor adit portals. We propose to install these systems inside the adit to minimize freezing issues. As shown in Figure 1, the capture systems consist of concrete dams about six feet high constructed inside the adits about 50 feet back from the portal entrances. The entrance to the transport pipes would be set about two feet below the top of the dam so sediment transported by the mine discharge would be trapped below the pipe entrances. The 50-foot run of transport pipe between the dams and portals would be backfilled with material from the mine portal pads to bury the transport pipes and provide frost protection at the portals. To maintain access for maintenance of the sediment traps and transport pipe intakes, locking doors would be constructed at the portals. These doors will be sized to accommodate a small backhoe and truck to periodically clean out the sediment traps.

Small reservoirs would be created in the adits behind the concrete dams. The accumulated water could potentially infiltrate into fractures or unconsolidated material in the adit floors and walls and be released to the environment. Fractures and other leakage paths in the area below the elevation of the top of the concrete dam should be grouted to minimize any such releases.

The design has two transport pipes with their intake elevations staggered so the higher one would only come on line when flow into the mine increases. The lower intake would be for

Figure 1. Conceptual design of mine water capture system.



the new transport line described in this memorandum. The higher intake would tie to the existing reclaim water line. As the new transport line reaches capacity, flow would enter the reclaim water line without the need for a valve. With proper maintenance of the system, it is anticipated that any foreseeable discharge could be accommodated by the two lines flowing at full capacity.

In the unlikely event that the capacity of both these lines is exceeded, water would flow over the dam and pass through the rock backfill. At the mine portal it would drain to a constructed channel which would lead to Stanley Creek. This emergency channel would require a MPDES permit. Figure 2 is a conceptual design showing these water lines and the channel to Stanley Creek.

If, at some point in the future, the mine water quality improves to the point that it can be directly discharged to Stanley Creek, the capture system will be altered so the mine discharge

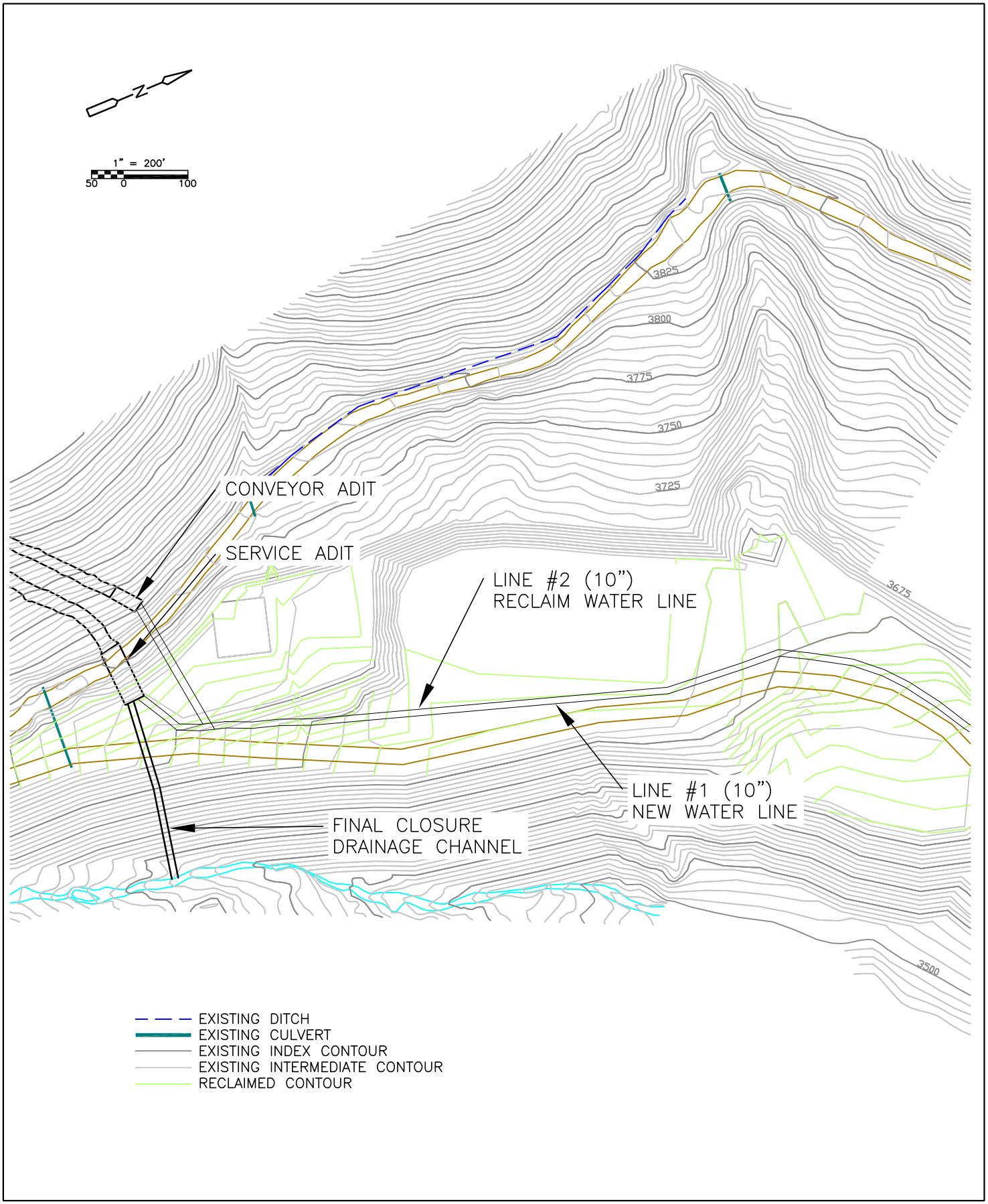


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FIGURE 2
TROY MINE RECLAMATION MINE WATER
DISCHARGE PIPELINES AND CHANNEL

is routed to a small channel that routes directly to Stanley Creek as shown on Figure 2. The transport lines will then be abandoned.

Cost Estimate and Assumptions

Table 1 is a preliminary cost estimate for construction of the capture system and new transport pipeline. Unit prices for the pipeline used in this cost estimate were taken from several contractors' bids for similar, prior work. The run of pipe would follow the existing tailings/slurry line as shown on *Exhibit A, Troy Mine Facilities Current Status* of Genesis's March 2006 *Troy Mine Revised Reclamation Plan* report (Genesis, 2006). Pipe slopes were estimated from topographic maps with the assumption that pipes will closely follow the land gradient. The pipe diameter was designed to correspond to the anticipated gradient of the pipe run. Pipe capture items were estimated using Means Costworks cost estimating software. The cost of installing buried power to the mine portal area for operation of the valves is included. The total cost estimate of about $2.9 million includes installation of all components, mobilization, erosion control, 10% engineering, and 15% contingencies. Operation and maintenance costs are not included. Details on the cost estimate are attached in Appendix B.

Table 1. Cost Estimate

			Engineer's Estimate	
Unit Description	**Quantity**	**Unit**	**Unit Price**	**Total Price**
10" Smooth HDPE	7,708	LF (installed)	$50	$385,400
12" Smooth HDPE	5,604	LF (installed)	$55	$308,220
15" Smooth HDPE	10,246	LF (installed)	$65	$665,990
18" Smooth HDPE	6,763	LF (installed)	$75	$507,225
Reinforced Concrete Dam	2	LS	$8,000	$16,000
Tunnel Grouting	2	LS	$9,900	$19,800
Door construction	2	LS	$10,000	$20,000
Adit Backfill	466	CY	$4	$1,864
Flowmeters	2	each	$10,500	$21,000
Solar Panel	2	each	$3,600	$7,200
PLC	2	each	$2,400	$4,800
Ethernet Radio	2	each	$2,100	$4,200
Buried power	15,000	LF (installed)	$0.50	$7,500
Mobilization (10%)	-	-	-	$196,170
Erosion Control (5%)	-	-	-	$98,085
Engineering (10%)	-	-	-	$226,345
Contingency (15%)	-	-	-	$373,470
			Total Estimate:	**$2,863,269**

Conclusion

This technical memorandum was prepared to provide a conceptual design of a new, buried water line to transport mine pool discharge through the service and conveyor adits to the infiltration pond located in the tailings impoundment. The design flow of 6.9 cfs is estimated to be the maximum discharge (CDM, 2010a). The new pipe system conceptual design consists of 10", 12", 15", and 18" smooth HDPE pipes operating under gravity flow. The smooth interior of HDPE provides hydraulic efficiency, has a long service life (estimated at 75 years), is virtually chemically inert, is easy to install, is watertight, and provides an overall cost savings as compared to other materials. SCADA would be incorporated to detect leaks in the pipe line, and, if needed, alert personnel and automatically divert flow into the existing water reclamation line while any leak is repaired. The existing reclaim water line will be kept as a backup transport pipe should the capacity of the new pipe be exceeded or the new pipe require repair. Water collection systems have been conceptually designed inside the adit entrances to capture the mine pool water and direct it into the transport pipes. The cost estimate to construct this project is about $2.8 million.

References

CDM, 2010a. Mine Water Management Analysis – Troy Mine. Prepared for Montana Department of Environmental Quality and Kootenai National Forest, December 3, 2010.

CDM, 2010b. Mine Water Balance Analysis - Troy Mine. Technical Memorandum to Emily Corsi and Herb Rolfes, Montana Department of Environmental Quality dated April 12, 2010.

Genesis, Inc., 2006. Troy Mine Revised Reclamation Plan. March, 2006. Troy, MT.

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Appendix A
FlowMaster Calculations and Topo Map

Worksheet for 10" Smooth HDPE

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Slope

Input Data

Roughness Coefficient	0.012	
Channel Slope	8.45157	%
Normal Depth	10.00	in
Diameter	10.00	in
Discharge	6.90	ft^3/s

Results

Channel Slope	8.45157	%
Normal Depth	10.00	in
Flow Area	0.55	ft^2
Wetted Perimeter	2.62	ft
Top Width	0.00	ft
Critical Depth	0.83	ft
Percent Full	100.0	%
Critical Slope	0.07994	ft/ft
Velocity	12.65	ft/s
Velocity Head	2.49	ft
Specific Energy	3.32	ft
Froude Number	0.00	
Maximum Discharge	7.42	ft^3/s
Discharge Full	6.90	ft^3/s
Slope Full	0.08452	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for 10" Smooth HDPE

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	10.00	in
Critical Depth	0.83	ft
Channel Slope	8.45157	%
Critical Slope	0.07994	ft/ft

Worksheet for 12" Smooth HDPE

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Slope

Input Data

Roughness Coefficient	0.012	
Channel Slope	3.19622	%
Normal Depth	12.00	in
Diameter	12.00	in
Discharge	6.90	ft^3/s

Results

Channel Slope	3.19622	%
Normal Depth	12.00	in
Flow Area	0.79	ft^2
Wetted Perimeter	3.14	ft
Top Width	0.00	ft
Critical Depth	0.97	ft
Percent Full	100.0	%
Critical Slope	0.02830	ft/ft
Velocity	8.79	ft/s
Velocity Head	1.20	ft
Specific Energy	2.20	ft
Froude Number	0.00	
Maximum Discharge	7.42	ft^3/s
Discharge Full	6.90	ft^3/s
Slope Full	0.03196	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for 12" Smooth HDPE

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	12.00	in
Critical Depth	0.97	ft
Channel Slope	3.19622	%
Critical Slope	0.02830	ft/ft

Worksheet for 15" Smooth HDPE

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Slope

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.97226	%
Normal Depth	15.00	in
Diameter	15.00	in
Discharge	6.90	ft^3/s

Results

Channel Slope	0.97226	%
Normal Depth	15.00	in
Flow Area	1.23	ft^2
Wetted Perimeter	3.93	ft
Top Width	0.00	ft
Critical Depth	1.05	ft
Percent Full	100.0	%
Critical Slope	0.00927	ft/ft
Velocity	5.62	ft/s
Velocity Head	0.49	ft
Specific Energy	1.74	ft
Froude Number	0.00	
Maximum Discharge	7.42	ft^3/s
Discharge Full	6.90	ft^3/s
Slope Full	0.00972	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for 15" Smooth HDPE

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	15.00	in
Critical Depth	1.05	ft
Channel Slope	0.97226	%
Critical Slope	0.00927	ft/ft

Worksheet for 18" Smooth HDPE

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Slope

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.36769	%
Normal Depth	18.00	in
Diameter	18.00	in
Discharge	6.90	ft^3/s

Results

Channel Slope	0.36769	%
Normal Depth	18.00	in
Flow Area	1.77	ft^2
Wetted Perimeter	4.71	ft
Top Width	0.00	ft
Critical Depth	1.02	ft
Percent Full	100.0	%
Critical Slope	0.00571	ft/ft
Velocity	3.90	ft/s
Velocity Head	0.24	ft
Specific Energy	1.74	ft
Froude Number	0.00	
Maximum Discharge	7.42	ft^3/s
Discharge Full	6.90	ft^3/s
Slope Full	0.00368	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for 18" Smooth HDPE

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	18.00	in
Critical Depth	1.02	ft
Channel Slope	0.36769	%
Critical Slope	0.00571	ft/ft

Worksheet for Existing 10" Steel

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.012	
Channel Slope	3.60000	%
Normal Depth	10.00	in
Diameter	10.00	in
Discharge	4.50	ft^3/s

Results

Discharge	4.50	ft^3/s
Normal Depth	10.00	in
Flow Area	0.55	ft^2
Wetted Perimeter	2.62	ft
Top Width	0.00	ft
Critical Depth	0.81	ft
Percent Full	100.0	%
Critical Slope	0.03203	ft/ft
Velocity	8.26	ft/s
Velocity Head	1.06	ft
Specific Energy	1.89	ft
Froude Number	0.00	
Maximum Discharge	4.84	ft^3/s
Discharge Full	4.50	ft^3/s
Slope Full	0.03600	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for Existing 10" Steel

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	10.00	in
Critical Depth	0.81	ft
Channel Slope	3.60000	%
Critical Slope	0.03203	ft/ft

Worksheet for Existing 12" Steel

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.012	
Channel Slope	1.03000	%
Normal Depth	12.00	in
Diameter	12.00	in
Discharge	3.92	ft^3/s

Results

Discharge	3.92	ft^3/s
Normal Depth	12.00	in
Flow Area	0.79	ft^2
Wetted Perimeter	3.14	ft
Top Width	0.00	ft
Critical Depth	0.84	ft
Percent Full	100.0	%
Critical Slope	0.00988	ft/ft
Velocity	4.99	ft/s
Velocity Head	0.39	ft
Specific Energy	1.39	ft
Froude Number	0.00	
Maximum Discharge	4.21	ft^3/s
Discharge Full	3.92	ft^3/s
Slope Full	0.01030	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	in
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	in
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%

Worksheet for Existing 12" Steel

GVF Output Data

Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	12.00	in
Critical Depth	0.84	ft
Channel Slope	1.03000	%
Critical Slope	0.00988	ft/ft

TROY MINE - NEW WATER LINE VOLUME

Diam (in)	Length (ft)	Volume (cf)
10	7708	31430
12	5604	32906
15	10246	94004
18	6763	89350
Total:		247690

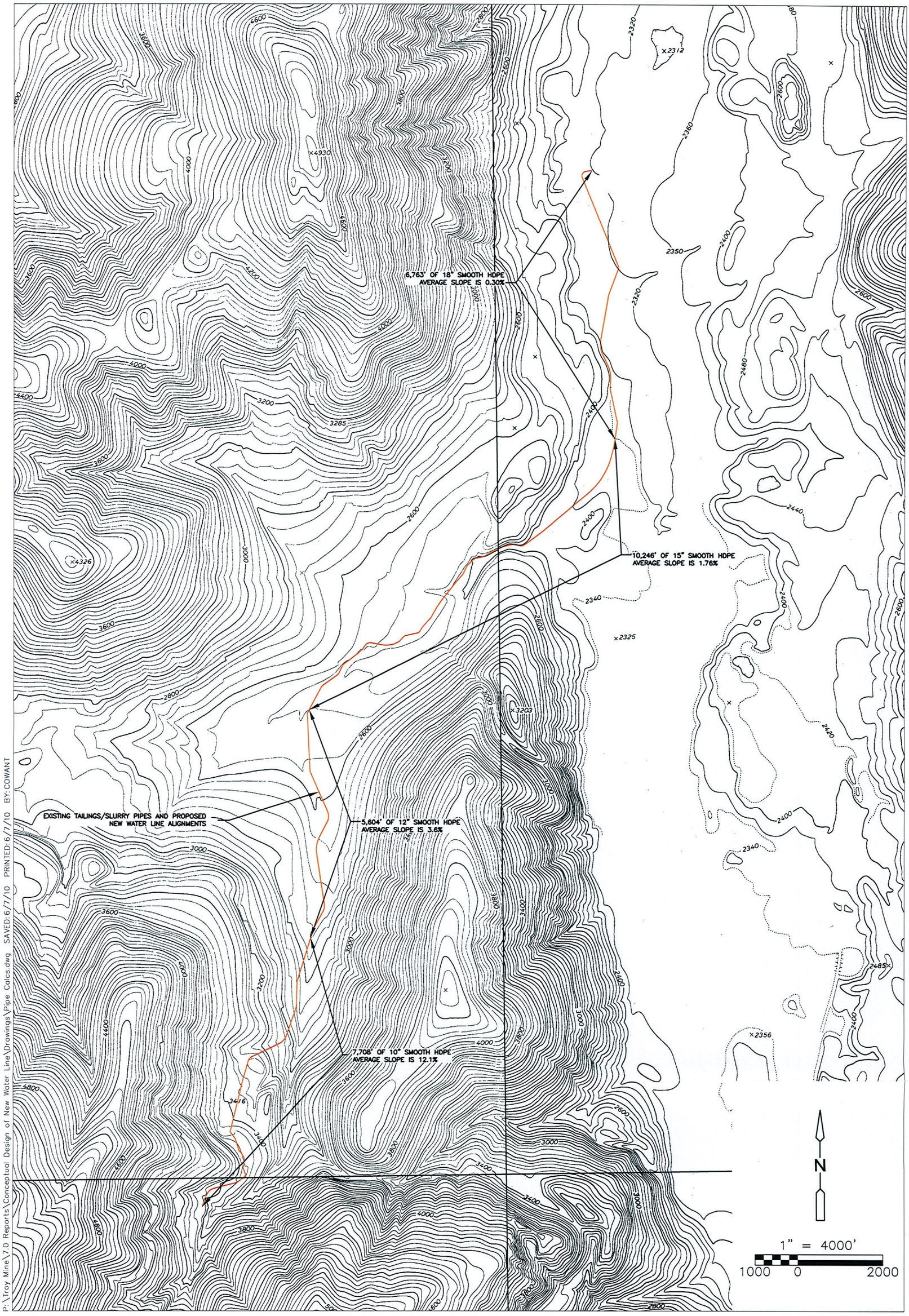

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Figure No. 1
Plan View

Appendix B
Cost Estimate

Troy Mine
Mine Pool Water Capture System
Cost Estimate - Single Adit
July 1, 2010

			Engineer's Estimate		
Unit Description	**Quantity**	**Unit**	**Unit Price**	**Total Price**	**Mean's Code**
Concrete Dam					
Forms	240	sq ft	$7.65	$1,836	03 11 13 85 2000
Rebar	0.2	ton	$2,126.25	$425	03 21 10 60 700 + 1000
Concrete	8.9	cy	$143.00	$1,273	03 31 05 35 0300
Place Concrete (pumped)	8.9	cy	$28.00	$249	
Subtotal - Dam				$3,783	
Given Location, double cost.				$8,000	
Tunnel Grouting					
Mobilization				$4,000	Engineer's Estimate
Grout	100	cu ft	$59.00	$5,900	31-73-13-10-0820
Subtotal - Dam				$9,900	
Door Construction	1	ea	$10,000.00	$10,000	Engineer's Estimate
Backfill	233	cu yd	$4.00	$932	Engineer's Estimate
Total Cost:				**$28,832**	

Transport pipe cost in pipeline cost estimate.

Appendix H
Mine Water Plume Location and Identification Phase I Results and Phase 2 & 3 Work Plan

Mine Water Plume Location and Identification

Phase 1 Results and Phase 2 & 3 Workplan
Sterling Troy Mine

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TABLE OF CONTENTS

LIST OF TABLES ii
LIST OF FIGURES ii
LIST OF APPENDICES ii
LIST OF ATTACHMENTS ii
1.0 INTRODUCTION 1-1
1.1 BACKGROUND 1-2
1.2 PHASE 1 SUMMARY 1-4
2.0 METHODS 2-1
2.1 SAMPLING AND EVALUATION OF MONITORING WELLS 2-1
2.2 TRACER TEST 2-1
3.0 PHASE 1 RESULTS 3-1
3.1 GROUNDWATER SAMPLING AND EVALUATION 3-1
3.2 TRACER TEST 3-1
3.2.1 Chemical Effects of the Tracer on Groundwater 3-1
3.2.2 Decant Pond Infiltration Rate 3-2
4.0 PHASE 2 AND 3 WORKPLAN 4-1
4.1 CONCEPTUAL MODEL OF HYDROGEOLOGIC SYSTEM 4-1
4.2 PHASE 2 MONITORING WELL INSTALLATION AND TESTING 4-3
4.3 PHASE 3 GROUNDWATER TRACER TEST 4-5
5.0 REFERENCES 5-1

LIST OF TABLES

TABLE 1 SEPTEMBER 2000 WATER QUALITY DATA 3-1
TABLE 2. MARCH 2001 WATER QUALITY DATA (BEFORE TRACER TEST) 3-2
TABLE 3. APRIL 2001 WATER QUALITY DATA (AFTER TRACER ADDITION PERIOD) 3-3
TABLE 4. IDENTIFIED PERMEABLE ZONES IN THE VICINITY OF THE DECANT PONDS 4-3

LIST OF FIGURES

FIGURE 1 MONITORING WELL LOCATIONS 2-1
FIGURE 2 TYPICAL SHALLOW MONITORING WELL CONSTRUCTION 4-7

LIST OF APPENDICES

APPENDIX A. GROUNDWATER MONITORING PROPOSAL
(August 16, 2000 letter from Genesis Inc. to MDEQ)
APPENDIX B. TRACER TEST PROPOSAL, REQUEST AND APPROVAL
(December 4, 2001 letter from Genesis Inc. to MDEQ)
(January 22, 2001 letter from MDEQ to Genesis Inc.)
APPENDIX C. TRACER TEST PROTOCOL REVISION 1
(February 2, 2001 letter from Hydrometrics to MDEQ)
APPENDIX D. TRACER TEST PROTOCOL REVISION 2
(March 6, 2001 letter from Hydrometrics to MDEQ)
APPENDIX E. PIPER DIAGRAMS
APPENDIX F. TRACER TEST RESULTS – SC, Na, CL Trendplots

Mine Water Plume Location and Identification

Phase 1 Results and Phase 2 & 3 Workplan
Genesis Inc. Troy Mine

1.0 INTRODUCTION

This report summarizes results of investigations in 2000 and 2001 that were conducted to locate and identify the minewater flowpath from the decant pond at the Troy Mine tailings impoundment. Additionally, this report describes the workplan for continued investigation of the minewater flowpath in 2001 and 2002.

Phase 1 results continue to support the hypothesis that copper in minewater that is discharged to the decant ponds is strongly attenuated (immobilized) in the groundwater system, probably within a short distance of the decant ponds. Groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. This groundwater does not contained elevated copper concentrations (0.003 mg/L or less). However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local geology, it is hypothesized that a shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the 2001 tracer test. Phases 2 and 3 of the evaluation include additional monitoring well drilling targeting the shallow gravel unit and an additional groundwater tracer test.

1.1 BACKGROUND

The Troy Mine was developed by Asarco in 1979 and went into production in 1981. The mine was operated by Asarco until 1993 when the mine was placed on temporary shutdown. In 1999, the mine was purchased by Genesis Inc., a subsidiary of Sterling Mining Company. Since 1993, Asarco and Genesis Inc. have disposed of water from the underground workings by discharge to the impoundment in one of three ways:

- Sprinkler irrigation over the impoundment (primarily during the growing season).
- Discharge to the decant pond (also known as the barge pond).
- Discharge to the Section III pond.

The primary chemical of concern in mine water is copper, which is typically present at concentrations of approximately 0.1 mg/L. For comparison, surface water in Lake Creek adjacent to the impoundment typically contains approximately 0.003 mg/L and the chronic aquatic life standard for copper is approximately 0.004 mg/L (assuming hardness of 35 mg/L). In spite of the higher copper concentrations discharged to the impoundment, copper concentrations in Lake Creek and in monitoring wells installed in the impoundment vicinity have not increased measurably as a result of the discharge (*see* Summit, 1999; Parametrix, 1999).

The observation that mine water has been discharged with little or no apparent effect on ambient water quality has led to the preliminary consideration of continued discharge of mine water to the decant pond as a potential long-term method of mine water disposal (see Revised Reclamation Plan, Sterling 2000). In order for impoundment discharge to be considered further, both the physical flow paths and the transport and attenuation mechanisms for copper in the impoundment/groundwater system must be understood. In particular, the flow paths must be identified so that an effective groundwater monitoring system can be installed. Transport and attenuation mechanisms must be understood to determine the long-term fate of constituents in mine water and the effects of long-term discharge on ambient groundwater and stream quality.

In September 2000, Hydrometrics prepared a "Minewater Fate and Transport Study Plan" (Hydrometrics, 2000a) to collect information needed to evaluate the fate and transport of mine water that is disposed at the decant pond. An initial obstacle to the study of fate and transport in the system is the absence of any evidence of a copper-bearing mine water discharge plume in the groundwater system. Therefore, the first phase of the fate and transport study is to locate and identify the groundwater flow paths for discharged mine water. Later phases of the study plan will identify probable fate and transport mechanisms, and evaluate potential implications under a long-term discharge scenario.

Plume location and identification is anticipated to consist of three phases as follows:

1. Sampling and evaluation of all available monitoring wells and further evaluation of water quality data.
2. Construction, sampling, and evaluation of additional excavations, borings, and wells to supplement the existing monitoring well network.
3. Tracer testing to verify plume location and flow paths

1.2 PHASE 1 SUMMARY

As initially proposed in the study plan, Phase 1 of plume location consisted of sampling and evaluation of all available monitoring wells and further evaluation of water quality data. Based on the water quality evaluation it was thought that one of the existing wells (IW-1, the "irrigation well") was effectively monitoring the mine water plume. Therefore, a preliminary tracer test was conducted in spring 2001 to test the hypothesis that well IW-1 is located in, and monitors, the minewater plume. Results of this tracer test (summarized in Section 3 of this report) indicate that none of the existing wells is located in the primary flowpath from the pond. Based on these Phase 1 results, it is determined that additional investigations as outlined in Phases 2 and 3 of the Fate and Transport Study are needed. Workplans for Phases 2 and 3 are described in Section 4 of this report.

2.0 METHODS

Monitoring and testing plans for Phase 1 work are included in Appendices A through D. The following sections provide an overview of the plans and methods. Locations of wells near the tailings impoundment are shown on Figure 1.

2.1 SAMPLING AND EVALUATION OF MONITORING WELLS

A proposed plan for groundwater monitoring in and near the tailings impoundment was submitted to MDEQ by Genesis Inc. in August 2000. This plan (see Appendix A) proposed sampling of 9 wells near the impoundment (MW-1, MW-2, MW-3, MW-4, MW-95-5, MW-95-7, MW-95-8, IW-1 or the Irrigation well, and the Quonset hut well). All of the wells were sampled on September 7, 2000 except for MW-95-7 which was dry. Wells MW-95-5 and MW-95-8 were sampled by bailing with disposable plastic bailers. The remaining wells were sampled with submersible pumps.

2.2 TRACER TEST

Tracer testing at the decant pond consisted of adding salt (NaCl or sodium chloride) to the mine water flowing to the decant pond to raise the TDS, specific conductivity, sodium, and chloride concentrations of water in the decant pond to levels much higher than ambient groundwater. At the same time, monitoring of groundwater in adjacent wells was conducted in order to identify increases in these chemical parameters in groundwater and thus locate the minewater flowpath in the groundwater system. Methods of conducting the tracer test were originally described in a December 4, 2001 letter from Sterling Mining Co. (Frank Duval) to MDEQ (Abe Horpestad) proposing the test and requesting permission from DEQ to run the test (see Appendix B). As originally proposed, the tracer test was to consist of adding salt to the minewater inflow to the decant pond at the rate of approximately 500 pounds per day for a period of about 18 days. MDEQ granted approval to conduct the tracer test on January 22, 2001 (see Appendix B).

FIGURE 1 MONITORING WELL LOCATIONS

In February 2001, it was recognized that minewater flows were sufficiently low that all minewater flows to the decant pond could be suspended for a period of about 2 weeks. Without minewater inflows to the pond, it was believed that it would be be easier to simply add the salt to the pond as a "slug" and eliminate the need for daily salt additions. Moreover, it was believed that slug addition of salt would result in more constant salt concentrations in the pond and overall a better tracer test. The testing protocol was revised in a February 2, 2001 letter to MDEQ (see Appendix C). The revised testing protocol also provided a monitoring schedule and analytical parameter list.

During preparation for the tracer test it was discovered that the system for remote monitoring of some wells in the tailings impoundment area were not functioning, perhaps as the result of snowplowing to access the wells. Therefore, the monitoring schedule for the tracer test was revised to eliminate remote monitoring (see Appendix D).

The tracer test was conducted during the period of March 8 to May 31, 2001. In general, monitoring during the test followed the schedule outlined in Table 1 of Appendix D. A timeline and summary of the tracer test is as follows:

- March 8 – All wells and decant ponds were sampled to collect baseline water quality data for major ions, nutrients, and metals prior to tracer (salt) addition. Decant pond cell #3 and well MW-97-14 were dry and could not be sampled.
- March 12 – Salt addition started at 8 am; 5 tons of salt were added by 9:50 am and 10 tons of salt were added by 11:45 am. Salt was added to the reclaim water pipeline at the mill pond. At 2:30 pm, monitoring of the decant pond specific conductivity was started.
- March 13 – Mine water flows to decant pond were shut off at 5 pm. Decant pond staff gage installed. Decant pond specific conductivity monitoring continued (3 times daily) and daily sampling of wells IW-1, MW-95-3, MW-95-7, and MW-95-8 was initiated.
- March 16 – Decant pond monitoring continued on a daily basis.

- March 14 through April 2 – Daily sampling of wells (IW-1, MW-95-3, MW-95-7, and MW-95-8) and decant ponds continued. (March 18 – Decant pond #3 dry and no longer sampled. March 30 – Well MW-95-8 dry and could not be sampled.)
- April 2 – All wells, including MW-1 through MW-4, MW-95-5, and MW-97-12 sampled prior to reduction in monitoring frequency to weekly.
- April 9 – Mine water flow to decant pond resumed; water from section 3 pond allowed to flow to decant pond.
- April 9 through May 31 – Weekly sampling of wells and decant ponds continued. (April 25, decant pond #2 dry and could no longer be sampled. May 31, well MW-95-8 again contained water and was sampled.)
- May 31 – Tracer test terminated.

3.0 PHASE 1 RESULTS

Phase 1 results continue to support the hypothesis that copper in minewater that is discharged to the decant ponds is strongly attenuated (immobilized) in the groundwater system, probably within a short distance of the decant ponds. Groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. This groundwater does not contained elevated copper concentrations (0.003 mg/L or less). However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local stratigraphy (see Section 4), it is hypothesized that a shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the relatively short duration of the tracer test.

3.1 GROUNDWATER SAMPLING AND EVALUATION

Groundwater quality data for wells around the decant ponds was collected three times in the past year (September 2000, March 2001, April 2001). Comparisons of groundwater quality data and minewater/decant pond water are provided in Tables 1 through 3 and Piper diagrams in Appendix E. As these comparisons indicate, groundwater in wells near the decant pond (IW-1, MW-95-8, MW-95-7) has an overall chemical signature that is very similar to the decant pond with the exception of the lack of copper in groundwater. This is true not only of major ion chemistry as shown by the Piper diagrams, but also nitrate + nitrite concentration (see Tables 1-3). Of particular note on the Piper diagrams is the seasonal shift in decant water composition and corresponding shifts in groundwater composition between September 2000 and March 2001.

TABLE 1 SEPTEMBER 2000 WATER QUALITY DATA

	Service Adit Minewater	IW-1	QW-1	MW-4	MW-2	MW-3	MW-1	MW95-8	MW95-5
Alkalinity.	76	72	24	16	156	124	108	170	170
Arsenic	0.003	<0.003	<0.003	<0.003	0.027	0.01	0.007	<0.003	0.003
Calcium	23	26	7	4.3	29	36	33	62	47
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	0.056	0.002	0.001	<0.001	<0.001	0.001	<0.001	0.003	0.003
Iron	<0.020	<0.020	0.16	<0.020	<0.020	7.8	7.7	<0.020	30
Hardness	81	86	24	15	109	106	103	184	171
Bicarb.	76	72	24	16	156	124	108	170	170
Potassium	<2	<2.0	<2.0	<2.0	2.7	1.1	1.5	2.1	10
Magnesium	5.5	5	1.7	1	8.7	4	5.3	6.9	13
Manganese	0.024	0.081	0.018	0.04	0.25	0.66	0.57	<0.005	4.8
Sodium	NA	3	<2.0	<2.0	21	5.1	4.9	2.5	7.7
Ammonia	0.1	0.061	<0.050	0.13	0.43	0.39	0.11	0.051	0.21
Nitrate+nitrite	0.69	0.69	<0.050	0.11	0.094	<0.050	0.12	1.2	0.075
Lead	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
pH	8.3	7.2	6.3	6.6	7.5	6.9	6.9	7.9	6.3
Antimony	0.009	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Silica	NA	9.3	8.4	7.5	11	28	22	11	65
Sulfate	15	19	3.9	2.6	<2.0	<2.0	9.1	15	7.3
TDS	112	115	52	36	197	166	159	235	361
Zinc	<0.010	<0.010	0.32	0.023	<0.010	<0.010	<0.010	0.19	0.35

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO3), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved.

TABLE 2. MARCH 2001 WATER QUALITY DATA (BEFORE TRACER TEST)

	MW 95-5	MW 95-4	MW 95-3	MW 97-12	MW-1	MW-2	MW-3	MW-4	MW 95-7	MW 95-8	IW-1	DECANT POND 1	DECANT POND 2
Alkalinity.	154.	22.	89.	61.	114.	21.	113.	168.	71.	81.	75.	74.	76.
Arsenic	0.008	0.004	<0.002	<0.002	0.006	<0.002	0.019	0.029	0.002	<0.002	<0.002	<0.002	<0.002
Calcium	46.	38.	130.	12.	35.	4.6	32.	30.	30.	41.	28.	31.	30.
Chloride-	3.9	4.2	2.7	3.0	2.1	<1.0	1.1	<1.0	<1.0	1.1	<1.0	<1.0	<1.0
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.049	0.043
Iron	36.	17.	0.22	0.20	6.9	<0.030	12.	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Hardness	171.	139.	503.	54.	111.	16.	97.	112.	92.	125.	98.	116.	113.
Bicarb.	154.	22.	89.	61.	114.	21.	113.	168.	71.	81.	75.	74.	76.
Potassium	11.	24.	74.	5.3	1.1	<1.0	<1.0	2.4	<1.0	<1.0	<1.0	<1.0	<1.0
Magnesium	13.	11.	43.	5.6	5.7	1.1	3.9	9.0	4.1	5.6	6.7	9.5	9.1
Manganese	5.8	3.0	0.99	0.10	0.55	0.14	0.59	0.24	<0.005	<0.005	<0.005	0.040	0.037
Sodium	9.0	35.	53.	5.8	5.6	<1.0	5.4	23.	1.3	1.3	2.0	1.6	1.5
Ammonia	0.60	4.2	10.	<0.10	<0.10	0.20	0.30	0.42	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate+nitrite	0.19	0.31	<0.10	<0.10	0.32	0.13	<0.10	<0.10	1.1	1.6	0.79	1.6	1.4
Lead	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
pH	8.0	6.6	7.9	6.7	8.0	6.9	7.2	8.2	8.1	8.4	8.1	8.3	8.2
Antimony	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	0.011
Silica	58.	43.	10.	54.	25.	10.	30.	13.	12.	9.8	9.8	8.1	8.3
Sulfate	9.2	292.	693.	14.	9.6	5.3	1.4	1.2	27.	41.	25.	39.	42.
TDS	284.	406.	1060.	150.	160.	31.	178.	197.	136.	164.	133.	171.	164.
Zinc	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO3), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved.

TABLE 3. APRIL 2001 WATER QUALITY DATA (AFTER TRACER ADDITION PERIOD)

	DECANT POND-1	DECANT POND-2	MW-95-3	MW-95-7	IW-1
Alkalinity.	50.	76.	146.	220A	70.
Arsenic	<0.002	<0.002	0.002	<0.002	<0.002
Calcium	22.	30.	130.	32.	26.
Chloride-	96.	67.	2.6	1.3	<1.0
Carbonate	<1.0	<1.0	<1.0	<1.0	<1.0
Copper	0.040	0.036	<0.002	0.002	<0.002
Iron	<0.050	<0.050	<0.050	<0.050	<0.050
Hardness	82.	113.	502.	96.	90.
Bicarb.	50.	76.	146.	220A	70.
Potassium	1.6	1.9	79.	1.8	1.5
Magnesium	6.5	9.2	43.	4.2	6.2
Manganese	0.053	0.036	1.0	<0.005	<0.005
Sodium	51.	38.	56.	1.5	2.8
Ammonia	<0.10	<0.10	12.	0.12	<0.10
Nitrate+nitrite	0.80	1.5	<0.050	1.0	0.71
Lead	<0.002	<0.002	<0.002	<0.002	<0.002
pH	7.8	8.0	7.8	7.9	8.0
Antimony	0.007	0.010	<0.005	<0.005	<0.005
Silica	7.0	7.3	10.	11.	13.
Sulfate	33.	40.	730.	31.	24.
TDS	243.	246.	1051.	160.	135.
Zinc	<0.010	<0.010	<0.010	<0.010	<0.010

Note: All units (mg/L) except pH (std. units), alkalinity, carbonate, bicarbonate and hardness (all mg/L as CaCO3), ammonia and nitrate + nitrite (mg/L as N). All metals are dissolved. Alkalinity and bicarbonate values for MW-95-7 are suspected to be in error (cation/anion balance is significantly off); 70 mg/L assumed for Piper diagram in Appendix E.

3.2 TRACER TEST

The addition of salt to the decant ponds caused the following changes in decant pond water chemistry:

- increased the specific conductivity (SC) of the decant ponds to approximately 400 to 700 micromhos/cm (2 to 3 times higher than ambient groundwater, i.e. IW-1, MW-95-7 and MW-95-8);
- increased the sodium concentration to 40 to 90 mg/L (20 to 50 times higher than ambient groundwater); and
- increased the chloride concentration to 60 to 160 mg/L (60 to 160 times higher than ambient groundwater).

The premise of the tracer test is that because SC, sodium, and chloride were elevated in the decant pond by the salt addition, the presence of increased concentrations of these parameters in ambient groundwater would demonstrate a connection (i.e., a groundwater flowpath) between the decant ponds and the monitoring wells. Because of residual process water within the tailings, the specific conductivity and sodium concentrations in water in well MW-95-3 (completed in the tailings west of the decant ponds) were similar to, or higher than decant pond water prior to, during, and after the tracer test. Therefore, the presence of increased SC and sodium in well MW-95-3 is unrelated to the addition of salt to decant pond water.

3.2.1 Chemical Effects of the Tracer on Groundwater

Results of the groundwater tracer test are shown in the trend plots (SC, sodium, chloride versus time) in Appendix F. Overall, there was no meaningful increase in concentrations of the tracer (salt) in any monitoring wells during the test. Therefore, the tracer test indicates poor hydrologic connection (low or slow rate of flow) between the decant ponds and the units in which the monitoring wells are completed. As noted above, groundwater quality data suggests that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from

minewater disposed in the decant ponds. However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water.

3.2.2 Decant Pond Infiltration Rate

Water levels in the decant ponds were monitored over the course of the tracer addition period (24 days, from March 13 to April 6) while no water was discharged to the ponds. Based on the volume of water lost from the ponds over this period it is possible to calculate an infiltration rate for the ponds. Decant pond #1 and decant pond #2 have surface areas of approximately 3.2 and 1 acres, respectively and during the tracer addition period, water levels in the ponds dropped 10.7 and 8.8 feet, respectively. Total volume of water infiltrated through the ponds is therefore approximately 14 million gallons. Since the tracer addition period was 34,380 minutes, the average infiltration rate for the period was about 400 gpm or about 0.2 in/hr (0.4 ft/day).

The calculated infiltration rate is not particularly high and is in the range of what might be expected for a fine sand. However, this infiltration rate implies that the hydraulic conductivity of the groundwater aquifer that transports the minewater away from the decant pond is much larger, perhaps on the order of 500 ft/day or more, typical of coarse sands or gravel. The decant ponds have a large surface area for infiltration (about 180,000 ft^2) and the hydraulic gradient in the pond is 1 (vertical gradient). In the groundwater system near the pond it is likely that the gradient is much less than 1 (i.e. flow is not strictly vertical but likely has a large horizontal component) and the cross-sectional area of the aquifer is likely a fraction of the surface area of the ponds. Given the likely much lower gradient and smaller area of the aquifer in the flowpath, the aquifer would have to have a much higher hydraulic conductivity to transmit the flow from the decant ponds.

4.0 PHASE 2 AND 3 WORKPLAN

4.1 CONCEPTUAL MODEL OF HYDROGEOLOGIC SYSTEM

Groundwater in the Lake Creek Valley occurs in glaciolacustrine deposits and alluvium (Levings et al, 1984). Within the glaciolacustrine deposits groundwater occurs primarily in the sand, gravel, and cobble zones. Silt and clay zones within the glaciolacustrine deposits are confining beds that restrict vertical ground-water movement. Although the general directions of groundwater movement in the area are likely towards the north (in the general direction of flow in Lake Creek) and towards the west (toward Lake Creek), local groundwater flow directions are likely controlled primarily by the location and orientation of permeable water bearing zones within the glaciolacustrine and alluvial deposits.

Previous monitoring well drilling (see Summit and MF&G, 1996) and geotechnical boring investigations (see Woodward-Clyde, 1977) in the area have identified the presence of sand and gravel zones within the glaciolacustrine deposits in the general vicinity of the decant ponds. As summarized in the Draft EIS (p. 103),

> ”The surficial geology of the pond [tailing impoundment] site reflects the complex geology of the area and varies from fine-grained clayey silts to coarse rock and gravel. The coarser deposits tend to be nearer the edge of the valley and along the lower reaches of Camp Creek. Test wells and test holes also reflect the complex geology of the area with substantial vertical variations in materials encountered.”

The most notable sand and gravel occurrences in wells and test holes are summarized in Table 4. Data from wells and test holes suggest permeable gravels are located at or near the surface near the decant ponds and extending to the east and south of the ponds. Gravels are also present at depth near the decant ponds and to the west of the impoundment near Lake Creek. Groundwater sampling and

tracer testing in spring 2001 indicate that the groundwater in deeper gravel/sand units near the decant ponds (e.g., units monitored by wells IW-1, MW-95-7, and MW-95-8) is derived primarily from minewater disposed in the decant ponds. However, tracer test results suggests that these gravel units are not the primary groundwater flowpath for decant pond water. Based on Phase 1 results and review of the local stratigraphy (see Section 4), it is hypothesized that the shallow gravel unit may provide the primary flowpath for transport of water from the decant ponds. While this shallow unit is believed to transport water primarily laterally away from the decant pond, some slow transport of water downward to the deeper gravels (i.e., leakage through the silts/fine sands that underlie the shallow gravel) is believed to also occur. The slow rate of the vertical transport of water to the deeper gravels is believed to account for the lack of detection of the tracer in the deeper gravels during the relatively short tracer test.

TABLE 4. IDENTIFIED PERMEABLE ZONES IN THE VICINITY OF THE DECANT PONDS

Well/Boring	Location	Zone Description	Other
MW-95-7	Approx. 250 feet east southeast of decant pond #3	Gravel 0 to 18 ft bgs;	Well screened 79 to 89 ft bgs.
MW-95-8	Approx. 50 feet north of decant pond #1, north side of Section 2/3 divider dike.	Gravel, cobbles, sand 0 to 20 ft bgs;	Well screened 48 to 53 ft bgs.
IW-1	Approx. 20 feet north of decant pond #1.	No drilling logs can be found, Asarco internal memos refer to well as screened in "lower sand and gravel aquifer".	Well screened 190 to 210 ft bgs.
MW-1	Approx. 4,000' northwest of decant ponds between dike and Lake Creek	Clean sand and gravel 160 to 280 bgs	Well perforated 55' to 100' bgs in silt/clay and 160' to 280't bgs
MW-3	Approx. 3,000' west of decant ponds between dike and Lake Creek.	Sand and gravel 118 to 125' bgs	Open-ended casing
TH-10	Section 2 approx. 1,000' west of decant ponds	Very gravelly sand 8 to 40' bgs	Field permeability 4,400 ft/yr
TH-11	In section 1 approx. 800' south of decant ponds	Gravel 0 to 40' bgs	Field permeability 8,100 ft/yr
TH-12	Southeast portion section 2; approx. 1200 feet southwest decant ponds	Gravelly sand to gravel 5 to 40'bgs	Field permeability 1,100 ft/yr

*bgs = below ground surface.

4.2 PHASE 2 MONITORING WELL INSTALLATION AND TESTING

The primary target for additional borings and well construction is shallow gravel and cobble units similar to the shallow materials encountered in well MW-95-8 (located 50 feet north of the decant pond), well MW-95-7 (located approximately 250 feet east of the decant pond), and exposed in the terraces immediately to the northeast of the decant pond. The quantity of water disposed in the decant pond (greater than 1,000 gpm or more at times) requires that the pond must be underlain by a relatively permeable unit in order to percolate and transmit the disposed water. The presence of approximately 20 feet of "gravel, cobbles and sand" material at MW-95-8 and MW-95-7 (Appendix II in MFG and Summit, 1996) suggests that surficial gravel materials are a likely conduit for mine water flows.

In summer 2001, excavations were made adjacent to the decant pond in an attempt to locate the surficial gravel materials and install monitoring wells as proposed in the first step in Phase II of the Fate and Transport Study (Hydrometrics, 2000). Although the surface of the tailings near the ponds is stable and workable by heavy equipment, it was not possible to maintain an open excavation sufficient to reach the base of the tailings. Therefore, future work will require drill rigs.

The proposed drilling program to install monitoring wells is anticipated to require one or two phases, Phases 2a and 2b. Phase 2a will include initial well installation to find and identify the groundwater flow path(s) from the decant ponds. Phase 2a will be comprised of wells relatively close to the ponds. Proposed Phase 2a monitoring well locations are shown on Figure 1. Wells are proposed to the west of decant pond #1, south of decant pond #1, south of decant pond #2, north of decant ponds #1 and #2 near the pond divider dike, and east of decant pond #3. Anticipated depth of completion of the wells is 20 to 40 feet, within the shallow gravel zone. Typical monitoring well construction details are shown on Figure 2. Actual well locations and construction details will be selected in the field and may be modified based on field conditions. Wells will be

developed after well construction by pumping with a submersible pump, purging with rig air, bailing, or surging with a block.

Phase 2b of well installation will include wells completed further downgradient in the groundwater flowpath(s) identified in Phase 2a. The exact number and locations of Phase 2b wells will be determined based on Phase 2a results.

Monitoring wells completed in Phase 2 will be sampled after well development for the water quality parameters listed in Table 2.

4.3 PHASE 3 GROUNDWATER TRACER TEST

The need for another groundwater tracer test will be determined based on the results of monitoring well installation and sampling. If a chemical tracer from minewater (i.e., copper) can be found in the monitoring wells then tracer testing may not be needed. If it is believed that the minewater flowpath has been found but minewater can not be definitively identified in groundwater based on water quality analyses, then a tracer test will be conducted. Protocol for the tracer test would be developed at that time, similar to the protocol used in spring 2001 (e.g. see Appendix D).

TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER MONITORING AT THE TROY MINE

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
Common Ions and Physical Parameters		
pH	0.1 S.U.	EPA 150.1
TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as $CaCO_3$	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
Nutrients		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
Dissolved Metals (filtered sample)		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

** Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

FIGURE 2 TYPICAL SHALLOW MONITORING WELL CONSTRUCTION

5.0 REFERENCES

Hydrometrics, 2000. Minewater Fate and Transport Study Plan – Draft. September, 2000

Levings, G. W., R.F. Ferreira and J.H. Lambing, 1984. Water Resources of Lake Creek Valley, Northwestern Montana

Sterling Mining Co., 2000. Genesis Inc. Troy Mine Revised Reclamation Plan.

Summit Envirosolutions and McCulley Frick & Gilman, Inc., 1996. Interim Report of Findings, Hydrologic and Hydrogeologic Assessment, Asarco Troy Mine, Troy Montana.

Summit Envirosolutions, 1999 Site Instrumentation Status Report Troy Tailings Impoundment, Lincoln County, Montana.

Woodward-Clyde Consultants, 1977. Phase II Geotechnical Services, Troy Pojectnear Troy Montana. Prepared for ASARCO, Inc. January 25, 1977.

APPENDIX A

GROUNDWATER MONITORING PROPOSAL

(August 16, 2000 letter from Genesis Inc. to MDEQ)

APPENDIX B

TRACER TEST PROPOSAL, REQUEST AND APPROVAL

(December 4, 2001 letter from Genesis Inc. to MDEQ)

(January 22, 2001 letter from MDEQ to Genesis Inc.)

APPENDIX C

TRACER TEST PROTOCOL REVISION 1

(February 2, 2001 letter from Hydrometrics to MDEQ)

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February 2, 2001

Mr. Joe Gurrieri
MT Dept. of Environmental Quality
PO Box 200901
Helena, MT 59620-0901

RE: Groundwater Tracer Test at the Troy Mine

Dear Joe:

Sterling Mining Companyreceived permission from MDEQ (Abe Horpestad) to proceed with the tracer test at the Genesis Inc. Troy Mine and was requested by Abe to inform you of our progress. Because minewater flows and conditions at the decant ponds have changed somewhat since the tracer test proposal was submitted in early December, we are planning to modify the test procedure. This letter describes the modifications to the tracer test and our final proposed monitoring schedule.

Schedule
We are tentatively planning to start the test the week of February 12, 2001 and would like you to observe the test, if possible. This schedule is contingent on our testing and identifying an appropriate method to add the salt to the ponds. As we have discussed, it will be important to make sure that all of the salt is dissolved quickly in the ponds. We will do some testing of salt additions prior to the start of the actual tracer test. We will inform you of any changes to this schedule.

Test Modification
Based on current conditions in the ponds and mine water flow rates, we now plan to add all of the salt to the ponds (approximately 10 tons) and cease all minewater flows to the ponds for the duration of the salt addition period (approximately 1 to 2 weeks).

As described in Sterling's tracer test proposal, in December the decant ponds contained approximately 12 million gallons of water and mine water inflows to the ponds were approximately 470 gpm. Based on these water volumes, we intended to add approximately 5 tons of salt to the ponds to achieve the desired initial TDS concentration in the ponds. Then approximately 500 pounds of salt would be added daily to maintain this TDS.

Currently, the volume of water in the ponds is much higher (21 million gallons) and minewater flows are much lower (around 200 gpm). At these flow rates, Sterling can divert all minewater flows to the thickener and mill water pond for storage and thereby eliminate minewater flows to the decant ponds for a period of approximately 1 to 2 weeks (actual duration of minewater storage will depend on precipitation runoff to mill water pond during this period). Given these conditions, we believe that it will be easier to simply add the salt to the pond as a "slug" and eliminate the need for daily salt additions. Moreover, this will result in more constant TDS concentrations in the pond. Therefore, we intend to add all of the salt to the pond over an approximately 8 hour period. We plan to add the salt into the tailings reclaim water line (the buried 10-inch line that goes from the mill water pond to the decant pond) at the mill water pond. At the end of the salt addition the reclaim water line will be turned off and minewater flow will be diverted to the thickener and/or mill water pond

Proposed Monitoring Schedule

The overall schedule for monitoring is described in attached Table 1. In this table, "tracer addition period" means the period after the salt has been added to the pond and during the period that mine water is not discharged to the pond.

Prior to tracer addition, the decant pond and adjacent monitoring wells (Irrigation Well, MW-95-3, MW-95-7, and MW-95-8) will be sampled and analyzed for major ion, nutrient, metals and physical parameters according to the schedule in the attached Table 2. Wells around the perimeter of the impoundment will also be sampled for the complete analytical schedule.

During tracer addition, the specific conductivity (SC) of the various waters will be measured daily to track TDS concentrations and waters will be sampled weekly for sodium and chloride. Waters to be monitored include the decant pond and adjacent monitoring wells and wells that can be remotely monitored. Specific conductivity will be measured at four points (1 point along each side) in each pond. To document mixing in the ponds, specific conductivity in the ponds will be measured three times per day during the first 3 days of the test.

If the tracer is detected at adjacent monitoring wells during the tracer addition period, then the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters according to the schedule in Table 2.

At the end of the tracer addition period, the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters (Table 2). Perimeter monitoring wells will be sampled and analyzed for specific conductivity, sodium, and chloride. If the specific conductivity of any perimeter well is more than 10 percent higher than pre-test baseline conductivity, then the well will be sampled for a full suite of analytical parameters (Table 2).

If the tracer has not been detected at adjacent monitoring wells by the end of the tracer addition period, monitoring of SC will be continued on a daily basis for an additional two weeks, then on a weekly basis thereafter. Sodium and chloride will also be monitored weekly in the adjacent wells until the test is terminated.

At the end of the tracer test, the decant pond and adjacent monitoring wells will be sampled and analyzed for major ion, nutrient, and metal parameters (Table 2). Perimeter monitoring wells will be sampled and analyzed for specific conductivity, sodium, and chloride. If the specific conductivity of any perimeter well is more than 10 percent higher than pre-test baseline conditions, then the well will be sampled for a full suite of analytical parameters (Table 2).

Water levels in the ponds will be monitored with staff gages throughout the test. Static water levels in the wells will be monitored at the time of sampling, or in instrumented wells, continuously throughout the test.

The decision of when to terminate the test will be based on monitoring results and will be coordinated with DEQ.

Please let me know if you would like any modifications to this test. I look forward to seeing you on Site for this tracer test.

Sincerely,

Scott Mason
Geochemist

c: Bruce Clark
Frank Duval

Table 1. Monitoring Schedule for Troy Tracer Test

	Pre-Test Baseline	Tracer Addition Period			End of Tracer Addition Period		Post Tracer Addition Period			End of Test	
Monitoring Location	Major Ions, Nutrients, & Metals (see Table 2)	Continuous Specific Conductivity	Daily Specific Conductivity & Water Level	Weekly Sodium and Chloride	Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, & Specific Conductivity Only	Continuous Specific Conductivity	Daily Specific Conductivity & Water Level	Weekly Sodium and Chloride	Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, & Specific Conductivity Only
Decant Pond 1 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Decant Pond 2 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Decant Pond 3 *	Yes		Yes **	Yes	Yes			Yes	Yes	Yes	
Irrigation Well	Yes		Yes	Yes	Yes			Yes	Yes	Yes	
MW-95-8	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-7	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-3	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
MW-95-4	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-97-12	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-97-14	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-95-5	Yes	Yes	Yes		?	Yes	Yes	Yes		?	Yes
MW-1	Yes				?	Yes				?	Yes
MW-2	Yes				?	Yes				?	Yes
MW-3	Yes				?	Yes				?	Yes
MW-4	Yes				?	Yes				?	Yes

Notes:

? Well will be sampled for major ions, nutrients, and metals per Table 2 only if specific conductivity is 10% or more greater than pre-test result.

* Specific conductivity will be measured at four points (1 point along each side) in each pond.

** Specific conductivity will be measured three times per day during the first 3 days of the test to document mixing in the ponds.

TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER MONITORING AT THE TROY MINE

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
Common Ions and Physical Parameters		
pH	0.1 S.U.	EPA 150.1
TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as $CaCO_3$	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
Nutrients		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
Dissolved Metals (filtered sample)		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

** Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

APPENDIX D

TRACER TEST PROTOCOL REVISION 2

(March 6, 2001 letter from Hydrometrics to MDEQ)

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March 6, 2001

Mr. Joe Gurrieri
MT Dept. of Environmental Quality
PO Box 200901
Helena, MT 59620-0901

RE: Groundwater Tracer Test at the Troy Mine

Dear Joe:

Sterling Mining Company received permission from MDEQ (Abe Horpestad) to proceed with the tracer test at the Genesis Inc. Troy Mine and was requested by Abe to inform you of our progress. Because the remote groundwater monitoring system was damaged and is no longer functioning, the planned monitoring schedule has changed somewhat since the tracer test proposal revision in early February. This letter describes the modifications to the proposed monitoring schedule. We plan to conduct pre-test sampling of the wells on March 8 and 9 and to start the tracer (salt) addition on March 12, 2001.

The revised schedule for monitoring is described in attached Table 1. In this table, "tracer addition period" means the period after the salt has been added to the pond and during the period that mine water is not discharged to the pond. Revisions to the Table have been done in "redline" mode (additions are italicized, deletions are strikeout) to clarify the changes that have been made. The primary change is that continuous monitoring of wells is not possible and will not be done. To offset the loss of continuous specific conductivity data, the frequency of sampling of wells near the decant pond for SC, sodium, and chloride has been increased from weekly to daily.

Please let me know if you would like any modifications to the planned monitoring schedule.

Sincerely,

Scott Mason
Geochemist

c: Abe Horpestad
Bruce Clark
Frank Duval

Table 1. Revised Monitoring Schedule for Troy Tracer Test

	Pre-Test Baseline	Tracer Addition Period			End of Tracer Addition Period		Post Tracer Addition Period			End of Test	
Monitoring Location	Major Ions, Nutrients, & Metals (see Table 2)		Daily Specific Conductivity, Sodium, Chloride & Water Level		Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, Water Level & Specific Conductivity Only		Daily Specific Conductivity, Sodium, Chloride & Water Level		Major Ions, Nutrients, & Metals (see Table 2)	Sodium, Chloride, Water Level & Specific Conductivity Only
Decant Pond 1 *	Yes		Yes **		Yes			Yes		Yes	
Decant Pond 2 *	Yes		Yes **		Yes			Yes		Yes	
Decant Pond 3 *	Yes		Yes **		Yes			Yes		Yes	
Irrigation Well	Yes		Yes		Yes			Yes		Yes	
MW-95-8	Yes		Yes		Yes			Yes		Yes	
MW-95-7	Yes		Yes		Yes			Yes		Yes	
MW-95-3	Yes		Yes		Yes			Yes		Yes	
MW-95-4	Yes				?	Yes				?	Yes
MW-97-12	Yes				?	Yes				?	Yes
MW-97-14	Yes				?	Yes				?	Yes
MW-95-5	Yes				?	Yes				?	Yes
MW-1	Yes				?	Yes				?	Yes
MW-2	Yes				?	Yes				?	Yes
MW-3	Yes				?	Yes				?	Yes
MW-4	Yes				?	Yes				?	Yes

Notes:

? Well will be sampled for major ions, nutrients, and metals per Table 2 only if specific conductivity is 10% or more greater than pre-test result.

* Specific conductivity will be measured at four points (1 point along each side) in each pond.

** Specific conductivity will be measured three times per day during the first 3 days of the test to document mixing in the ponds.

TABLE 2 ANALYTICAL PARAMETERS FOR GROUNDWATER MONITORING AT THE TROY MINE

Analytical Parameter	Required Reporting Value * (mg/L)	Analytical Method **
Common Ions and Physical Parameters		
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TDS	(10)	EPA 160.1
Calcium	(1)	EPA 6010
Magnesium	(1)	EPA 6010
Hardness	(1)	ASTM 2340B
Potassium	(2)	EPA 6010
Sodium	(1)	EPA 6010
Total Alkalinity as $CaCO_3$	(1)	EPA 310.1
Bicarbonate	(1)	EPA 310.1
Carbonate	(1)	EPA 310.1
Chloride	(1)	EPA 300.0
Sulfate	(1)	ASTM 9036
Silica	(0.1)	EPA 6010
Temperature (field)	0.1 °C	(field)
Specific Conductivity (field)		(field)
Static Water Level (field)		(field)
Nutrients		
Ammonia as N	0.05	EPA 350.1
Nitrate + Nitrite as N	0.01	EPA 353.2
Dissolved Metals (filtered sample)		
Antimony	0.003	EPA 6020M
Arsenic	0.003	EPA 6020M
Copper	0.001	EPA 6020M
Iron	0.01	EPA 6010/6020
Lead	0.003	EPA 6020M
Manganese	0.005	EPA 6020M
Zinc	0.01	EPA 6020M

* Values in parentheses are detection limit goals, no RRVs exist for these parameters.

** Dissolved metals will be analyzed by ICP-MS (methods 6010, 6020, or 6020M).

APPENDIX E

PIPER DIAGRAMS

APPENDIX F

TRACER TEST RESULTS – SC, Na, CL Trendplots

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Appendix I
Assessment of Natural Attenuation of Metals in a Decant Pond Disposal System

ASSESSMENT OF NATURAL ATTENUATION OF METALS IN A DECANT POND DISPOSAL SYSTEM

TROY MINE

Prepared for:

Genesis Inc. Troy Mine
P.O. Box 1660
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Prepared by:

Hydrometrics, Inc.
3020 Bozeman Avenue
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May 2010

TABLE OF CONTENTS

LIST OF TABLES iv
LIST OF FIGURES v
LIST OF APPENDICES vii
EXECUTIVE SUMMARY viii
1.0 INTRODUCTION 1-1
1.1 BACKGROUND 1-3
1.2 PURPOSE AND SCOPE OF EVALUATION 1-6
1.3 LIMITATIONS AND UNCERTAINTIES 1-7
2.0 OCCURRENCE OF METALS IN TROY MINE WATER 2-1
2.1 SOURCE OF METALS 2-1
2.2 CONCENTRATIONS OF METALS IN WATER 2-2
2.3 CONCENTRATION OF COMMON ION PARAMETERS IN WATER 2-5
3.0 REVIEW OF METAL ATTENUATION LITERATURE 3-1
3.1 NATURAL ATTENUATION MECHANISMS 3-1
3.2 ANTIMONY 3-4
3.3 ARSENIC 3-4
3.4 CADMIUM 3-5
3.5 COPPER 3-6
3.6 LEAD 3-7
3.7 MERCURY 3-9
3.8 SILVER 3-10
3.9 URANIUM 3-10
4.0 FIELD EVIDENCE FOR NATURAL ATTENUATION 4-1
4.1 FIELD EVIDENCE OF ACTIVE METALS REMOVAL 4-1
4.1.1 Changes in Metal Concentrations in Groundwater 4-1
4.1.2 Changes in Metal Concentrations in Mixed Water Samples 4-3
4.1.3 Metals Enrichment of Decant Pond Sediment 4-5
4.2 FIELD EVIDENCE OF ATTENUATION MECHANISMS 4-6
4.2.1 Identification of Metal Phases in Sediment 4-7

4.2.2 Decant Pond/Mine Water and Groundwater Mixing Tests 4-8
5.0 GEOCHEMICAL EQUILIBRIUM MODELING 5-1
5.1 PROCESS MODEL FOR GEOCHEMICAL EQUILIBRIUM MODELING 5-2
5.2 GEOCHEMICAL MODELING SOFTWARE AND THERMODYNAMIC DATABASE 5-4
5.3 REPRESENTATIVE DISPOSAL WATER (MINE WATER AND DECANT POND WATER) 5-5
5.4 REPRESENTATIVE REDUCTION-OXIDATION CONDITIONS 5-6
5.5 AQUEOUS SPECIATION AND MINERAL SATURATION INDICES ... 5-11
5.6 STABILITY AND SOLUBILITY DIAGRAMS 5-16
5.6.1 Copper Oxides and Copper Iron Oxides 5-20
5.6.2 Copper Carbonates 5-22
5.6.3 Copper Hydroxysulfate 5-24
5.6.4 Copper Silicates 5-26
5.6.5 Iron 5-28
5.6.6 Lead 5-32
5.6.7 Manganese 5-34
6.0 SUMMARY SITE MODEL FOR NATURAL ATTENUATION 6-1
7.0 EVALUATION OF LONGEVITY OF NATURAL ATTENUATION MECHANISMS 7-1
7.1 ATTENUATION BY MINERAL PRECIPITATION 7-1
7.2 NEUTRAL TO ALKALINE PH 7-2
7.3 OXIDIZING REDOX CONDITIONS 7-2
7.3.1 Dissolved Silica 7-3
7.3.2 Dissolved Bicarbonate 7-4
7.4 ATTENUATION BY ADSORPTION TO MINERALS AND SEDIMENTS 7-5
7.4.1 Water pH 7-6
7.4.2 Quantity of Sorbent Material 7-7
7.4.3 Concentration of Competing Ions 7-7

8.0 MANAGEMENT PRACTICES AND MONITORING TO VERIFY CONTINUED EFFECTIVENESS OF METAL ATTENUATION 8-1
8.1 MONITORING 8-1
8.2 MANAGEMENT PRACTICES 8-1
8.3 POTENTIAL CORRECTIVE ACTIONS..... 8-2
9.0 SUMMARY AND CONCLUSIONS..... 9-1
9.1 EFFECTIVENESS AND LONGEVITY OF MONITORED NATURAL ATTENUATION 9-1
9.2 ANTIMONY 9-2
9.3 ARSENIC..... 9-3
9.4 CADMIUM 9-3
9.5 COPPER..... 9-4
9.6 LEAD 9-4
9.7 MERCURY 9-5
9.8 SILVER..... 9-5
9.9 URANIUM..... 9-5
10.0 REFERENCES..... 10-1

LIST OF TABLES

TABLE 1. METALS AND BICARBONATE CONCENTRATIONS IN TROY MINE WATER..... 2-3
TABLE 2. SUMMARY OF ATTENUATION PROCESSES FOR ANTIMONY, MERCURY AND SILVER 3-3
TABLE 3. SUMMARY OF ATTENUATION PROCESSES FOR ARSENIC, CADMIUM, COPPER, LEAD, URANIUM, AND ZINC..... 3-3
TABLE 4. RESULTS OF LABORATORY TESTING OF METAL ATTENUATION BY MIXING WITH AMBIENT GROUNDWATER 4-4

TABLE 5. TOTAL COPPER AND IRON CONTENT OF DECANT POND SOIL SAMPLES 4-5
TABLE 6. SUMMARY OF FIELD EVIDENCE OF ATTENUATION MECHANISMS 4-7
TABLE 7. PRINCIPLE COMPONENTS OF THE PROCESS MODEL FOR GEOCHEMICAL EQUILIBRIUM MODELING..... 5-3
TABLE 8. COMPARISON OF FIELD MEASURED EH AND EH CALCULATED FROM REDOX PAIRS 5-8
TABLE 9. PRIMARY AQUEOUS SPECIES OF METALS..... 5-13
TABLE 10. MINERALS SATURATED IN MINE WATER AND GROUNDWATER 5-14
TABLE 11. SUMMARY OF FACTORS AFFECTING METAL ATTENUATION BY MINERAL PRECIPITATION 6-2
TABLE 12. SUMMARY OF FACTORS AFFECTING METAL ATTENUATION BY CO-PRECIPITATION OR ADSORPTION WITH IRON AND MANGANESE MINERALS 6-3

LIST OF FIGURES

FIGURE 1. LOCATION OF TROY MINE..... 1-2
FIGURE 2. MAP OF TAILING IMPOUNDMENT SHOWING LOCATION OF DECANT POND AND MONITORING WELLS 1-4
FIGURE 3. COMPARISON OF FIELD MEASURED EH AND EH CALCULATED FROM REDOX PAIRS 5-9
FIGURE 4. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) 5-19
FIGURE 5. EH-PH DIAGRAM FOR COPPER ACTIVITY = $10^{-7.5}$ 5-20
FIGURE 6. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH IRON 5-21
FIGURE 7. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH IRON 5-21

FIGURE 8. BICARBONATE-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) 5-23
FIGURE 9. BICARBONATE-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) 5-24
FIGURE 10. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$) 5-25
FIGURE 11. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-4.25}$) 5-25
FIGURE 12. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH SULFATE (ACTIVITY = $10^{-3.5}$) 5-26
FIGURE 13. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH SULFATE (ACTIVITY = $10^{-4.25}$) 5-26
FIGURE 14. SILICA-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) 5-28
FIGURE 15. SILICA-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) 5-28
FIGURE 16. EH-PH DIAGRAM FOR IRON (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$) AND POTASSIUM (ACTIVITY=$10^{-3.2}$) 5-29
FIGURE 17. EH-PH DIAGRAM FOR IRON (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$) AND POTASSIUM (ACTIVITY=$10^{-3.2}$), GOETHITE SUPPRESSED 5-30
FIGURE 18. EH-PH DIAGRAM FOR IRON (ACTIVITY = $10^{-6.2}$ WITH SULFATE (ACTIVITY = $10^{-4.25}$) AND POTASSIUM (ACTIVITY=$10^{-4.3}$) 5-30
FIGURE 19. EH-PH DIAGRAM FOR IRON (ACTIVITY = $10^{-6.2}$ WITH SULFATE (ACTIVITY = $10^{-4.25}$) AND POTASSIUM (ACTIVITY=$10^{-4.3}$), GOETHITE SUPPRESSED 5-31
FIGURE 20. LEAD ACTIVITY-PH DIAGRAM WITH BICARBONATE ACTIVITY = $10^{-2.6}$ 5-33
FIGURE 21. LEAD ACTIVITY-PH DIAGRAM WITH BICARBONATE ACTIVITY = $10^{-3.2}$ 5-33

FIGURE 22. MANGANESE-pH DIAGRAM
WITH BICARBONATE (ACTIVITY = $10^{-2.6}$) 5-34
FIGURE 23. MANGANESE-pH DIAGRAM
WITH BICARBONATE (ACTIVITY = $10^{-3.2}$) 5-35

LIST OF APPENDICES

APPENDIX A WATER QUALITY SAMPLE SUMMARIES AND LAB REPORTS
APPENDIX B CONCENTRATION TIME SERIES GRAPHS
APPENDIX C GEOCHEMICAL MODEL RESULTS

EXECUTIVE SUMMARY

Mine and tailings water have been directed to the Troy Mine tailings impoundment for over 30 years without appreciable transport of metals in groundwater away from the infiltration pond (decant pond). This is due in part to natural attenuation of metals in the sediments beneath the infiltration pond and in the groundwater aquifer. Field evidence for natural attenuation of metals is provided by the sampling and analysis of water and soil samples in the vicinity of the tailings impoundment infiltration pond and from laboratory testing.

Water quality data shows that the concentrations of parameters that are not attenuated (e.g. chemically conservative parameters such as nitrate) are similar between the mine water/decant pond water and the underlying groundwater. This similarity in concentrations indicates that mine water is not appreciably diluted in the groundwater system in close proximity to the infiltration pond. In contrast, the concentrations of metal parameters are much lower in the groundwater than in the mine water/decant pond, indicating that metal parameters are attenuated (removed) in the groundwater system.

Analyses of sediments in the subsurface of the decant pond reveal that metals are enriched in the sediments, indicating that the metals attenuated/removed from groundwater are retained on the sediments. Microscopic and electron microprobe examination of sediments document the occurrence of secondary copper minerals (i.e., non-ore forming minerals) in the sediments. These secondary minerals form by precipitation of copper from mine water. Geochemical equilibrium modeling confirms that copper, iron, lead, and manganese minerals are oversaturated in mine water and are favored to form from mine water.

The longevity of the natural attenuation mechanisms is dependent on the duration of the geochemical conditions conducive to attenuation and to the capacity of the tailing impoundment/aquifer sediments to continue to uptake metals. **The mineral precipitation and co-precipitation mechanisms are expected to last indefinitely or in perpetuity as long as geochemical conditions remain similar to current conditions.** The adsorption mechanisms are conservatively estimated to last a minimum of 600 years.

Potential monitoring and management practices that would help ensure the continued effectiveness of metal attenuation by maintaining the geochemical conditions that are conducive to attenuation are described. The goal of monitoring and management practices would be to maintain the following current conditions at the tailing impoundment:

1. Neutral or alkaline pH;
2. Oxidizing redox conditions (moderate to high Eh);
3. Presence of moderate amounts of dissolved silica;
4. Presence of moderate amounts of bicarbonate; and
5. Presence of low to moderate amounts of organic material.

Management practices should be aimed at maintaining the existing geochemical conditions by:

1. Maintaining exposure of disposal water to atmospheric oxygen and carbon dioxide;
2. Avoiding excessive use of phosphate fertilizer for reclamation (high levels of dissolved phosphate may suppress arsenic adsorption and limit arsenic attenuation);
3. Maintaining pH by monitoring or mitigation; and
4. Maintaining the decant pond/infiltration site as an aerobic environment by monitoring and if necessary removing excessive organic material that may build up.

ASSESSMENT OF NATURAL ATTENUATION OF METALS IN DECANT POND DISPOSAL SYSTEM

TROY MINE

1.0 INTRODUCTION

This report summarizes an assessment of the natural attenuation of selected metals (antimony, cadmium, copper, lead, mercury, silver, and uranium) in post-closure mine water that is proposed to be disposed by infiltration into the reclaimed tailing impoundment at the Troy Mine in Lincoln County, Montana (Figure 1). Although there are several different sources or types of water associated with the Troy Mine, "mine water" for purposes of this evaluation, refers to water that is pumped or that flows from the underground mine workings via the mine adits. After mine closure, mine water would be piped to the tailings pond area for disposal (Genesis Inc., 2006).

Water that is used in the milling circuit and/or to transport tailings to the tailings impoundment is termed "tailings water." During operational periods, tailings water flows over the deposited tailings to the tailings decant pond where a portion of the water infiltrates to the subsurface and the remainder is pumped back to the mine for use in the mill. During times of excess mine water (especially during the mine dewatering phase of the mine restart in 2005), mine water may also flow to the decant pond directly via the tailings lines. Thus during operational periods, water in the decant pond ("decant pond water") is composed of a varying mix of tailings water, mine water, and natural rainfall and snowmelt. Since decant pond water is partially composed of mine water and is similar in metal content and overall chemistry to mine water, the fate of metals in decant pond water that infiltrates from the decant pond during operations is also considered in this report to provide additional evaluation of attenuation mechanisms.

FIGURE 1. LOCATION OF TROY MINE

LOCATION MAP	LOCATION MAP TROY MINE SANDERS COUNTY, MT	FIGURE 1

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location map.dwg

Hydrometrics, Inc.
Consulting Scientists and Engineers

1.1 BACKGROUND

The Troy Mine was developed by Asarco in 1979 and went into production in 1981. Asarco operated the mine until 1993 when the mine was placed on temporary shutdown. In 1999, the mine was purchased Sterling Mining Company (now Revett Minerals, Inc) and has been operated by Genesis Inc., a subsidiary of Revett. Mining restarted in 2005 with milling and tailings production beginning in November 2005 and continuing to this day.

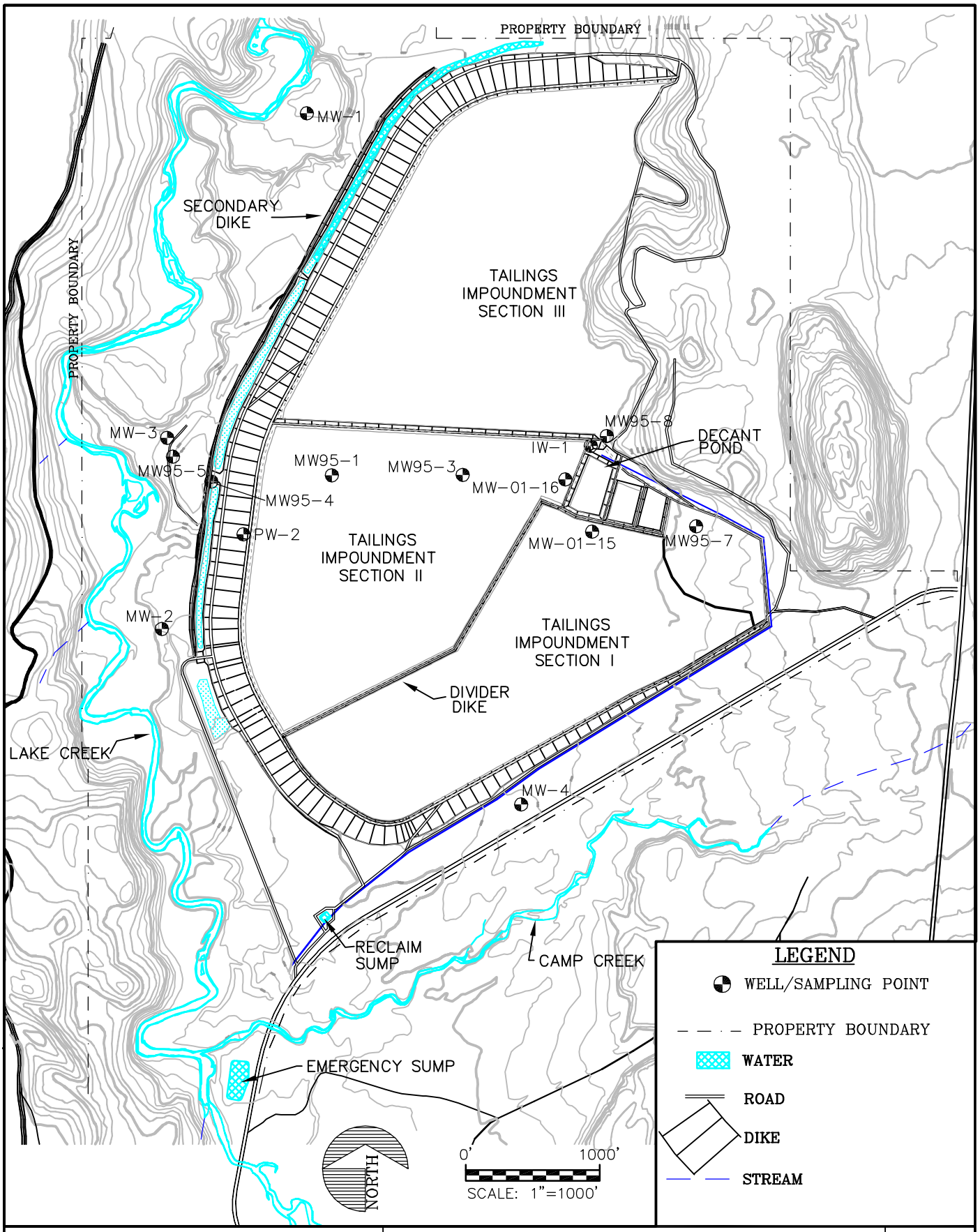
During the interim shutdown period of 1993 through 2004, Asarco and Genesis Inc. disposed of water from the underground workings by discharge to the tailings impoundment in one of three ways:

- Sprinkler irrigation over the impoundment (primarily during the growing season).
- Discharge to the decant pond (also known as the barge pond in some reports).
- Discharge to the Section III pond (an area in Section III of the impoundment where water ponds on the surface before flowing through a pipe to the decant pond).

The general layout of the tailings impoundment and associated ponds and monitoring wells is shown on Figure 2. Long-term disposal of mine water though the decant pond system after mine closure has been proposed as part of the Mine's final reclamation plan (Genesis, Inc., 2006) and is being evaluated by Montana Department of Environmental Quality (DEQ) as part of the ongoing environmental assessment of the final reclamation plan.

The primary constituent of concern is copper, which is typically present in mine water at concentrations of approximately 0.04 to 0.17 mg/L during shutdown periods. For comparison, copper concentrations in Lake Creek adjacent to the impoundment typically range from approximately <0.001 to 0.003 mg/L (higher values occur during high flow events), the chronic aquatic life standard for copper is approximately 0.004 mg/L (assuming hardness of 35 mg/L) and the Montana groundwater quality standard and Federal drinking water standard is 1.3 mg/L. In spite of the higher copper concentrations discharged to the impoundment, copper concentrations in Lake Creek and in groundwater monitoring wells installed in the impoundment vicinity have not increased measurably as a result of the

FIGURE 2. MAP OF TAILING IMPOUNDMENT SHOWING LOCATION OF DECANT POND AND MONITORING WELLS



TROY MINE	TAILINGS IMPOUNDMENT AND MONITORING WELLS	FIGURE 2

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discharge of mine waters (see Summit, 1999; Parametrix, 2008). Similar to copper, concentrations of other metals (arsenic, antimony, lead, and uranium) are significantly reduced as decant water infiltrates the sediments beneath the pond and flows in the groundwater system. Other metals of interest (cadmium, lead, mercury, silver) are present at very low concentrations and are rarely detected in mine water and decant pond water.

The observed natural attenuation of copper and other metals (i.e., the reduction in metal concentrations through natural geochemical processes) in the decant pond and groundwater system led to the consideration of the infiltration of mine water at the tailing impoundment as a potential long-term disposal and treatment method for mine water following mine closure. From 2000 through 2004, a series of field and laboratory investigations were conducted to identify the geochemical processes responsible for the natural attenuation of copper in the decant pond and groundwater system (Hydrometrics, 2000 and 2001; Land & Water Consulting, 2004). The primary findings of these studies are:

1. Permeable sand and gravel layers beneath the decant pond provide the primary pathway for transport of mine water in the subsurface;
2. Copper concentrations are quickly attenuated (reduced) to levels below human health and aquatic life standards during groundwater transport within a short distance (ten to one hundred feet) of the decant ponds; and
3. Geochemical mechanisms responsible for copper attenuation include primarily the formation of copper minerals and secondarily adsorption by organic matter in soils and sediment beneath the decant pond.

The copper minerals forming in the pond sediments and groundwater are identical to the secondary copper minerals that form within the underground workings as the primary sulfide minerals are exposed to oxygen, become thermodynamically unstable, and oxidize to form new (i.e., secondary) minerals. Thus, the copper attenuation mechanism occurring in the decant pond sediments and groundwater is the completion of a chemical reaction started in the underground mine.

Subsequent to the 2000-2004 studies (that focused on copper), the natural attenuation of arsenic, antimony, cadmium, lead, mercury, silver, and uranium from mine water and decant pond water have been evaluated by additional investigations. CDM (2010) conducted geochemical modeling and lab experiments to demonstrate the natural attenuation provided by the precipitation of iron from mixing of mine water and decant pond water with natural ambient groundwater. These studies demonstrated that precipitation of naturally-occurring iron and manganese in groundwater can significantly reduce the concentrations of arsenic, antimony, copper, lead, and uranium in mine water and decant pond water.

1.2 PURPOSE AND SCOPE OF EVALUATION

The purpose and scope of this evaluation is to further evaluate the natural attenuation of copper as well as other metals in mine water and groundwater beneath the decant pond. The purpose and scope is based on addressing issues identified in the following communications/ interactions with Montana DEQ and Kootenai National Forest:

- March 27, 2008 DEQ Task Order to CDM on copper attenuation;
- May 8, 2008 letter from DEQ to Doug Miller (Genesis);
- December 3, 2008 conference call with Wayne Jepson and Jim Castro (DEQ), Kent Whiting (CDM), Fess Foster (consultant to Genesis), Doug Parker and Scott Mason (Hydrometrics);
- December 10 meeting in Helena with DEQ, KNF (by phone), Genesis, Fess Foster, and Hydrometrics; and
- January 8, 2009 conference call with Wayne Jepson, Jim Castro, Lisa Boettcher, and Pat Plantenberg (DEQ), Kent Whiting (CDM), and Scott Mason (Hydrometrics).

The metal attenuation issues identified in these meetings and communications are:

- Evaluation of metals (antimony, cadmium, lead, mercury, silver, and uranium) in addition to copper that are present in mine water;
- Evaluation of the longevity of the natural metal attenuation mechanisms; and

- Identification of management practices and monitoring to ensure continued effectiveness of metal attenuation.

The Scope of Work for this evaluation was further clarified in the *Proposed Scope of Work for Copper Attenuation Study Addendum* (Hydrometrics, 2009). The proposed project is organized in a phased or tiered manner that follows the Tiered Analysis Approach recommended by EPA in *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volumes 1 and 2* (EPA, 2007a). EPA's tiered approach addresses four primary issues:

1. Demonstration of active contaminant removal from ground water;
2. Determination of the mechanism(s) and rate of attenuation;
3. Determination of the long-term capacity for attenuation and stability of immobilized contaminants; and
4. Design of performance monitoring program.

Some metal parameters that were initially identified for evaluation (mercury and silver) are not present at measurable concentrations in mine water and decant pond water. Moreover, potential concentrations (i.e., detection limit concentrations) in mine water and decant pond water are better than (below) applicable water quality standards. Therefore, this evaluation of the fate of these metals does not include a detailed evaluation of their attenuation behavior based on field evidence or geochemical modeling. For these parameters, the evaluation is limited to a summary of the available literature.

1.3 LIMITATIONS AND UNCERTAINTIES

As with all predictive studies, this study has certain limitations and uncertainties. They are listed below, and discussed in the following paragraphs. In spite of these uncertainties, it is felt that this study is a reliable prediction of post-mine closure water quality and the behavior

of metals in the infiltration pond and groundwater system. The reliability of these predictions is bolstered by the empirical evidence of attenuation that has occurred for over thirty years.

Limitations and uncertainties in this evaluation include:

1. The lack of actual post-closure mine water for evaluation;
2. The lack of the analysis of several metals in some previous investigations;
3. The very low or non-detectable concentrations of some metals;
4. The assumption of chemical equilibria or disequilibria in geochemical modeling; and
5. Uncertainties in the thermodynamic data upon which geochemical calculations and modeling is based.

After mine closure, disposal water would be composed exclusively of mine water plus rainfall and snowmelt that enters the disposal pond. Because the mine is not yet permanently closed, post-closure mine water does not yet exist and post-closure mine water quality cannot be directly measured. Therefore, it is necessary to base the evaluation of natural attenuation on the behavior of metals in analogous waters, namely interim shutdown mine water, operational mine water, and decant pond water. Although this adds some uncertainty to this analysis, the Troy Mine has been operating for over 30 years and there is an extensive record of mine water quality data that indicates that mine water quality is consistent over time. In addition, mine water quality data for the interim closure period (1995 through 2004) is believed to be a very good predictor of future post-closure water quality.

Concentrations of some metals (in particular arsenic, cadmium, lead, and uranium) in mine water, decant pond water, and groundwater are frequently below or just above the analytical reporting limit. The inability to determine actual concentrations in waters with reported “nondetect” results limits the extent of the evaluation of the attenuation behavior of these metals because known concentrations are required in order to quantify the amount of attenuation and to conduct geochemical models. In addition, detected results that are near the limits of analytical detection have a relatively high amount of uncertainty or imprecision.

However, because concentrations of these metals are very low and near or below detection limits, they also tend to be below applicable water quality standards and are of less environmental concern.

Extensive field and laboratory studies were conducted in 2000 through 2004 on the mechanisms of the natural attenuation of copper in mine water disposed at the decant pond (Land and Water Consulting, 2004). Metals in addition to copper were not identified as potential problems at the time and little data concerning the mechanisms of attenuation of other metals were collected. Although the evidence for natural attenuation of these other metals is strong (i.e., concentrations of arsenic, antimony, lead, and uranium in groundwater are demonstrated to be significantly reduced through natural geochemical processes), field evidence of the specific mechanisms of attenuation (e.g. adsorption, mineral precipitation, etc.) for metals other than copper is limited. In this report, the nature of attenuation mechanisms for copper and other metals is evaluated and demonstrated by additional site-specific laboratory testing and geochemical modeling of attenuation mechanisms. In addition, natural attenuation has been studied and demonstrated extensively at many other sites and a review of natural attenuation mechanisms based on scientific literature is also provided.

Virtually all geochemical modeling software including the geochemical model and software (Geochemist's Workbench; RockWare, 2010) used in this assessment are equilibrium models. Although complete chemical equilibrium is relatively rare in nature, equilibrium-based models remain powerful tools as they help to define geochemical conditions and indicate the types of geochemical changes that are likely to occur. In addition, if parts of the geochemical system are known to be in disequilibrium or partial equilibrium, the equilibrium models can be forced to maintain disequilibrium or partial equilibrium in portions of the modeled system. Instances where partial disequilibrium as assumed for modeling purposes are described in Section 5.

The thermodynamic data used for geochemical calculations and modeling in this report are from recognized sources (e.g. Lawrence Livermore National Laboratory, 2006) and are

generally considered to be valid. However, all measurements contain uncertainties and in the case of thermodynamic data such as equilibrium or solubility product constants, many of the numbers are extremely large or small (e.g. 10^{-50}) and small relative uncertainties in the data can yield relatively large uncertainties in the results of calculations (such as mineral saturation indices). To reduce the uncertainty in conclusions based on geochemical modeling, the model results are "field truthed" or corroborated with empirical evidence from field and laboratory studies to the extent possible.

2.0 OCCURRENCE OF METALS IN TROY MINE WATER

2.1 SOURCE OF METALS

The source of metals in the Troy mine water and decant pond water are the metal-bearing minerals present in and around the ore body and associated mineralized zones. As rainwater and snowmelt percolate through rock to the underground workings, the water contacts metal-bearing minerals and dissolves small amounts of copper and other trace metals. As described in the Rock Creek EIS (MDEQ and USFS, 2001):

> "Sulfide mineral oxidation is a process that may occur in pH-neutral conditions, and is the probable source of the elevated copper in the water that is in the underground workings in the Troy mine. The Troy mine has developed and exposed the bornite-digenite-native silver ore zone. Bornite is a copper-iron-sulfur mineral and digenite is a copper-sulfur mineral. The underground pillars that support the overlying sedimentary rocks are composed of ore grade bornite-digenite-native silver. In a pH-neutral oxidizing environment, the bornite-digenite-native silver minerals that occur on fracture and joint surfaces in the rock are oxidized in place to a mixture of various copper oxide minerals. These copper oxide minerals are exposed in the outcrops of the Troy orebody on the south side of Mt. Vernon and underground in the mine workings. The oxide minerals include tenorite, chrysocolla, brochantite, malachite, and cupriferous goethite, Hayes and Balla, (1986). These are all secondary copper oxide minerals which occur in areas of low acidity. The bornite and digenite minerals that occur between the individual sand grains and that comprise the main ore zone are not leached, as they are encapsulated by the quartz overgrowths that occurred during diagenesis and burial metamorphism.
>
> Subsequent melting snow water, percolating down through the various sedimentary rocks along these same fracture and joint surfaces, partially dissolve the oxidized copper oxide minerals, and the dissolved copper is seen and detected in the underground mine waters. It should be noted that in the Troy mine, the overlying galena halo zone and the pyrite halo zone were not mined and are not exposed in the Troy mine.
>
> It should also be noted that the melting snow water, percolating down through the overlying galena and pyrite halo zones, is not creating acid rock conditions, as the sampling of the underground mine waters consistently show that the pH of the mine waters is 7.2 to 7.4, a near-

neutral to alkaline condition. These conditions are what is expected be similar at the Rock Creek project site." (pg 3-29 Rock Creek FEIS Vol. 1. September 2001)

The source of other metals is similar to that of copper. Arsenic, antimony, cadmium, lead and mercury either form sulfide minerals or are present in sulfide minerals as substituting ions for sulfur or other metals. Oxidation of these sulfides leads to the release of trace amounts of these metals. Silver occurs as native silver and argentiferous sulfides in the ore body and is very slightly soluble (silver concentrations in mine water are below the analytical detection limit).

As described by Land and Water Consulting (2004) and summarized below, the copper attenuation mechanism operating in the decant pond and groundwater system today results in the formation of copper minerals that are identical to the secondary copper minerals that form within the underground workings as described in the Rock Creek EIS. Thus, the copper attenuation mechanism occurring in the decant pond sediments and groundwater is the continuation and completion of chemical reactions started in the underground mine.

2.2 CONCENTRATIONS OF METALS IN WATER

Mine water quality is routinely monitored by the collection of mine water from the mine adit at two locations: the Adit Ditch which includes wash down water from the Transfer Point and the Adit Pipe which is excess water pumped from the back of the mine. Over the course of the mine's life the analytical detection limits attainable from laboratories has continually improved (minimum detection limits have decreased) and much of the mine water quality data collected in the early years of mining was reported at elevated detection limits, relative to current limits. Inclusion of this early data skews statistical calculations and misrepresents actual concentrations. Therefore, in this evaluation only more recent data (2000 through 2009) is considered.

The concentration of metals in recent mine water (2000 through 2009) for both the interim shutdown period (2000 though November 2004 data) and the recent operational period

TABLE 1. METALS AND BICARBONATE CONCENTRATIONS IN TROY MINE WATER

Parameter (Dissolved)	Minimum (mg/L)	Maximum (mg/L)	Average* (mg/L)	Montana Groundwater Quality Standard** (mg/L)	Montana Surface Water Quality Standard** (mg/L)
Mine Water - Interim Shutdown Period 2000 through November 2004					
Arsenic	0.001	0.004	0.0021	0.010	0.010
Antimony	<0.003	0.016	0.0072	0.006	0.0056
Cadmium	No data	No data	No data	0.005	0.000097
Copper	0.044	0.17	0.076	1.3	0.00285
Iron	0.01	0.03	0.02	0.3	1
Lead	<0.002	0.003	0.0013	0.015	0.000545
Manganese	0.011	0.22	0.099	0.05	none
Mercury	No data	No data	No data	0.002	0.00005
Silver	No data	No data	No data	0.100	0.00037
Uranium	No data	No data	No data	0.03	0.03
Bicarbonate	20	113	60	none	None
Mine Water - Operational Period – December 2004 through 2009					
Arsenic	0.001	0.008	0.0026	0.010	0.010
Antimony	<0.003	0.015	0.0081	0.006	0.0056
Cadmium	0.00087	0.0022	0.0015	0.005	0.000097
Copper	0.041	0.986	0.339	1.3	0.00285
Iron	0.01	0.81	0.20	0.3	1
Lead	0.002	0.059	0.0204	0.015	0.000545
Manganese	0.025	0.312	0.177	0.05	None
Mercury	<0.000005	0.000005***	0.0000025	0.002	0.00005
Silver	<0.0005	<0.003	NC	0.100	0.00037
Uranium	<0.0003	0.0013	0.000091	0.03	0.03
Bicarbonate	49	112	84	none	none
Decant Pond Water – Operational Period – December 2004 through 2009					
Arsenic	<0.0005	0.005	0.0019	0.010	0.010
Antimony	0.008	0.062	0.028	0.006	0.0056
Cadmium	<0.0001	0.00126	0.00062	0.005	0.000097
Copper	0.006	0.20	0.0238	1.3	0.00285
Iron	0.008	0.38	0.082	0.3	1
Lead	<0.0005	0.0016	0.0013	0.015	0.000545
Manganese	0.101	0.791	0.4927	0.05	none
Mercury	<0.000005	<0.000005	<0.000005	0.002	0.00005
Silver	<0.0005	<0.003	NC	0.100	0.00037
Uranium	0.0029	0.0033	0.0031	0.03	0.03
Bicarbonate	52	121	93	none	none

Period of Record = 2000 through 2009 Data. Mine water includes Adit Ditch and Adit Pipe sampling locations.
NC = average not calculated as all values are less than analytical detection limit.
* One half of the detection limit value used for nondetect results in calculation of average.
**Circular DEQ-7 Montana Numeric Water Quality Standards, February 2008. Values for surface water standards are the lower of the human health standard or the chronic aquatic life criteria. Hardness dependent criteria based on hardness of 25 mg/L. Values for iron and manganese in groundwater is the Federal Secondary Drinking Water Standard. For silver there is no chronic aquatic life criterion, value shown is acute criterion.
***Laboratory QC results indicate that this result is biased high.

(December 2004 through 2009 data) are given in Table 1. Both the Adit Ditch and Adit Pipe are representative of mine water and therefore data from both sites is combined in Table 1. For comparison, metal concentrations in decant pond water and Montana water quality standards are also shown. Graphs in Appendix B show the concentrations of selected chemical constituents in mine water and decant pond water for the period of 2000 through 2009 and for nitrogen species for the course of mine life.

There are several key observations regarding mine water and decant pond water quality:

1. Mercury and silver are not detected, or if detected, are present at concentrations below relevant Montana water quality standards.
2. On average, metal concentrations are generally higher in mine water during the operational period (e.g. copper average concentration of 0.076 mg/L during shutdown versus 0.339 mg/L during operations; lead average concentration of 0.0013 mg/L during shutdown versus 0.0204 mg/L during operations). However, more recent (2009) operational data indicates that copper and lead concentrations have returned to near interim shutdown levels.
3. During the shutdown period, antimony is the only metal parameter that exceeds the groundwater standard (average concentration of 0.0072 mg/L in mine water compared to the standard of 0.006 mg/L). Antimony concentrations are similar in operational period mine water (average of 0.0081 mg/L). Antimony concentrations are steady in operational period mine water and in decant pond water through 2007 (about 0.02 mg/L) but increased in decant pond water in 2009 to about 0.06 mg/L. After the cessation of mining, mine disposal water is expected to be similar to current mine water (<0.003 to 0.016 mg/L).

2.3 CONCENTRATION OF COMMON ION PARAMETERS IN WATER

Graphs in Appendix B show the concentrations of selected common chemical constituents in mine water and decant pond water over the course of mine life. Notable observations regarding common ion concentrations include:

1. Much lower nitrogen concentrations during interim shutdown. The source of nitrogen in mine water is predominantly from the residues of explosives used in blasting and mining. After mining (blasting) ceases, nitrogen levels quickly fall to low levels.
2. Sulfate concentrations and pH levels in mine water are somewhat variable, probably from seasonal variations in rain and snowmelt, but relatively steady exhibiting no overall trends. The lack of trend suggests that sulfide oxidation rates within the mine are relatively steady as well, and therefore no significant change in sulfide oxidation rate and mine water pH is expected after final mine closure.
3. Common cation (calcium, potassium, sodium) concentrations are steady in mine water but exhibit some variation in decant pond water due to the addition of potassium and sodium-bearing milling reagents. Potassium and sodium concentrations in decant pond water are similar to mine water during the interim shutdown period, but are increased during active mining phases. Calcium concentrations are higher during the recent mining phase and correlate with increases in bicarbonate concentrations.
4. Bicarbonate (the principle contributor to alkalinity) concentrations during the interim mine closure typically varied between 20 and 80 mg/L and typically were about double calcium concentrations, suggesting some control of bicarbonate levels by calcite (CaCO3) solubility. Since the mine re-start in 2005, bicarbonate levels have increased and in 2009 ranged from approximately 80 to 120 mg/L (Table 1). This increase is believed to reflect the geology of the current mining area where the ore body is higher in carbonate minerals.

3.0 REVIEW OF METAL ATTENUATION LITERATURE

This Section describes the environmental chemistry and behavior of selected metals in the natural environment. This information is summarized from the following EPA publications:

- Water-related Environmental Fate of 129 Priority Pollutants, Volume 1 and 2. (EPA, 1979);
- Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 1 and 2, (EPA, 2007a);
- Metal Attenuation Processes at Mining Sites (EPA, 2007b);
- Issue Paper on the Environmental Chemistry of Metals (Langmuir et al., 2004); and
- Understanding Variation in Partition Coefficient, K_d, Values, Volumes II and III (EPA, 1999 and 2004).

3.1 NATURAL ATTENUATION MECHANISMS

Natural attenuation is typically defined as the removal or immobilization of dissolved chemical constituents (e.g. metals such as copper) from groundwater by interactions with natural aquifer materials such as soil, rock and organic matter. For inorganic constituents such as metals, the primary attenuation mechanisms are:

1. Sorption to aquifer solids;
2. Mineral precipitation; and
3. Co-precipitation.

These mechanisms may work independently or combined. For instance a metal may initially be primarily sorbed to a substrate at low surface concentrations and then form a surface precipitate as the surface concentration reaches a level where mineral nucleation and growth can occur. Langmuir et al (2004) describe this combined adsorption/precipitation as follows:

> "Except for Al and sometimes Mn, concentrations of trace metals in the environment are generally too low for those metals to exceed the solubility products of their pure metal solids and thus to precipitate. Instead, toxic metal concentrations are generally limited by sorption onto the

> surfaces of minerals, and onto organic matter including microbial cell wall surfaces. For aluminosilicate-rich soils, however, surface precipitation of Zn, Ni, and Co as layered double hydroxides was reported (e.g. Ford and Sparks, 2000). As metal concentrations further increase and fill available sorption sites, most metals tend to be incorporated in the structures of major mineral precipitates as "coprecipitates" in which they substitute for major metal cations, forming so-called solid solutions (Langmuir, 1997a). At higher metal concentrations, the metals may be precipitated in pure metal phases, limiting further increases in metal concentration."

The extent of sorption of trace metals in groundwater is largely controlled by the following factors:

1. Groundwater pH;
2. Metal concentration in solution;
3. The quantity of sorbent material (principally hydrous ferric and manganese oxides, organic matter, and clays) within the aquifer; and
4. The concentration of competing ions in solution.

The extent of co-precipitation and precipitation of metals in groundwater is largely controlled by the following factors:

1. Groundwater pH;
2. Groundwater redox (e.g. Eh or pe) conditions;
3. Metal concentrations in solution;
4. The concentrations of common ions (e.g. sulfate, bicarbonate/carbonate, hydroxide) that can form minerals with the metal ions;
5. The solubility and stability of metal-bearing minerals; and
6. The concentrations of common ions that form soluble metal complexes in solution.

Summaries of the attenuation mechanisms that have been identified in the scientific literature as controlling factors for the metals of interest are provided in Tables 2 and 3.

TABLE 2. SUMMARY OF ATTENUATION PROCESSES FOR ANTIMONY, MERCURY AND SILVER

Metal	Attenuation Mechanisms
Antimony	Sorption by iron, manganese, and aluminum oxides and clay
Mercury	Sorption by organic matter, iron and manganese oxides and clays
Silver	Sorption by iron and manganese oxides and organic matter

TABLE 3. SUMMARY OF ATTENUATION PROCESSES FOR ARSENIC, CADMIUM, COPPER, LEAD, URANIUM, AND ZINC

Contaminant	Possible Attenuation Reactions	Relevant parameters
As	Sorption in aerobic environments Sorption/Precipitation in anaerobic environments	• Abundance/stability of hosts; typically Fe and Al (hydr)oxides • Solid-phase sulfide accumulation; redox buffer capacity, sulfate reducing activity
Cd	Sorption in aerobic environments Sorption/Coprecipitation carbonates Sorption/Precipitation in anaerobic environments	• Abundance/stability of hosts; typically Fe and Al (hydr)oxides • Abundance/stability of hosts; may require consideration of pH buffer capacity • Solid-phase sulfide accumulation; redox buffer capacity, sulfate reducing activity
Cu	Sorption in aerobic environments Sorption/Coprecipitation carbonates Sorption/Precipitation in anaerobic environments	• Abundance/stability of hosts; typically Fe and Al (hydr)oxides • Abundance/stability of hosts; may require consideration of pH buffer capacity • Solid-phase sulfide accumulation; redox buffer capacity, sulfate reducing activity
Pb	Sorption/Coprecipitation in aerobic environments Precipitation as hydroxycarbonate or sulfate Sorption/Precipitation in anaerobic environments	• Abundance/stability of hosts; typically Fe and Al (hydr)oxides • Aquifer pH buffer capacity • Solid-phase sulfide accumulation; redox buffer capacity, sulfate reducing activity
U	Reductive Precipitation Sorption	• Abundance/reactivity of electron donors • Abundance of hosts; typically metal (hydr)oxides
Ni	Sorption in aerobic environments Sorption Sorption/Precipitation in anaerobic environments	• Abundance/stability of hosts; typically Fe and Al (hydr)oxides • Abundance of hosts (clays) • Solid-phase sulfide accumulation; redox buffer capacity, sulfate reducing activity

Note: *Measurement objectives and methodologies to support MNA investigations are documented in U.S. Environmental Protection Agency (2007). MNA assessments focus on both the aqueous phase and the solid phase in order to identify attenuation pathways.*

Source: Table 2 in Metal Attenuation Processes at Mining Sites (EPA, 2007b).

3.2 ANTIMONY

The attenuation of antimony is primarily controlled by adsorption mechanisms as described by Langmuir et al (2004):

> "[Antimony occurs] chiefly as oxyanions in oxidizing environments. As such they are relatively mobile, although they are adsorbed by ferrihydrite under acid to neutral conditions." (p. 60)

> "[A]ntimony may be too soluble for its concentration to be limited by mineral precipitation. The least soluble Sb phase is probably $Sb(OH)_3$, which does not precipitate until Sb concentrations exceed about $10^{-6.67}$ mol/kg, or 26 ug/L (Barnes and Langmuir, 1978). Antimony is a weak complex former, except for its reaction with sulfur at low Eh to form sulfide complexes." (p. 60)

As described by USEPA (1979):

> "The extent to which sorption reduces the aqueous transport of antimony is unknown, but it is clear that sorption processes are normally the most important mechanisms resulting in the removal of antimony from solution. Antimony apparently has an affinity for clay and other mineral surfaces. Coprecipitation of antimony with hydrous iron, manganese, and aluminum oxides may exert a significant control on antimony mobility in areas where there is active precipitation of these metals."(p. 5-3)

3.3 ARSENIC

The attenuation of arsenic in groundwater is primarily controlled by adsorption onto iron oxides and clays. As described by EPA (2004):

> "Arsenic is a known carcinogen, and occurs in natural systems in the +5 (arsenate) and +3 (arsenite) valence states. Arsenic(III) (As(III)) is more mobile (adsorbs less) and is many times more toxic than As(V). The pH and redox conditions are the two most important geochemical factors affecting the mobility of arsenic in the environment. Sorption studies indicate that the concentrations of dissolved As(V) and As(III) are controlled by adsorption on iron and aluminum oxides and clays. The adsorption of As(V) is high and independent of pH at acidic pH values, and decreases with increasing pH in the range of 7 to 9. Arsenic(V) adsorption will be decreased in soils with high phosphate concentrations because of anion competition." (EPA, 2004, p. 5.14)

"Sorption studies have also been conducted to determine the effect on arsenic sorption by the presence of other anions, such as dissolve phosphate, sulfate, nitrate, and chloride (Reynolds et al., 1999; Livesey and Huang, 1981). The results of these studies indicate that dissolved phosphate competes with arsenic for adsorption sites, and thus suppressing arsenic adsorption and enhancing the mobility of arsenic. Livesey and Huang (1981) found that dissolved sulfate, nitrate, and chloride present at concentrations present in saline soils had little effect on arsenic adsorption." (EPA, 2004, p. 5.14)

As described by USEPA (1979):

"Cycling of arsenic in the aquatic environment is dominated by adsorption and desorption to sediments. Arsenic may be sorbed onto clays, aluminum hydroxide, iron oxides, and organic material. … Under most conditions, coprecipitation or sorption of arsenic with hydrous oxides of iron is probably the prevalent process in the removal of dissolved arsenic." (p. 6-6)

3.4 CADMIUM

The attenuation of cadmium is primarily controlled by mineral precipitation and adsorption mechanisms as described by EPA (1999):

"The dominant cadmium aqueous species in groundwater at pH values less than 8.2 and containing moderate to low concentrations of sulfate ($<10^{-2.5}$ M SO_4^{2-}) is the uncomplexed Cd^{2+} species. The dominant cadmium solution species in groundwater at pH values greater than 8.2 are $CdCO_3$ (aq) and to a smaller extent $CdCl^+$. Both precipitation/coprecipitation/dissolution and adsorption/desorption reactions control cadmium concentrations. Several researchers report that otavite ($CdCO_3$) limits cadmium solution concentrations in alkaline soils. The solid $Cd_3(PO_4)_2$ has also been reported to be a solubility-controlling solid for dissolved cadmium. Under low redox conditions, sulfide concentrations and the formation of Cd precipitates may play an important role in controlling the concentrations of dissolved cadmium. At high concentrations of dissolved cadmium ($>10^{-7}$ M Cd), either cation exchange or (co)precipitation are likely to control dissolved cadmium concentrations. Precipitation with carbonate is increasingly important in systems with a pH greater than 8, and cation exchange is more important in lower pH systems. At lower environmental concentrations of dissolved cadmium, surface complexation with calcite and aluminum- and iron-oxide minerals may be the primary process influencing retardation. Transition metals (e.g. copper, lead, zinc) and alkaline earth (e.g. calcium, magnesium) cations

reduce cadmium adsorption by competition for available specific adsorption and cation exchange sites. In conclusion, the key aqueous- and solid-phase parameters influencing cadmium adsorption include pH, cadmium concentration, competing cation concentrations, redox, cation exchange capacity (CEC), and mineral oxide concentrations." (EPA, 1999)

Competition between cations for adsorption sites strongly influences the adsorption behavior of cadmium. The presence of calcium, magnesium, and trace metal cations reduce cadmium adsorption by soils (Cavallaro and McBride, 1978; Singh, 1979), iron oxides (Balistrieri and Murray, 1982), manganese oxides (Gadde and Laitinen, 1974), and aluminum oxides (Benjamin and Leckie, 1980). … The addition of copper or lead, which are more strongly adsorbed, slightly reduces cadmium adsorption by iron and aluminum oxides … In contrast, zinc almost completely displaces cadmium, indicating that cadmium and zinc compete for the same group of binding sites. (EPA, 1999, p.5.11)

Langmuir et al (2004) summarize cadmium mobility in the environment as follows:

"[Cadmium] sulfides are quite insoluble at low Eh, even at low metal and sulfide concentrations (Figures 18 through 23). … Other important Cd and Zn minerals include their carbonates, although the carbonates are relatively soluble at pH values below 8. Pure metal-containing mineral phases generally do not control the dissolved concentrations of Cd, Ni, or Zn in aerobic soils. These metals are more often controlled through adsorption or coprecipitation by oxyhydroxides of iron, manganese, and aluminum."

3.5 COPPER

Langmuir et al (2004) summarize copper mobility in the environment as follows:

"Silver, copper, and mercury are highly insoluble in reduced environments, where they precipitate as metals or as sulfides. In the absence of ligands other than OH-and depending on the copper concentration, the solubility of copper above pH 7–8 can be very low, due to the precipitation of tenorite (CuO). Moreover, in the presence of abundant carbonate, relatively insoluble Cu2+ carbonate minerals can precipitate. (p. 49)

Mercury and copper are strongly adsorbed by organic matter. All three metals are also strongly adsorbed by Fe(III) and Mn oxides, and secondarily by clays. Sorption of mercury is very fast

and practically irreversible (Bodek et al., 1988). By inhibiting mercury sorption, Hg-Cl complexing helps to mobilize the metal. Dimethyl mercury is very insoluble in water and tends to be volatilized from soils." (p. 60)

As described by USEPA (1979):

"Sorption of copper by precipitating hydrous iron and manganese oxides is an effective control on dissolved copper concentrations where these metals are being actively weathered or otherwise introduced into unpolluted aquatic environments." (p. 11-1)

"Copper has a strong affinity for hydrous iron and manganese oxides, clays, carbonate mineral, and organic matter. Sorption to these materials, both suspended in the water column and in the bed sediment, results in relative enrichment of the solid phase and reduction in dissolved levels. Hem and Skougstrad (1960) demonstrated that coprecipitation of copper with the hydrous oxides or iron effectively scavenges copper from solution." (p. 11-6)

"Copper is adsorbed to clay and mineral surfaces and organic materials. … The addition of various anions significantly increased adsorption. Humic acid was particularly effective in this regard." (p 11-9)

3.6 LEAD

The mobility and attenuation of lead is primarily controlled by mineral precipitation and adsorption mechanisms as described by EPA (1999):

"Lead has 3 known oxidation states, 0, +2, and +4, and the most common redox state encountered in the environment is the divalent form. Total dissolved lead concentrations in natural waters are very low (~10^{-8} M). Dissolved lead in natural systems may exist in free ionic form and also as hydrolytic and complex species. Speciation calculations show that at pH values exceeding 7, aqueous lead exists mainly as carbonate complexes [PbCO3 (aq), and $Pb(CO3)2^{2-}$]. Important factors that control aqueous speciation of lead include pH, the types and concentrations of complexing ligands and major cationic constituents, and the magnitude of stability constants for lead-ligand aqueous complexes.

A number of studies and calculations show that under oxidizing conditions depending on pH and ligand concentrations, pure-phase lead solids, such as PbCO3, Pb3(OH)2(CO3)2, PbSO4,

Pb5(PO4)3(Cl), and Pb4SO4(CO3)2(OH)2, may control aqueous lead concentrations. Under reducing conditions, galena (PbS) may regulate the concentrations of dissolved lead. It is also possible that lead concentrations in some natural systems are being controlled by solid solution phases such as barite (Ba(1-x)PbxSO4), apatite [Ca(1-x)Pbx(PO4)3OH], calcite (Ca (1-x)PbxCO3), and iron sulfides (Fe(1-x)PbxS).

Lead is known to adsorb onto soil constituent surfaces such as clay, oxides, hydroxides, oxyhydroxides, and organic matter. In the absence of a distinct lead solid phase, natural lead concentrations would be controlled by adsorption/desorption reactions. Adsorption data show that lead has very strong adsorption affinity for soils as compared to a number of first transition metals. Lead adsorption studies on bulk soils indicate that the adsorption is strongly correlated with pH and the CEC values of soils. Properties that affect CEC of soils, such as organic matter content, clay content, and surface area, have greater affect on lead adsorption than soil pH." (EPA, 1999)

Langmuir et al (2004) summarize lead mobility in the environment as follows:

"Lead is relatively immobile in soils, sediments, and ground waters. This reflects its strong tendency to be adsorbed by Fe and Mn oxides, but also the insolubility of a number of lead minerals including lead hydroxycarbonate, which limits lead concentrations in some public water systems, and pyromorphite, which controls lead concentrations in some soils adjacent to highways affected by road salt and leaded gasoline exhaust."

3.7 MERCURY

Mercury is not present at measurable concentrations in mine water and decant pond water. USEPA (1979) summarize the fate and mobility of mercury in the environment as follows:

> "Mercury's major removal mechanism from a natural water system is adsorption on the surfaces of particulate phases and subsequent settling to the bed sediment. The overwhelming majority of any dissolved mercury is removed in this manner with a relatively short time, generally in the immediate vicinity of the source." (p. 14-1)
>
> "Mercury is strongly sorbed to inorganic and organic particulates. Deposition of mercury-laden sediments in reducing zones can result in precipitation of the sulfide."
>
> "In summary, it is evident from environmental studies and theoretical considerations, that mercury adsorption onto the sediments is probably the most important process for determining the fate of mercury in the aquatic environment." (p. 14-8.)

Langmuir et al (2004) summarize mercury mobility in the environment as follows:

> "Bodek et al. (1988) offer a useful summary of the behavior of mercury. Hg(II) is usually complexed—in pure water as $Hg(OH)_2^o$, and at chloride concentrations typical of fresh waters (<10-2 mol/kg) as $HgCl_2^o$. Both Hg(II) and Cu(II) form strong humate complexes, so that in soils >99.9% of the metals may be complexed." (p. 49)
>
> "Mercury and copper are strongly adsorbed by organic matter. All three metals are also strongly adsorbed by Fe(III) and Mn oxides, and secondarily by clays. Sorption of mercury is very fast and practically irreversible (Bodek et al., 1988). By inhibiting mercury sorption, Hg-Cl complexing helps to mobilize the metal. Dimethyl mercury is very insoluble in water and tends to be volatilized from soils." (p. 60)

3.8 SILVER

Silver is not present at measurable concentrations in mine water and decant pond water. USEPA (1979) summarize the fate and mobility of silver in the environment as follows:

> "Sorption by manganese dioxide and precipitation with halides are probably the dominant controls on the mobility of silver in the aquatic environment." (p. 17-1)

> "Sorption appears to be the dominant process leading to partitioning of silver into the sediments. …. It appears that manganese dioxide has a strong affinity for [silver], followed by ferric hydroxide and clay minerals. … Organic materials also adsorb silver." (p. 17-3.)

Langmuir et al (2004) summarize silver mobility in the environment as follows:

> "As soft metals, silver and mercury form strong complexes with borderline soft Cl ion, which may dominate the solution chemistry of these metals. Silver and mercury form even stronger complexes with the soft halogens bromide and iodide. Silver, copper, and mercury are highly insoluble in reduced environments, where they precipitate as metals or as sulfides." (p. 49)

> "All three metals [copper, mercury, silver] are also strongly adsorbed by Fe(III) and Mn oxides, and secondarily by clays." (p. 60)

3.9 URANIUM

Uranium attenuation is primarily controlled by adsorption. As described by EPA (1999):

> "Uranium (VI) species dominate in oxidizing environments. Uranium(VI) retention by soils and rocks in alkaline conditions is poor because of the predominance of neutral or negatively charged species. An increase in CO2 pressure in soil solutions reduces U(VI) adsorption by promoting the formation of poorly sorbing carbonate complexes." (p. 5.66)

> "Some of the sorption processes to which uranyl ion is subjected are not completely reversible. Sorption onto iron and manganese oxides can be a major process for extraction of uranium from solution (Hsi and Langmuir, 1985; Waite *et al.*, 1994). These oxide phases act as a somewhat irreversible sink for uranium in soils. … Naturally occurring organic matter is another possible sink for U(VI) in soils and sediments. … Uranium sorption to iron oxide minerals and smectite clay has been shown to be extensive in the absence of dissolved carbonate (Ames *et al.*, 1982; Hsi

and Langmuir, 1985; Kent *et al.*, 1988). However, in the presence of carbonate and organic complexants, sorption has been shown to be substantially reduced or severely inhibited (Hsi and Langmuir, 1985; Kent *et al.*, 1988)." (p. 5-73)

4.0 FIELD EVIDENCE FOR NATURAL ATTENUATION

As described in Section 3, natural attenuation of metals is well established in the scientific literature based on numerous field and laboratory investigations. This section presents the site-specific field evidence for natural attenuation of metals from decant water in the groundwater system at the Troy Mine. Field evidence for natural attenuation is provided by the sampling and analysis of water and soil samples in the vicinity of the decant pond and from laboratory testing. Water quality data shows that the concentrations of chemical parameters that are not attenuated (e.g. chemically conservative parameters such as nitrate) are similar between the mine water/decant pond water and the underlying groundwater. This similarity in concentrations indicates that mine water is not appreciably diluted in the groundwater system. In contrast, the concentrations of metal parameters are much lower in the groundwater than in the mine water/decant pond, indicating that metal parameters are attenuated (removed) in the groundwater system. Analyses of sediments in the subsurface of the decant pond reveal that the metals are enriched in the sediments, indicating that the metals attenuated/removed from groundwater are retained on the sediments. Geochemical modeling described in Section 5 corroborates the field evidence.

4.1 FIELD EVIDENCE OF ACTIVE METALS REMOVAL

Water and soil sampling demonstrates that metals are removed from water and retained on solid phases on the sediment matrix as water infiltrates the decant pond and moves through the groundwater system.

4.1.1 Changes in Metal Concentrations in Groundwater

Decreases in metal concentrations in water (absent dilution) as decant pond/mine water moves through the groundwater system is evidence of active metals removal/attenuation. Since the changes in metal concentrations are rapid and dramatic, the effects of the infiltration of mine water at the decant pond can only be observed in close proximity to the pond. As described by Parametrix (2008), no changes in metal concentrations are detectable in Lake Creek adjacent the tailings impoundment or in groundwater monitoring wells near the toe of the impoundment. Changes in metal concentration (but not conservative species)

are apparent by comparison of decant pond and mine water with the three wells adjacent the pond: IW-1 (screened at 65 to 150 and 165 to 280 feet bgs), MW-95-8 (screened at 48 to 53 feet bgs), and MW-01-15 (screened at 30 to 40 feet bgs). Locations of these wells are shown on Figure 2.

Graphs comparing nitrogen and metal concentrations over time for decant pond, mine water and groundwater in the wells are provided in Appendix B. During active mine operations, mine water and decant pond water are typically elevated in nitrogen compounds (ammonia and nitrate) due the use of nitrogen-based explosives for mining purposes. Because nitrate is commonly a conservative species that is not attenuated in groundwater systems, a comparison of nitrogen concentrations between mine water/decant pond water and groundwater in the wells can be used to determine the extent of dilution in the groundwater system. As shown by the graphs in Appendix B, ammonia and nitrate + nitrite concentrations in groundwater in the monitoring wells match the concentrations in mine water and decant pond very closely, demonstrating that there is no appreciable dilution of the decant pond/mine water by ambient groundwater. In other words, groundwater near the decant pond is composed of mine water/decant pond that infiltrates the decant pond.

Because there is no appreciable dilution of mine water/decant pond water in the groundwater system monitored by the wells, any difference in metal concentration between the mine water/decant pond water and groundwater in the monitoring wells must be caused by removal (attenuation) of metals from the groundwater. As shown by the graphs in Appendix B, significant attenuation of arsenic, antimony, copper, and uranium is demonstrated to occur:

- Arsenic concentrations in decant pond water are very low (0.001 to 0.008 mg/L) and are reduced further such that arsenic is not detectable in groundwater in the monitoring wells (<0.001 to <0.003 mg/L).
- Antimony concentrations are low in mine water but range up to 0.062 mg/L in decant pond water. Concentrations are reduced to about 50 percent of the decant pond water

in the shallowest groundwater (0.032 mg/L in well MW-01-15) and further reduced to 0.005 mg/L in deeper groundwater (well MW-95-8).

- Copper concentrations were attenuated strongly, by approximately an order of magnitude in the mine shutdown phase, and to a slightly lesser extent in the current mining phase.
- Lead concentrations in mine water were very low (<0.002 to 0.003 mg/L) during the interim shutdown period and slightly higher (0.002 to 0.008 mg/L in 2009) during the current active mining phase with the exception of the mine re-start period in 2005 (up to 0.059 mg/Lin 2005). Lead concentrations range from <0.0005 to 0.0016 mg/L in decant pond water during the current active mining phase. Lead concentrations are attenuated and reduced in groundwater adjacent the decant pond as the highest groundwater concentration is 0.0011 mg/L.
- Uranium concentrations are reduced by approximately a third between the decant pond (0.003 mg/L) compared to groundwater in the closest, shallowest monitoring well (0.002 mg/L in well MW-01-15, located approximately 100 feet from the pond) and further reduced by approximately 85 percent in the deeper well (0.0005 mg/L in well MW-95-8, located approximately 150 feet from the decant pond).

Cadmium concentrations in decant pond water and mine water are low, typically <0.001 to 0.002 mg/L. Cadmium concentrations in nearby groundwater are similar to decant pond indicating that little attenuation occurs over short transport distances.

4.1.2 Changes in Metal Concentrations in Mixed Water Samples

CDM (2010) conducted geochemical modeling and a series of jar tests where mine water and decant pond water were mixed with natural groundwater from well MW-95-4 in varying ratios. The purpose of the test was to test the hypothesis that mixing of decant pond water with ambient groundwater with naturally high iron concentrations would result in the precipitation of iron oxyhydroxides and attenuation of metals by co-precipitation and adsorption mechanisms. Well MW-95-4 is located below the toe of the tailing impoundment, between the impoundment and Lake Creek as shown on Figure 2. Groundwater with naturally high dissolved iron concentrations is known to exist in the area, along, and on both

sides of Lake Creek (EPA, 1991). If water from the decant pond were to flow toward Lake Creek, it is likely that decant water would become mixed with ambient groundwater in the area, such as that monitored by well MW-95-4.

Geochemical modeling of the mixing of decant pond water with groundwater in MW-95-4 by CDM (2010) suggests that upon mixing, large amounts of iron and manganese oxyhydroxides would precipitate. The formation of iron oxyhydroxides is known to result in strong attenuation of other metals (see for instance, Langmuir, et al 2004). CDM conducted a series of mixing tests in jars to further test this effect. In these tests, samples of decant pond water and mine water were mixed with samples of groundwater from well MW-95-4, allowed to sit and react for a period of 22 days, and then were analyzed for metal concentrations. Results of the jar tests are summarized in Table 4, Section 4.1.2. In all of the jar tests, the mixing of the more oxidized decant pond and mine water caused large amounts of iron to precipitate in the groundwater resulting in strong decreases in antimony, copper, lead and uranium concentrations.

TABLE 4. RESULTS OF LABORATORY TESTING OF METAL ATTENUATION BY MIXING WITH AMBIENT GROUNDWATER

Sample	Arsenic (mg/L)	Antimony (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Uranium (mg/L)
Groundwater MW-95-4	<0.003	<0.003	0.006	15.5	<0.0005	5.34	0.0005
Decant Pond Water	<0.003	0.068	0.032	<0.05	0.0008	0.862	0.0033
Mine Water (7 East Dam)	<0.003	0.015	0.114	0.114	0.001	0.105	0.0011
25% groundwater 75% decant	<0.001	0.046	0.007	0.008	<0.0005	2.17	0.0017
50% groundwater 50% decant	<0.001	0.026	0.005	0.009	<0.0005	3.49	0.0009
75% groundwater 25% decant	<0.001	0.010	0.003	0.008	<0.0005	4.86	0.0004
25% groundwater 75% mine water	<0.001	0.010	0.012	<0.005	<0.0005	1.52	0.0007
50% groundwater 50% mine water	<0.001	0.006	0.005	0.007	<0.0005	2.74	0.0004
75% groundwater 25% mine water	<0.001	0.002	0.003	<0.005	<0.0005	4.47	<0.0005

Source: Table 4-1. CDM (2010). Mine water was collected within the mine behind the 7 East Dam.

4.1.3 Metals Enrichment of Decant Pond Sediment

Geochemical testing of aquifer materials was conducted in 2003 during the interim shutdown period (Land & Water Consulting, 2004). Testing was conducted on sediment materials collected from pits dug in the bottom of the decant pond while the pond was nearly dry. Laboratory testing consisted of total metal analyses, sequential extraction analyses, microscopic examination and electron microprobe analyses.

Total metal analyses were performed to determine the overall metal content of sediments in order to identify areas of metal enrichment. Comparison of copper concentration in decant pond sediment with copper concentrations in Troy tailings and native soils indicates that all of the sediment samples collected at depths of less than four inches are strongly enriched in copper relative to native soils and tailings (Table 5 and Figure 3). Some soil/sediment samples (DP-1 3 ¾ "and DP-1 4") are enriched to the extent that they contain nearly twice the copper content as ore from the Troy mine. Total copper concentrations in decant pond sediments are evidence that copper is attenuated in surficial soil/sediments in the decant pond.

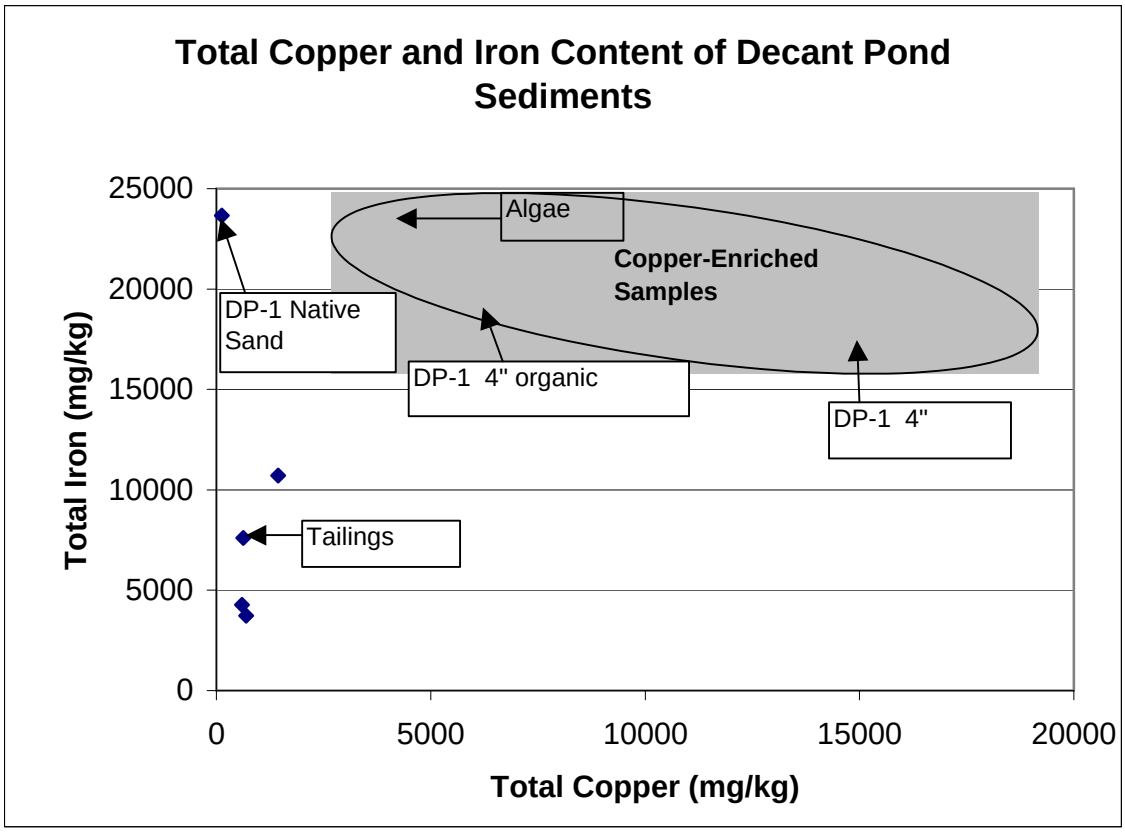
TABLE 5. TOTAL COPPER AND IRON CONTENT OF DECANT POND SOIL SAMPLES

Sample Designation	Total Copper (mg/kg or ppm)	Total Iron (mg/kg or ppm)
DP-1 algae	3,881	23,380
DP-1 0-1"	5,672	21,520
DP-1 3 ¾"	14,010	18,170
DP-1 4"	14,850	17,580
DP-1 4" organic	5,987	19,450
DP-1 2-4" slime tails	1,441	10,720
DP-1 4-8" sand tails	698	3,724
DP-1 1-4' sand tails	594	4,269
DP-1 native sand	127	23,660
Troy tailings (1)	630	7,600
Troy ore (2)	7,600	--
Native soil (3)	10 to 30	

(1) Data source: Table 4-23, Rock Creek Final EIS, September 2001.
(2) Data source: Table 3-2, Rock Creek Final EIS, September 2001.
(3) Data source: Appendix D, Troy Unit Revised Reclamation Plan, (Hydrometrics et al, December 2000).

Source of Table: (Land and Water Consulting, 2004)

FIGURE 3. COPPER AND IRON CONTENT OF DECANT POND SEDIMENTS



4.2 FIELD EVIDENCE OF ATTENUATION MECHANISMS

Evidence of attenuation mechanisms and rates of attenuation comes from the sampling and analysis of water and soil samples in the vicinity of the decant pond, laboratory mixing and testing of waters, and correlations between metal concentrations and water chemical indicators. Field evidence is corroborated by geochemical modeling as illustrated by Eh-pH and activity diagrams in Section 5. A summary of the identified attenuation mechanisms and the evidence supporting these mechanisms is provided in Table 6.

TABLE 6. SUMMARY OF FIELD EVIDENCE OF ATTENUATION MECHANISMS

Mechanism	Metals Attenuated by Mechanism	Field Evidence
Carbonate Mineral Formation	Cu	Sequential extraction Visual identification Electron microprobe analysis
Ion Exchange/Adsorption	As, Cu, Sb, Pb and U	Sequential extraction Jar mixing tests
Organic Matter	Cu	Sequential extraction Visual identification
Silicate Mineral Formation	Cu	Sequential extraction Visual identification Electron microprobe analysis
Co-precipitation with Iron oxides	As, Cu, Sb, Pb and U	Sequential extraction Visual identification Electron microprobe Jar mixing tests

4.2.1 Identification of Metal Phases in Sediment

As decant pond water infiltrates sediments beneath the pond, metals are removed from the water and incorporated into the sediments as evidenced by the decrease in groundwater metal concentrations and the corresponding increase in sediment metal concentrations. The forms of occurrence or phases of metals in decant pond sediments are indicative of the mechanisms of attenuation that cause the forms or phases to occur. Thus, the attenuation mechanisms can be identified by identifying the forms of occurrence of metals in decant pond sediments. Corroboration of these mechanisms is also provided by geochemical modeling that indicates that mine water and decant pond are oversaturated with copper, iron, lead, and manganese minerals, thus metals are expected to precipitate and to be removed from these waters.

Geochemical testing of decant pond sediments was conducted in 2003 during the interim shutdown period (Land & Water Consulting, 2004). Testing was conducted on sediment materials collected from pits dug in the bottom of the decant pond while the pond was nearly dry. Laboratory testing consisted of total metal analyses, sequential extraction analyses, and

visual reflected light microscopy and electron microprobe analyses. As described in Section 4.1.3, total metal analyses demonstrated that sediment beneath the decant pond is highly enriched in copper due to the attenuation of copper as decant infiltrates the sediments. Sediments were also analyzed by sequential extraction and electron microprobe to identify the forms of copper in the sediments.

Sequential extraction analyses were performed to identify the sediment solid phases enriched in copper. These analyses determined the trace metal contents of six phases: water soluble, exchangeable and carbonate, manganese oxides, organic matter, amorphous iron oxides, silicates and crystalline oxides (see Gatehouse et al, 1977). Sequential extraction results indicate that the dominant copper-bearing phases in the decant pond soils are exchangeable ions and carbonates, organic matter and sulfides, and silicates. It should be noted that the sulfide minerals are believed to be ore minerals that were not captured during the milling and metal concentration process and are not believed to represent attenuation of metals by sulfide formation.

Visual (stereo microscope) and electron microprobe analyses of sediment samples were performed to identify mineral phases enriched in copper (Cannon Microprobe, 2003). Copper phases identified in the samples included:

1. Copper silicates (likely the blue-green mineral chrysocolla);
2. Copper carbonates (likely the green mineral malachite);
3. Copper manganese silicates;
4. Copper iron oxides; and
5. Copper iron sulfides (likely chalcopyrite and bornite).

4.2.2 Decant Pond/Mine Water and Groundwater Mixing Tests

Geochemical modeling of the mixing of decant pond water with groundwater in MW-95-4 by CDM (2010) indicates that upon mixing, large amounts of iron oxyhydroxides would precipitate. The formation of iron oxyhydroxides is known to result in strong attenuation of other metals (see for instance, Langmuir, 2004). To further test this adsorption/co-

precipitation effect, a series of water mixing tests were conducted in jars. In these tests, samples of decant pond water and mine water were mixed with samples of groundwater from well MW-95-4, allowed to sit and react for a period of 22 days and then were analyzed for metal concentrations. Results of the jar tests are summarized in Table 4, Section 4.1.2. In all of the jar tests, the mixing of the more oxidized decant pond and mine water caused large amounts of iron to precipitate in the groundwater resulting in strong decreases in antimony, copper, lead and uranium.

5.0 GEOCHEMICAL EQUILIBRIUM MODELING

The geochemical system considered in this report includes mine water, decant pond water, and groundwater and associated minerals (e.g. in sediments beneath the decant pond) and gases (e.g. oxygen and carbon dioxide in the atmosphere) that comprise the decant pond and adjacent groundwater system. In this assessment of natural attenuation mechanisms, the purpose of constructing thermodynamic equilibrium models of the geochemical system is to:

1. Determine the geochemical conditions of disposal water including redox conditions, the activities of metals and other ions in water, and the saturation indices of metal-bearing minerals that may be important in attenuation of metals;
2. Identify the geochemical controls on metal attenuation mechanisms and water quality;
3. Identify geochemical changes that are likely to occur to the water as water approaches geochemical equilibrium in the disposal pond and groundwater system; and
4. Identify the potential geochemical changes that could impede or preclude the attenuation of metals and potential mitigation methods.

The overall approach to geochemical modeling in this assessment is as follows:

1. Define the framework and goals of modeling;
2. Select the geochemical software and thermodynamic database;
3. Select the representative waters to be modeled and the system constraints;
4. Calculate the activities of the important aqueous metal species and the saturation indices of solid metal phases (i.e., minerals); and
5. Construct stability and solubility diagrams to graphically show the relationships between aqueous metal species, minerals, and the geochemical parameters (e.g. Eh and pH) controlling the relationships between the aqueous species and mineral phases.

5.1 PROCESS MODEL FOR GEOCHEMICAL EQUILIBRIUM MODELING

The first and most critical step in developing a geochemical model is conceptualizing the system or process of interest in a useful manner (Bethke, 2008). As described by EPA (2007a):

> "The modeling effort begins with the careful identification of the processes that play significant roles in contaminant migration and attenuation at the site. In this way a conceptual model emerges that will eventually be coded into the input streams of the software packages that will produce the modeling results." (p. 10)

The process model of the Troy Mine water disposal cycle is a description of the processes affecting water quality and forms a guide or general framework for formulating the computer-based geochemical model. In most cases, it is not necessary or practical to construct a geochemical model that includes all aspects of the process model. For this assessment of natural attenuation the primary area of interest is the water in the decant pond and groundwater system. Therefore, this portion of the water disposal cycle model is examined in detail using computer-based geochemical equilibrium models as described in this section.

The process model for geochemical equilibrium modeling is summarized in Table 7. In this model, water is initially formed in the atmosphere and falls as rain or snow. It then interacts with a variety of different phases (atmospheric gases, minerals, organic matter, etc.) present in soil, groundwater systems, and the tailings impoundment and disposal pond. Several trends or cycles in the major element composition of water are observed as water moves through the hydrologic system of the mine:

1. Oxygen – Meteoric water is fully oxygenated but as the water moves through the soil profile oxygen is consumed by microbes and the decomposition of organic matter. In the bedrock aquifer, oxygen is further consumed by sulfide minerals. Upon entering the mine voids water is once again exposed to atmospheric oxygen and becomes more oxygenated; this process of oxygenation continues as water is transported to the decant pond and infiltrates to the groundwater system. The formation of oxide

TABLE 7. PRINCIPLE COMPONENTS OF THE PROCESS MODEL FOR GEOCHEMICAL EQUILIBRIUM MODELING

Water Type	General Water Quality	Principle Phases in Contact with Water	Principle Changes/Reactions Occurring
Meteoric Water	Dilute, slightly acidic, oxygenated rainwater	Atmospheric gases (O_2, CO_2, SOx, NOx) and particulates	Equilibrium with atmospheric gases
Soil Water	Less dilute, less oxygenated, high pCO_2	Soil gases, minerals, organic matter	Equilibrium with soil gases Consumption of oxygen by microbes/organic matter Dissolution of soil minerals Ion exchange
Groundwater	Less dilute, less oxygenated, high pCO_2, some metals	Aquifer minerals (primarily bedrock)	Partial equilibrium with minerals Sulfide mineral oxidation
Mine Water	More oxygenated, higher metals	Atmospheric gases Waste rock and ore including sulfide minerals Explosive residues (temporary)	Partial equilibrium with atmospheric gases Partial equilibrium with waste rock and ore Sulfide mineral oxidation Dissolution of explosive residues (temporary)
Water Disposed to Impoundment surface	More oxygenated, higher silica	Atmospheric gases Tailings Soil (after reclamation) Organic material	Partial equilibrium with atmospheric gases Evaporation Dilution by rain/snowmelt Partial equilibrium with tailings
Decant/Disposal Pond Water	More oxygenated, decreased metals	Atmospheric gases Sediments Tailings	Partial equilibrium with atmospheric gases Evaporation Dilution by rain/snowmelt Partial equilibrium with tailings/sediment Precipitation of metallic minerals
Groundwater	More oxygenated, decreased metals	Aquifer minerals (primarily unconsolidated glacial and fluvial deposits)	Precipitation of metallic minerals Adsorption of metals to aquifer sediments

minerals is favored by the oxidizing nature of the water. Isolated from the atmosphere once again, the water becomes less oxygenated as it infiltrates to groundwater.

2. Carbon dioxide/carbonate – Meteoric water is in equilibrium with atmospheric CO_2 but contains relatively low amounts of carbonate. As water moves through the soil profile, microbes and the decomposition of organic matter generate CO_2 and reduce pH, water dissolves carbonate from rocks and soil particles and the partial pressure of CO_2 (pCO_2) and carbonate content rise. In the bedrock aquifer, carbonate content may increase further as carbonate minerals are contacted and dissolved. Upon entering the mine voids, water is once again exposed to the lower atmospheric pressure of CO_2, some degassing of CO_2 and reduction in carbonate alkalinity occurs, and pH may rise (depending on how much acid is contributed by sulfide mineral oxidation). As water is disposed at the decant pond and infiltrates sediments, carbonate content may rise again from contact with additional carbonate minerals in tailings and sediments and from decomposition of organic matter in sediments.
3. Silica – Silicate minerals are the major rock forming minerals. Silicate minerals generally have low solubilities and in addition the rate of silicate dissolution is slow. The silica content of meteoric water is initially low. As water moves through the soil, bedrock aquifer, and mine voids, the silica concentration slowly increases due to the dissolution of silicate minerals. This process continues as water contacts the tailings (predominately finely ground quartz silica) and moves through the decant pond sediments and groundwater system.

5.2 GEOCHEMICAL MODELING SOFTWARE AND THERMODYNAMIC DATABASE

Several computer software packages are available that are accepted and approved by the scientific community and that are commonly used for geochemical modeling (e.g. PHREEQC, WATEQ, and Geochemist's Workbench). Each of these software packages has its own nuances, strengths and weaknesses of use and the choice of the most appropriate software depends on the purpose of the model and to some extent personal preference of the modeler. For the purposes of this assessment, Geochemist's Workbench was selected due to

its ease of use and ability to generate a variety of visual aids (e.g. activity diagrams, solubility diagrams, Eh – pH diagrams) that are useful in interpreting and describing geochemical conditions.

Geochemist's Workbench includes several thermodynamic databases that can be employed, including Lawrence Livermore National Laboratory (LLNL) database, the PHREEQC database, the WATEQF database, and an updated version 8, release 6 LLNL database. All of these databases are generally accepted and approved by the scientific community and are commonly used for geochemical modeling. The choice of database for this assessment was based on the inclusion of data for the constituents of concern (arsenic, antimony, cadmium, copper, lead, uranium, and zinc) in the databases. The updated version 8, release 6 LLNL database (LLNL, 2006) is found to be the most complete and therefore is used in all modeling described in this report.

5.3 REPRESENTATIVE DISPOSAL WATER (MINE WATER AND DECANT POND WATER)

After mine closure, disposal water would be composed exclusively of mine water plus rainfall and snowmelt that enters the reclaimed tailing impoundment infiltration area. Because the mine is not yet permanently closed, post-closure mine water quality can not be directly measured but instead must be estimated based on past and present quality of mine water and decant pond water. Waters that are believed to be most representative of post-closure are mine water and decant pond during the interim shutdown period of 1993 through 2004 and recent (2009) mine and decant pond water, with some exceptions (i.e., nitrogen levels after closure will be much lower than during operations). However, the majority of water quality analyses conducted on mine water, decant pond water and groundwater did not contain a complete list of analytes sufficient to support geochemical modeling. Therefore, water samples used for geochemical modeling are limited to samples collected in 2003 during the investigation of attenuation mechanisms described in Land and Water Consulting (2004) and samples collected in 2009 specifically for geochemical modeling. Sampling summaries and lab reports for these samples are included in Appendix A.

5.4 REPRESENTATIVE REDUCTION-OXIDATION CONDITIONS

Reduction-oxidation conditions (commonly referred to as "redox") control many of the primary equilibria or relationships that characterize water and affect the attenuation of metals. For instance, redox conditions control whether an aqueous species (such as Fe^{++} or Cu^{+}) is stable and soluble in water or whether the aqueous species is unstable and will react to form a different aqueous species (e.g. Fe^{+++} or Cu^{++}) or a solid mineral phase (such as hematite or cuprite). Some metals, such as arsenic, may exhibit different adsorption behavior depending on whether the aqueous species is more or less oxidized. Redox conditions are typically defined in terms of potential (i.e., Eh measured in millivolts). Redox relationships involve at least two aqueous species or phases (e.g. a gas or mineral) in which one species is more reduced, one species is more oxidized, and electrons are exchanged. The two related species are termed a "redox pair." Common redox relationships or pairs in water include:

- Ammonia (NH_3^o)and nitrate (NO_3^{-2});
- Ferrous iron (Fe^{++}) and ferric hydroxide ($Fe(OH)_3$) iron; and
- Sulfide (S^-) and sulfate (SO_4^{-2}).

Unfortunately redox conditions in water are difficult to assess or define and difficult to model as very few waters are actually in complete redox equilibrium where all redox pairs demonstrate equilibria with the same redox condition or Eh value. Lindberg and Runnels (1984) recommend evaluating all of the redox couples within a solution to determine if the system is in redox equilibrium. The definition of redox conditions for geochemical modeling in this assessment used a weight-of-evidence approach as follows:

- Step 1 – Field measurements of ORP (oxidation-reduction potential made with a platinum electrode) were made at the time of sample collection and converted to Eh values (adjustment of potential to be relative to the standard hydrogen electrode and corrected for temperature).
- Step 2 – Eh values were calculated based on measured concentrations of all available redox pairs:

    - Assume measured concentration defines overall or bulk concentration of redox pair species.
    - Calculate activities of redox pair species using Geochemist's Workbench software.
    - Calculate Eh values for redox pairs using Geochemist's Workbench software.
- Step 3 – Consider chemical indicators of redox conditions and processes.
- Step 4 – Select Eh value for modeling:
    - Select system Eh value based on weight-of-evidence from Steps 1 through 3.
    - Allow selected redox pairs to remain in disequilibria.
- Step 5 – Construct Eh –pH diagrams to show metal solubility under a range of redox conditions.

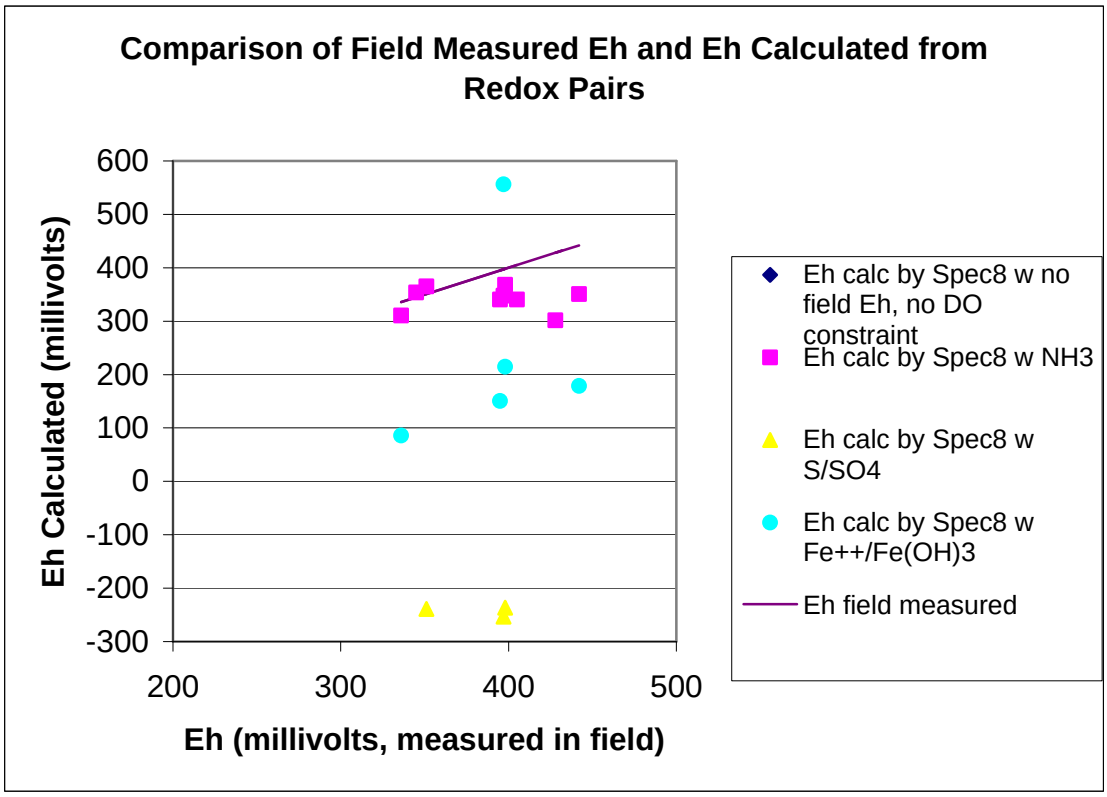
Table 8 summarizes field measurements and calculated Eh values for the ammonia/nitrate, sulfide/sulfate, and ferrous iron/ferric hydroxide redox pairs for the various water samples. As shown in Figure 3, field measured Eh and calculated Eh for sulfide/sulfate and ferrous/ferric hydroxide do not correlate well, indicating that the redox pairs are in disequilibrium. Field measured Eh values correlate fairly well with Eh calculated based on total ammonia and nitrate+nitrite concentrations. Although it is tempting to view this correlation as proof that field and ammonia/nitrate Eh values are the most correct, this correlation may simply reflect the fact that the platinum electrode used in the field measurements is more responsive to nitrogen species than to iron and sulfur species (perhaps due to the relatively high concentrations of the nitrogen species compared to sulfur and iron species). It should also be noted that the concentrations of iron and sulfide are generally low, just slightly higher than the analytical detection limits and may be subject to a relatively high degree of uncertainty; thus Eh calculated from iron and sulfur redox pairs may also be subject to a relatively high degree of uncertainty.

TABLE 8. COMPARISON OF FIELD MEASURED EH AND EH CALCULATED FROM REDOX PAIRS

	Ferrous Iron (mg/L)	Diss. Oxygen (mg/L)	Sulfide (mg/L)	Nitrate (mg/L)	Eh field (milliV)	Eh calc. from redox pairs (millivolts)		
						NH_3/NO_3	S^-/SO_4	$Fe^{2+}/Fe(OH)_3$
Mine Water Adit Ditch May 2009	ND	10.75	ND	14.25	405	340.4		
Mine Water Adit Pipe May 2009	0.05	11.11	ND	35.37	395	340.6		150.7
MW-01-15 May 2009	0.06	5.17	0.05	74.37	398	368.4	-236.2	214.6
Decant Pond May 2009	0.06	8.19	0.04	77.91	397	348	-253.1	556
MW-01-15 June 2009	ND	4.35	0.04	64.19	351	365	-238.7	
Decant Pond June 2009	0.05	6.86	ND	64.19	336	310.8		85.7
MW-95-8 June 2009		4.52	ND	108.5	345	354		
MW-95-8 July 2009		5.37	ND	97.83	432			
Decant Pond July 2009		6.26	ND	60.2	428	301.6		
MW-01-15 July 2009	0.06	3.34		62.42	442	350.6		178.8
Mine Water Pipe April 2003			Na	4.869				
Mine Water Ditch April 2003			Na	0.5755				
Transfer Point April 2003			Na					
Mine Water 9 East April 2003			Na	1.726		353.8		
Mine Water UQ-1 April 2003			Na	1.815		347		

ND = not detected.

FIGURE 3. COMPARISON OF FIELD MEASURED EH AND EH CALCULATED FROM REDOX PAIRS



Chemical indicators of redox conditions (Table 8) include dissolved oxygen concentrations, presence/absence of sulfide, ammonia, and dissolved iron. McMahon and Chappelle (2008) propose that the dominant redox processes in groundwater can be classified based on dissolved oxygen (DO), ferrous iron, manganese, nitrate, sulfate, and sulfide concentrations. In this classification, all waters containing greater than 0.5 mg/L DO and less than 0.1 mg/L iron are considered to be oxic, with oxygen as the principle electron acceptor. Classification as oxic is also supported by comparison of the low concentrations of the reduced species sulfide, ammonia and ferrous iron. Westall (2002) notes that in the presence of dissolved oxygen, field Pt electrode measured Eh is typically high, in the range of 300 to 400 millivolts.

Although the data are not conclusive given the redox disequilibrium, the redox evidence points to a fairly high Eh indicative of an oxic environment. The field Eh measurements and ammonia/nitrate redox pairs both satisfy this requirement and are in good agreement. However, some water samples did not contain measurable amounts of ammonia. Therefore, field Eh was selected to define system Eh for purposes of modeling. For samples from 2003 in which field Eh is not available, Eh calculated from the ammonia/nitrate redox pair is assumed.

Given that none of the redox pairs exactly match the field Eh, the imposition of this Eh condition during modeling has the potential effect of causing chemical concentrations (and activities) to shift away from the measured concentrations toward the concentrations that are calculated to be in equilibrium with the imposed Eh. For instance, if a water sample has a field Eh of 400 millivolts and a calculated Eh based on the ammonia/nitrate pair of 300 millivolts then the ratio of ammonia and nitrate concentrations is not in equilibrium with the Eh of the system as defined in the model. If the model is configured to equilibrate aqueous redox species, then the activities (and concentrations) of ammonia and nitrate will be adjusted according to the redox reaction so that a portion of the ammonia is converted to nitrate and the calculated Eh of the ammonia/nitrate redox pair matches that of the system Eh, in this case field Eh. If this adjustment is not desired, the model may be configured to "decouple" the ammonia/nitrate redox pair from the system Eh and the redox disequilibria of the pair as compared to the system Eh will be retained.

The choice of whether to allow redox pairs to be "coupled" to the system Eh so that concentrations are in equilibria with system Eh or whether to decouple redox pairs to maintain the measured species concentrations depends on both the available data and the purpose of the modeling exercise. In this assessment, all metal redox pairs were coupled to system Eh (as defined by field Eh) for the following reasons:

- All metal concentrations are for bulk concentrations of the elements (e.g. iron as Fe, copper as Cu) and the concentrations of the aqueous ions (e.g. Fe^{2+}, Fe^{3+}, Cu^{+}, Cu^{++}) are unknown. Coupling of the redox pairs is necessary to allow calculation of the

concentrations (and activities) of aqueous metal species and the saturation indices of metallic minerals (see discussion in Section 5.5) below.

- One of the purposes of modeling is to identify attenuation reactions that are occurring or are likely to occur in the groundwater. To do this it is necessary to identify the saturation state of the various metallic minerals and in many cases mineral stabilities are dependent on redox conditions.

Other redox pairs, such as ammonia/nitrate and sulfide/sulfate were not coupled with system Eh. The potential or Eh of ammonia/nitrate pair is in close agreement with the selected system Eh (field Eh) (see Figure 5) and so little would be gained by this coupling. The sulfide/sulfate redox pair was not coupled because given the high system Eh, essentially all of the sulfide would be converted to sulfate. Although this would have little effect on sulfate concentrations since sulfide concentrations are several orders of magnitude less than sulfate, it would greatly affect the potential stability of sulfide minerals. In order to allow the assessment of the potential for sulfide minerals to precipitate from waters, the sulfide/sulfate pair was not coupled, allowing sulfide to remain in solution in the model runs.

5.5 AQUEOUS SPECIATION AND MINERAL SATURATION INDICES

All laboratory water analyses report constituent concentrations in terms of the bulk concentrations (mass/unit volume) of the constituent element (e.g. 1 mg/L copper as copper). In actuality, elements are present in water in a variety of ionic forms or " aqueous species" (e.g. Cu^{++}, Cu^{+}) and ion complexes (e.g. $Cu_2(OH)_2^{2+}$). Moreover, the equilibria of chemical reactions such as mineral precipitation, and therefore mineral saturation indices, are dependent on the activity of constituents rather than on concentration. Activity is defined as:

$$\text{Activity} = [\text{concentration} / \text{molecular weight}] \times \text{activity coefficient}$$

Where the activity coefficient is dependent on the amounts and types of other ionic species in water (i.e., the ionic strength of the solution).

The speciation of the various chemical constituents, the activities of all aqueous species, and mineral saturation indices for all mine water, decant pond, and groundwater samples were calculated using the Spec8 module of the Geochemist's Workbench program as follows:

- All model runs were constrained by field Eh or Eh calculated from the ammonia/nitrate redox pair if field Eh was not available.
- All redox pairs that include metals of interest (i.e., arsenic, copper, iron, manganese[DP1]) were coupled to system Eh.
- No minerals or gases were allowed to dissolve, precipitate, or exsolve (i.e., the system is closed).
- The original charge imbalance in the water analysis was retained (not balanced).

The primary aqueous species for the metals of concern are summarized in Table 9. Mineral saturation indices for saturated phases and select unsaturated phases containing metals of concern are summarized in Table 10. Complete outputs of the model runs are included in Appendix C.

Aqueous metal speciation is similar for all water types and is summarized as follows:

- Divalent metals cadmium, copper, lead, iron and manganese are predominately present as simple divalent cations (Cd^{+2}, Cu^{+2}, Pb^{+2}, Fe^{+2}, Mn^{+2}) and are not complexed to any significant extent by anionic species.
- Arsenic is present predominately as an oxide (monoprotic arsenic acid).
- Antimony is present predominately as a hydroxide complex.
- Uranium is present as a carbonate complex.

A "saturated" mineral phase is a mineral that is in equilibrium with water where the mineral ion activity product (IAP) is equal to the mineral solubility equilibrium constant (K). Mineral saturation index (SI) is defined as log IAP/K. Oversaturated minerals are favored to precipitate or form from solution and have positive SI values (SI greater than zero). Undersaturated minerals are favored to be dissolved into solution, and have negative SI

TABLE 9. PRIMARY AQUEOUS SPECIES OF METALS

	Arsenic	Antimony	Cadmium	Copper	Lead	Iron	Manganese	Uranium
Mine Water Adit Ditch May 2009	$HAsO_4^{-2}$	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Pb^{++}	Not detected	Mn^{++}	$UO_2(CO_3)_2^{-2}$
Mine Water Adit Pipe May 2009	$HAsO_4^{-2}$	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Pb^{++}	Fe^{+2}	Mn^{++}	$UO_2(CO_3)_3^{-4}$
MW-01-15 May 2009	Not detected	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Pb^{++}	Fe^{+2}	Mn^{++}	$UO_2(CO_3)_2^{-2}$
Decant Pond May 2009	$HAsO_4^{-2}$	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Pb^{++}	Fe^{+2}	Mn^{++}	$UO_2(CO_3)_2^{-2}$
MW-01-15 June 2009	Not detected	$Sb(OH)_3$	Not detected		Not detected	Not detected	Mn^{++}	$UO_2(CO_3)_2^{-2}$
Decant Pond June 2009	$HAsO_4^{-2}$	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Pb^{++}	Fe^{+2}	Mn^{++}	$UO_2(CO_3)_3^{-4}$
MW-95-8 June 2009	Not detected	Not detected	Cd^{++}	Cu^{++}	Not detected	Not detected	Not detected	$UO_2(CO_3)_3^{-4}$
MW-95-8 July 2009	Not detected	Not detected	Not detected	Cu^{++}	Not detected	Not detected	Not detected	$UO_2(CO_3)_3^{-4}$
Decant Pond July 2009	$HAsO_4^{-2}$	$Sb(OH)_3$	Cd^{++}	Cu^{++}	Not detected	Not detected	Mn^{++}	$UO_2(CO_3)_2^{-2}$
MW-01-15 July 2009	Not detected	$Sb(OH)_3$	Not detected	Cu^{++}	Not detected	Fe^{+2}	Mn^{++}	$UO_2(CO_3)_2^{-2}$
Mine Water 9 East April 2003	$HAsO_4^{-2}$	Not detected	Not analyzed	CuCO3(aq)	Not detected	Not detected	Mn^{++}	Not analyzed
Mine Water UQ-1 April 2003	Not detected	Not detected	Not analyzed	CuCO3(aq)	Not detected	Not detected	Mn^{++}	Not analyzed

TABLE 10. MINERALS SATURATED IN MINE WATER AND GROUNDWATER

	Antimony Cadmium	Copper	Lead	Iron	Manganese
Mine Water Adit Ditch May 2009	None	Brochantite Malachite Tenorite (Dioptase)	Cerussite	None	(Rhodochrosite)
Mine Water Adit Pipe May 2009	None	Ferrite-Cu Malachite Tenorite Delafossite Brochantite (Dioptase)	Cerussite	Hematite Ferrite-Cu Magnetite Delafossite Goethite Jarosite $Fe(OH)_3$	(Rhodochrosite)
MW-01-15 May 2009	None	Ferrite-Cu Malachite Tenorite Delafossite	(Cerussite)	Hematite Ferrite-Cu Magnetite Delafossite Goethite Jarosite $Fe(OH)_3$	(Rhodochrosite)
Decant Pond May 2009	None	Ferrite-Cu Malachite Tenorite Delafossite (Brochantite)	Cerussite	Hematite Ferrite-Cu Magnetite Delafossite Goethite Jarosite $Fe(OH)_3$	Rhodochrosite
MW-01-15 June 2009	None	(Tenorite) (Malachite)	None	None	(Rhodochrosite)
Decant Pond June 2009		Brochantite Ferrite-Cu Malachite Tenorite Delafossite (Dioptase)	Cerussite	Hematite Ferrite-Cu Magnetite Delafossite Goethite Jarosite $Fe(OH)_3$	Rhodochrosite
MW-95-8 June 2009	None	Tenorite (Malachite)	None	None	None
MW-95-8 July 2009	None	Tenorite (Malachite)	None	None	None
Decant Pond July 2009	None	Brochantite Malachite Tenorite (Dioptase)	None	None	Rhodochrosite (Hausmannite) (Pyrolusite)
MW-01-15 July 2009	None	(Tenorite) (Malachite)	None	None	(Rhodochrosite)
Mine Water 9 East April 2003	None	(Tenorite) (Malachite)	None	None	None
Mine Water UQ-1 April 2003	None	(Tenorite)	None	None	None

*Minerals in parentheses are near saturation (SI > approximately -1).

values. However, it is important to note that the calculated mineral saturation indices incorporate all of the uncertainties or errors associated with field collection of water samples and measurement of redox conditions, laboratory measurement of chemical concentrations of the metals and other elements, and thermodynamic data. Thus, the interpretation of saturation indices should consider the likelihood that some truly saturated minerals may have a calculated SI of <0 and conversely some truly unsaturated minerals may have a calculated SI of >0.

Mineral phases that are calculated by Geochemists Workbench to be saturated (SI>0) are summarized in Table 10 and described as follows:

- Arsenic, antimony, cadmium, uranium - no phases saturated.
- Copper – oxide, hydroxysulfate, and hydroxycarbonate minerals saturated:
    - Brochantite: $Cu_4SO_4(OH)_6$
    - Malachite: $Cu_2(OH)_2(CO_3)_2$; presence of this mineral in decant pond sediments was confirmed by microscopic examination (Cannon Microprobe, 2003)
    - Tenorite: CuO
    - Delafossite: $CuFeO_2$; presence of this mineral in decant pond sediments was confirmed by microscopic examination (Cannon Microprobe, 2003)
    - Ferrite-Cu: $CuFe_2O_4$
- Iron – oxide minerals saturated:
    - Hematite: Fe_2O_3
    - Ferrite-Cu: $CuFe_2O_4$
    - Magnetite: Fe_3O_4
    - Delafossite: $CuFeO_2$
    - Jarosite: $KFe^{3+}{}_3(OH)_6(SO_4)_2$
    - Iron hydroxide: $Fe(OH)_3$
    - Goethite: $FeO(OH)$

- Lead – carbonate mineral saturated:
    - Cerussite: $PbCO_3$
- Manganese – carbonate mineral saturated:
    - Rhodochrosite: $MnCO_3$

In addition to these phases that are calculated to be saturated, other important phases that are calculated to be undersaturated but near saturation (SI greater than approximately –1) include:

- Copper:
    - Dioptase: CuSiO2(OH)2; the occurrence of a hydrated copper silicate mineral in decant pond sediments was confirmed by microscopic and microprobe examination by (Cannon Microprobe, 2003). The phase was tentatively identified as chrysocolla ($CuSiO_3(H2O)_n$), a similar hydrated copper silicate.
- Manganese:
    - Hausmannite: Mn_3O_4
    - Pyrolusite: MnO_2

5.6 STABILITY AND SOLUBILITY DIAGRAMS

One of the goals of this evaluation is to identify attenuation mechanisms and to assess the long-term reliability of the mechanisms. For metals that are attenuated by mineral precipitation mechanisms or are adsorbed to freshly precipitated mineral surfaces, the effectiveness of the attenuation mechanisms are controlled by the stability of the associated minerals. As described in Section 5.5, mine water, decant pond water and groundwater are calculated to be near saturation or oversaturation with respect to copper, iron, lead, and manganese mineral phases and therefore the formation or precipitation of these minerals from these waters is favored. In the case of copper and lead, the precipitation of copper and lead minerals is a direct form of attenuation (i.e., copper and lead are removed from solution by the mineral precipitation). For other metals of interest (arsenic, antimony, cadmium, and uranium), the precipitation of iron or manganese minerals provides fresh mineral surfaces upon which the metals of interest may be adsorbed. Iron and manganese oxides and

hydroxide minerals have a strong affinity for adsorption of many metals (see discussion in Section 3).

Stability and solubility diagrams provide a visual method of showing the conditions under which minerals are likely to form, the factors controlling the stability of the mineral phases, and the changes in water chemical conditions that could limit mineral precipitation or lead to dissolution of existing mineral phases. Stability diagrams and solubility diagrams in this assessment were developed for copper, iron, lead, and manganese using the Act2 module of the Geochemist's Workbench software (RockWare, 2010).

For some metals, there are multiple minerals that are oversaturated or nearly saturated in solution. Theoretically, only the most stable (most saturated) mineral would be formed if the solution were allowed to come to chemical equilibrium. However, chemical equilibrium is rare in nature and formation of the most stable phases may not be kinetically favored. Moreover, given the uncertainties in the water chemical analyses and thermodynamic data, it is possible that minerals that are not quite saturated may in actuality be stable and perhaps even favored. In order to evaluate the stability of minerals in addition to those thought to be most thermodynamically stable, some minerals were "suppressed" or purposely omitted from some stability and solubility diagrams. In these cases, the suppressed minerals are identified in the notes on the diagrams and the rationales for suppression of the minerals are discussed in the text below.

All diagrams except those containing the copper silicate mineral chrysocolla are for the average temperature (11.4 C^o) in the mine water, decant pond water, and groundwater. For the copper silicate mineral chrysocolla, the only thermodynamic data available is for 25^oC and the information needed to extrapolate to lower temperatures is not available; therefore the copper silicate diagrams are for 25^oC.

Interpretation of the stability diagrams is illustrated by Figures 6 and 7 as follows:

- The diagrams show the Eh-pH conditions or aqueous species-pH conditions where mineral phases and aqueous species predominate for the given conditions.
- Solid mineral phases are yellow/tan in color and are labeled with the name of the mineral (e.g. tenorite).
- Aqueous phases are blue in color and are labeled with the name of the aqueous species (e.g. Cu^{++}).
- Lines on the diagrams denote phase boundaries where two or more distinct phases are in equilibrium. Lines may denote equilibrium between solid phases (e.g. the minerals tenorite and cuprite), between a solid phase and an aqueous phase (e.g. tenorite and the Cu^{++} ion at the specified aqueous activity), or between two or more aqueous phases (e.g. the redox equilibrium boundary between Cu^{+} and Cu^{++}).

As an example of the interpretation of activity diagrams, consider Figures 4 and 5 that show the Eh and pH for copper at copper activities of 10^{-6} (a concentration of about 0.08 mg/L, slightly less than measured in the Adit Ditch in May 2009) and $10^{-7.5}$ (a concentration of about 0.006 mg/L, similar to the concentration routinely measured in groundwater near the decant pond). Plotted on the diagrams are the Eh-pH conditions for mine water and decant pond water as measured in May 2009. From these diagrams it is possible to make a number of important observations regarding the changes in copper activities (and concentrations) that are likely to occur to attenuate copper and conversely the geochemical conditions that might impair or preclude copper attenuation:

1. At a copper activity of 10^{-6} (Figure 4), the waters are not at equilibrium with tenorite (equilibrium is on the boundary line between tenorite and aqueous copper) but rather are oversaturated with respect to tenorite. Therefore, under these conditions tenorite would be expected to precipitate, reducing the copper activity in the water until equilibrium is achieved. If the copper activity were reduced to $10^{-7.5}$ (a concentration of about 0.006 mg/L) then the diagram would look like Figure 5. At this lower copper activity, the waters plot near the equilibrium line and no further tenorite

precipitation is predicted. From these diagrams we would conclude that under current conditions of Eh and pH, copper is expected to be attenuated from mine and decant pond water until the copper concentration is approximately 0.006 mg/L, an observation confirmed by the concentration of copper in groundwater near the decant pond and the identification of copper oxide minerals in the decant pond sediments.

2. At the Eh typical of mine and decant pond waters (about 400 millivolts), there are only two dominant phases – the Cu^{++} ion and the mineral tenorite. The equilibrium relationship between these two phases is dependent on pH.
   - Higher pH conditions increase the stability of the solid phase (tenorite), therefore higher pH conditions will lead to more copper attenuation (lower copper concentration in water). Conversely, if conditions were to become more acidic (lower pH), copper attenuation would be less effective.
   - Therefore, the continuation or longevity of the copper attenuation mechanism is dependent on continued neutral pH conditions. If water were to become acidic, the attenuation of copper would be reduced. If this condition were to occur, an effective mitigation would be to take actions (e.g. addition of a base such as lime or limestone) to raise the pH of the water and restore the attenuation mechanism.

FIGURE 4. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6})

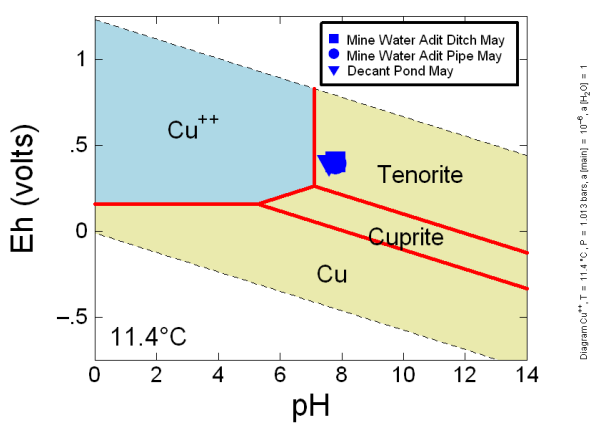
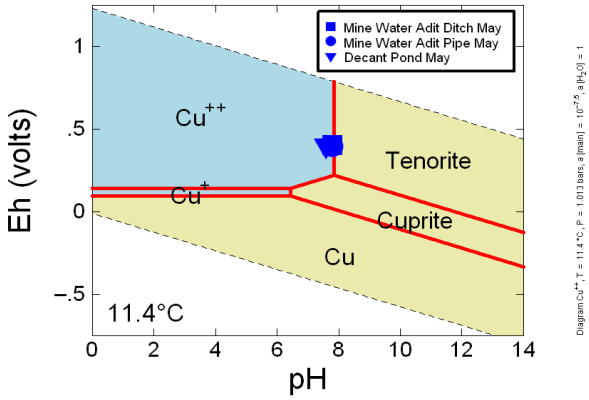


FIGURE 5. EH-PH DIAGRAM FOR COPPER ACTIVITY = $10^{-7.5}$



5.6.1 Copper Oxides and Copper Iron Oxides

Copper oxide minerals that are saturated or nearly saturated in mine water, decant water, and groundwater include tenorite (CuO), delafossite (CuFeO2), and copper ferrite ($CuFe_2O_4$). These minerals are defined by a system containing copper, iron, oxygen (Eh) and hydrogen (pH). The stability and solubility of the minerals are constrained by copper and iron activity and the Eh and pH of the solution.

Eh-pH diagrams for copper for the range of copper concentrations (and activities) present in water at the Troy Mine (activity of 10^{-6} to $10^{-7.5}$) are shown in Figures 4 and 5 (above). The Eh-pH of mine water, decant pond water, and groundwater are plotted on the diagrams for reference. The majority of the mine water, decant pond water, and groundwater samples plot in the tenorite mineral stability field. If allowed to come to chemical equilibrium, tenorite would be expected to precipitate from these waters, reducing the concentration of copper in the waters. Further, these diagrams illustrate that formation of copper oxide minerals is favored by:

1. Higher pH;
2. Higher copper concentrations; and
3. Higher Eh (more oxidizing conditions).

At the neutral pH typical of mine water, decant pond water and groundwater near the decant pond, the solubility of minerals is low, regardless of Eh conditions.

Some water samples are found to contain measurable amounts of iron. The effects of the addition of iron to the copper oxide system are shown in Figures 6 and 7. In the presence of iron, the copper oxide stability fields are diminished and copper iron oxides (delafossite and ferrite copper) are the most stable mineral phases at neutral to alkaline pH conditions. As noted above, there is field evidence corroborating the precipitation of delafossite in decant pond sediments as this mineral was identified in pond sediments by microscopic and electron microprobe analyses. The majority of the mine water, decant pond water, and groundwater samples plot in the delafossite mineral stability field. If allowed to come to chemical equilibrium, delafossite would be expected to precipitate from these waters, reducing the concentration of copper in the waters. Further, these diagrams illustrate that attenuation of copper by the formation of copper iron oxide minerals is favored by:

1. Higher pH;
2. Higher iron and copper concentrations; and
3. Higher Eh (more oxidizing conditions).

FIGURE 6. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH IRON

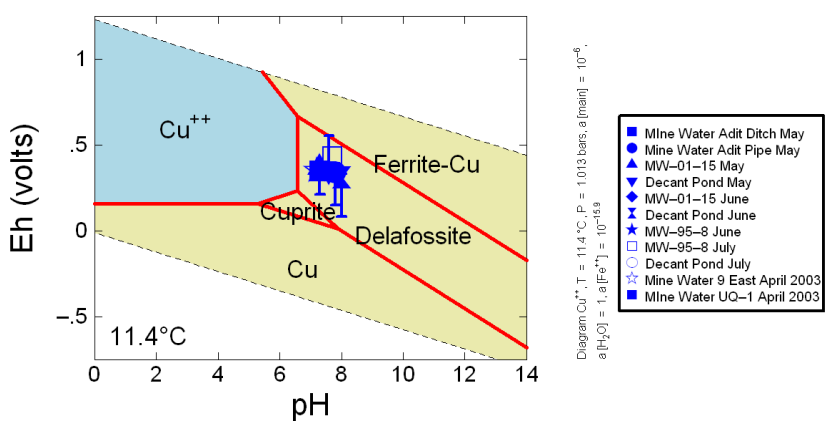
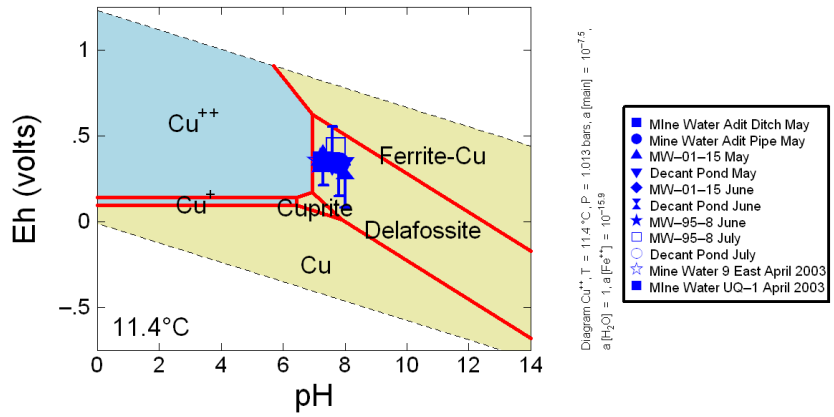


FIGURE 7. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH IRON



At the neutral pH typical of mine water, decant pond water and groundwater near the decant pond, the solubility of copper iron oxide minerals is low, regardless of Eh conditions. If waters were to become acidic, the attenuation of copper by the formation of copper iron oxide minerals would be reduced. If this condition were to occur, an effective mitigation would be to take actions (e.g. addition of a base such as lime or limestone) to raise the pH of the water and restore the attenuation mechanism.

5.6.2 Copper Carbonates

Copper carbonate mineral (e.g. malachite $Cu_2(OH)_2(CO_3)_2$) stability and solubility are constrained by copper and bicarbonate and pH of the solution. The presence of malachite in decant pond sediments was confirmed by microscopic examination (Cannon Microprobe, 2003). Stability diagrams for the copper bicarbonate system for the range of copper concentrations (and activities) present in water at the Troy Mine (activity of 10^{-6} to $10^{-7.5}$), average field Eh (393 millivolts) are shown in Figures 8 and 9. Because the stability and solubility of malachite is not directly dependent on Eh for the Eh range of interest, bicarbonate activity is shown on the y-axis instead of Eh. The bicarbonate activity and pH of mine water, decant pond water, and groundwater are plotted on the diagrams for reference.

These diagrams illustrate that formation of copper bicarbonate minerals is favored by:

1. Higher dissolved bicarbonate concentrations (at lower bicarbonate levels the copper oxide tenorite is stable);
2. Higher pH; and
3. Higher copper concentrations.

Attenuation of copper by the mechanism of copper carbonate mineral formation would be impaired by acidic (low pH) conditions or low dissolved bicarbonate concentrations. If waters were to become acidic, the attenuation of copper by the formation of copper carbonate minerals would be reduced. If this condition were to occur, an effective mitigation would be to take actions (e.g. addition of a base such as lime or limestone) to raise the pH and bicarbonate of the water and restore the attenuation mechanism.

FIGURE 8. BICARBONATE-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6})

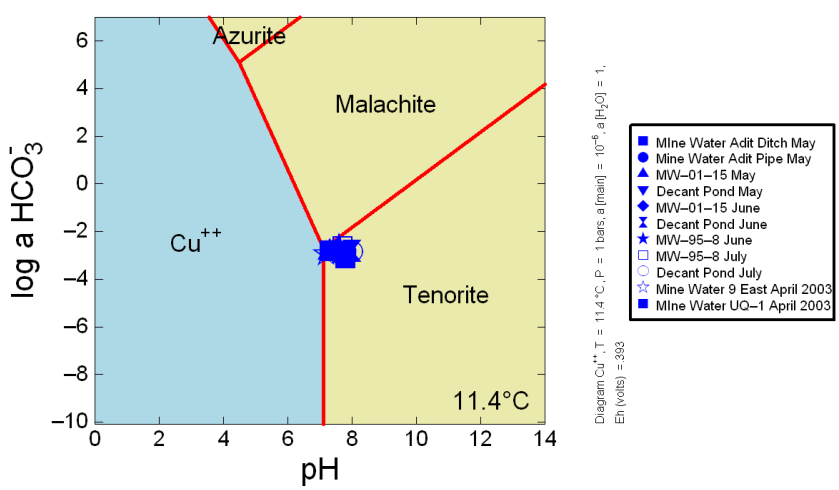
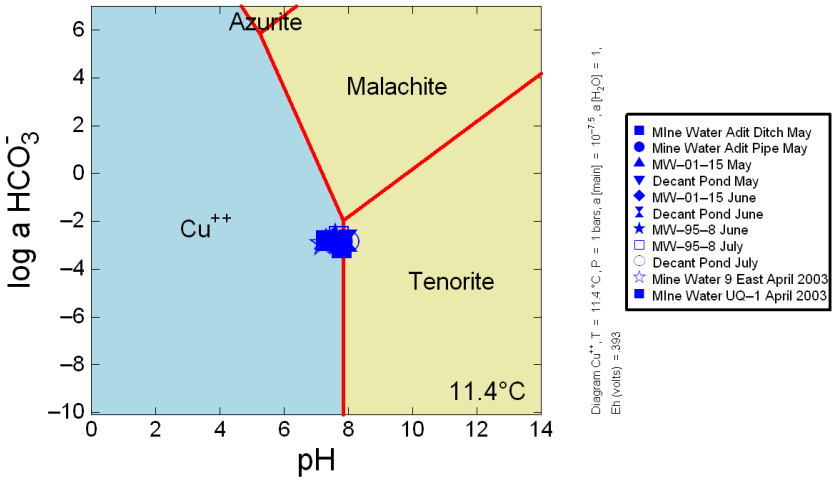


FIGURE 9. BICARBONATE-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$)



5.6.3 Copper Hydroxysulfate

Copper hydroxysulfate (brochantite) mineral stability and solubility are constrained by copper activity, sulfate activity and the Eh-pH of the solution. Eh-pH diagrams for copper for the range of copper activities (10^{-6} to $10^{-7.5}$) and sulfate activities ($10^{-3.49}$ to $10^{-4.25}$) present in water at the Troy Mine are shown in Figures 10 through 13. The Eh-pH of mine water, decant pond water, and groundwater are plotted on the diagrams for reference. The copper oxide minerals tenorite and cuprite are suppressed in these diagrams in order to show brochantite stability. The majority of the mine water, decant pond water, and groundwater samples plot near or in the brochantite mineral stability field. If allowed to come to chemical equilibrium, brochantite would be expected to precipitate from these waters, reducing the concentration of copper in the waters. Further, these diagrams illustrate that formation of brochantite minerals is favored by:

1. Higher pH;
2. Higher sulfate and copper concentrations; and
3. Higher Eh (more oxidizing conditions).

FIGURE 10. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$)

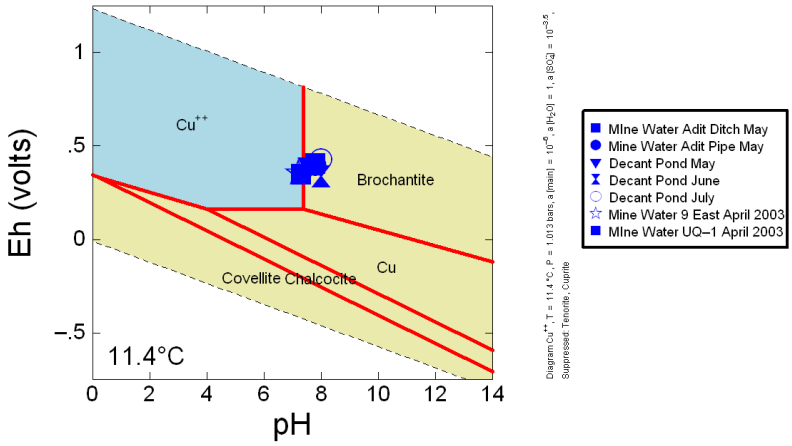


FIGURE 11. EH-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-4.25}$)

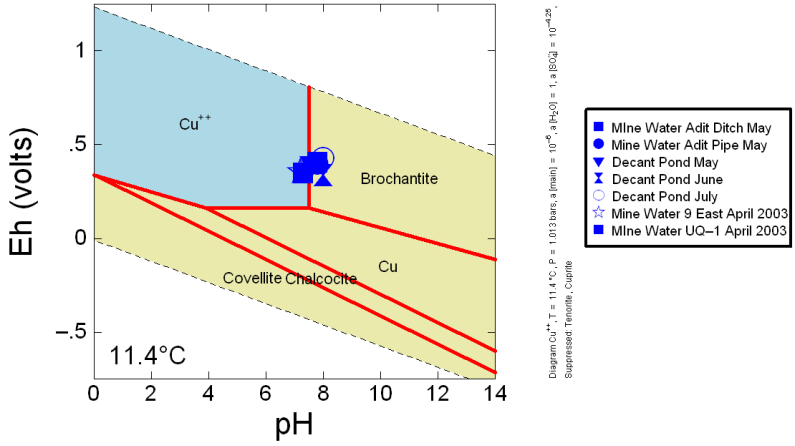


FIGURE 12. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH SULFATE (ACTIVITY = $10^{-3.5}$)

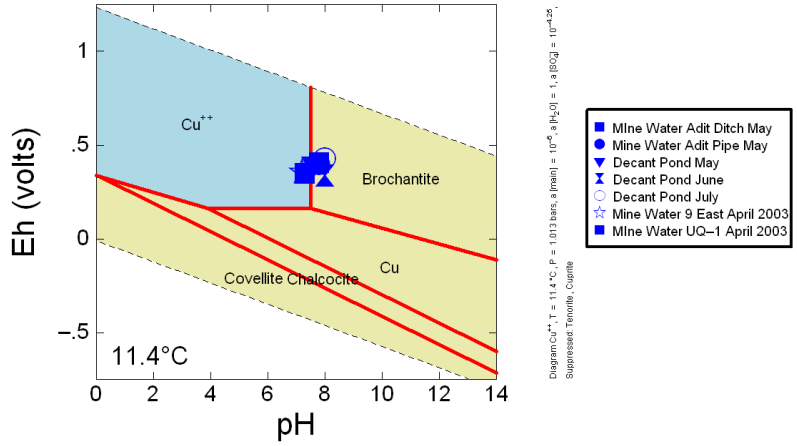
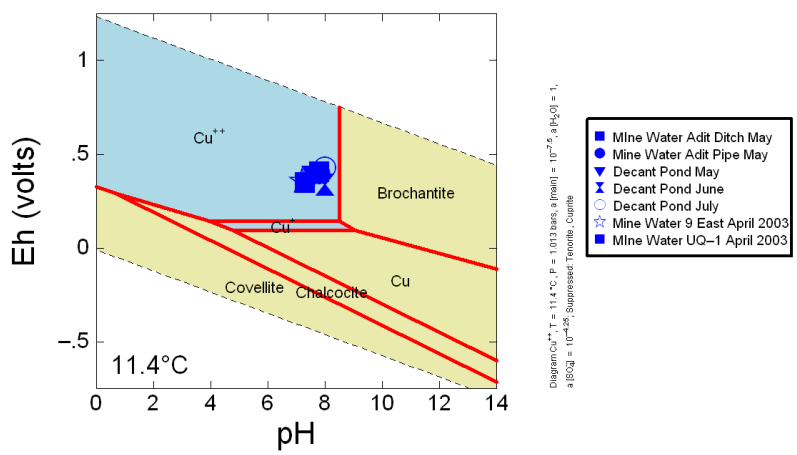


FIGURE 13. EH-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$) WITH SULFATE (ACTIVITY = $10^{-4.25}$)



5.6.4 Copper Silicates

Copper silicate mineral stability and solubility are constrained by copper and silicate activity and pH of the solution. Although the copper silicate mineral dioptase appears to be more saturated than chrysocolla in waters at the Troy Mine, dioptase was "suppressed" and was omitted from the copper silicate stability diagrams so that the stability/solubility of

chrysocolla could be shown instead. The suppression of dioptase was done for the following reasons. Field evidence (microscopic and electron microprobe evaluation of sediment pond samples, Land and Water (2004); Cannon Microprobe (2003)) indicates that the copper silicate mineral chrysocolla has precipitated from decant pond water and is a stable mineral phase whereas dioptase was not found in the decant pond. Dioptase is a relatively rare mineral. Some investigators have proposed that chrysocolla formation is kinetically favored over dioptase and that dioptase may be formed by aging of cryptocrystalline chrysocolla (Crane et al, 2001). Omission of dioptase from the stability diagrams allows the stability and solubility of chrysocolla to be illustrated.

Stability diagrams for the copper-silica system for the range of copper concentrations (and activities) present in water at the Troy Mine (activity of 10^{-6} to $10^{-7.5}$), average field Eh (393 millivolts), and temperature of 25°C are shown in Figures 14 and 15. Because the stability and solubility of chrysocolla is not directly dependent on Eh, silica activity is shown on the y-axis instead of Eh. The silica activity and pH of mine water, decant pond water, and groundwater are plotted on the diagrams for reference. These diagrams illustrate that formation of copper silicate minerals is favored by:

1. Higher dissolved silica concentrations;
2. Higher pH; and
3. Higher copper concentrations.

Attenuation of copper by the mechanism of copper silicate mineral formation would be impaired by acidic (low pH) conditions or low dissolved silica conditions.

FIGURE 14. SILICA-PH DIAGRAM FOR COPPER (ACTIVITY = 10^{-6})

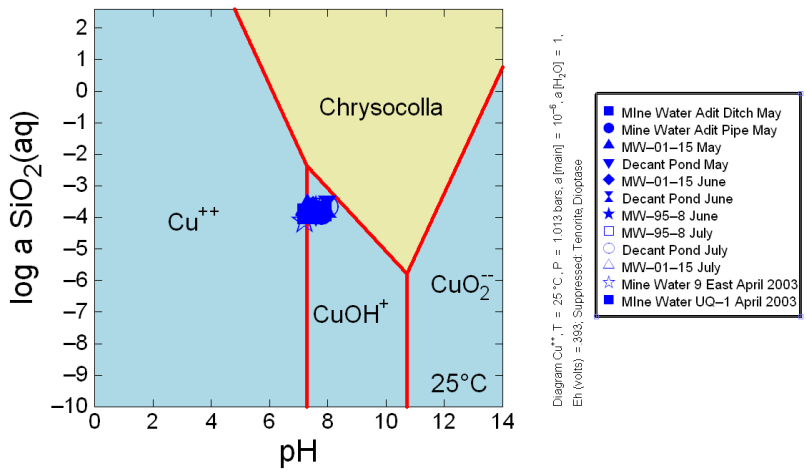
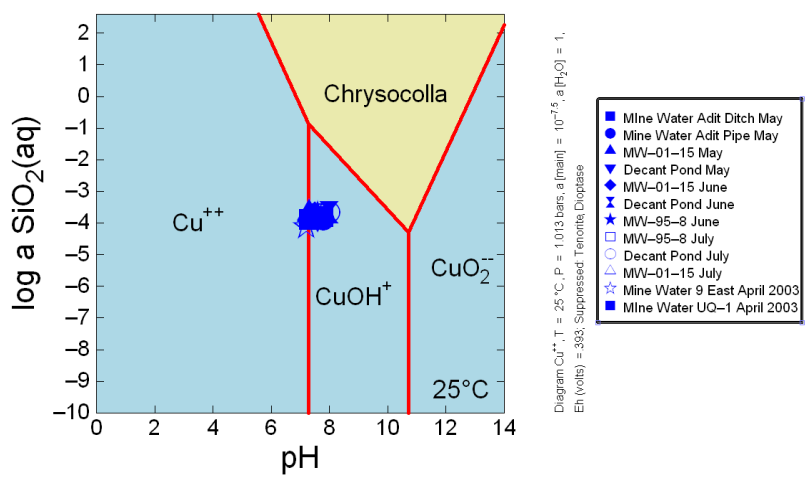


FIGURE 15. SILICA-PH DIAGRAM FOR COPPER (ACTIVITY = $10^{-7.5}$)



5.6.5 Iron

Iron minerals that are saturated or nearly saturated in mine water, decant water, and groundwater include iron oxides, copper iron oxides, iron hydroxides, and potassium iron hydroxysulfate minerals. These minerals are defined by systems containing iron, oxygen

(Eh), sulfate (sulfur), hydrogen (pH) and potassium. Copper iron oxides are discussed in Section 5.6.1 and are not further discussed in this section. Eh-pH diagrams for iron for the range of iron activities (10^{-6} to $10^{-6.2}$), sulfate ($10^{-3.5}$ to $10^{-4.25}$) and potassium ($10^{-3.2}$ to $10^{-4.3}$) activities present in water at the Troy Mine are shown in Figures 16 through 19. The Eh-pH of mine water, decant pond water, and groundwater are plotted on the diagrams for reference. The minerals hematite and magnetite were suppressed and omitted from the diagrams in order to show the more common secondary iron minerals ferric hydroxide ($Fe_3(OH)_3$), goethite ($FeO(OH)$), and jarosite ($KFe^{3+}{}_3(OH)_6(SO_4)_2$). Goethite was also suppressed in some diagrams to show ferric hydroxide stability.

FIGURE 16. EH-PH DIAGRAM FOR IRON (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$) AND POTASSIUM (ACTIVITY=$10^{-3.2}$)

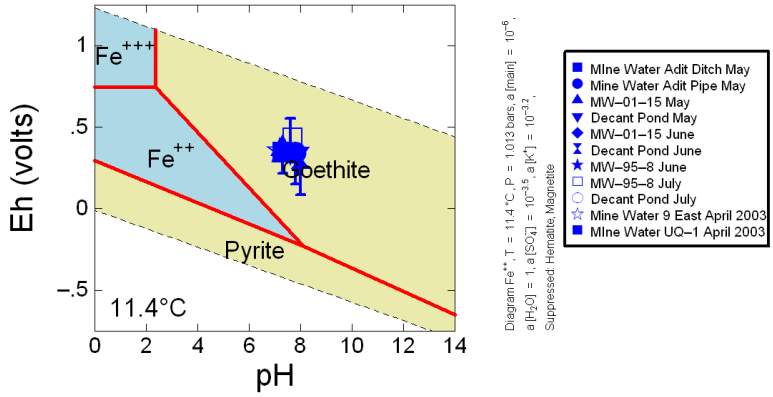


FIGURE 17. EH-PH DIAGRAM FOR IRON (ACTIVITY = 10^{-6}) WITH SULFATE (ACTIVITY = $10^{-3.5}$) AND POTASSIUM (ACTIVITY=$10^{-3.2}$), GOETHITE SUPPRESSED

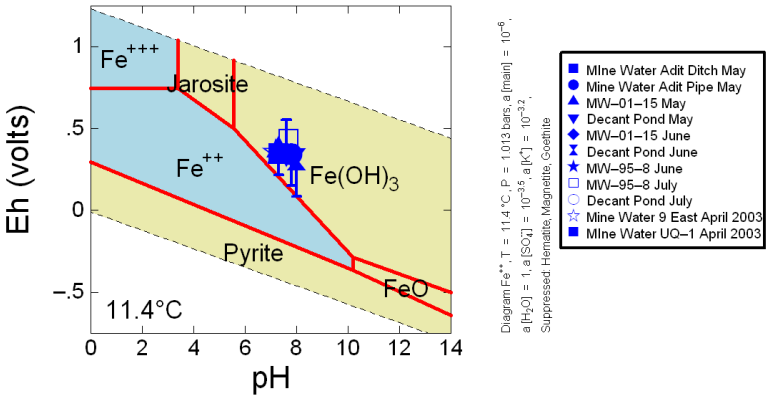


FIGURE 18. EH-PH DIAGRAM FOR IRON (ACTIVITY = $10^{-6.2}$ WITH SULFATE (ACTIVITY = $10^{-4.25}$) AND POTASSIUM (ACTIVITY=$10^{-4.3}$)

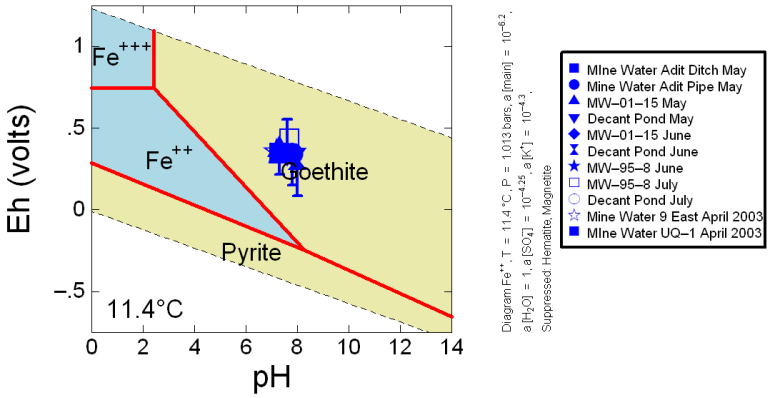
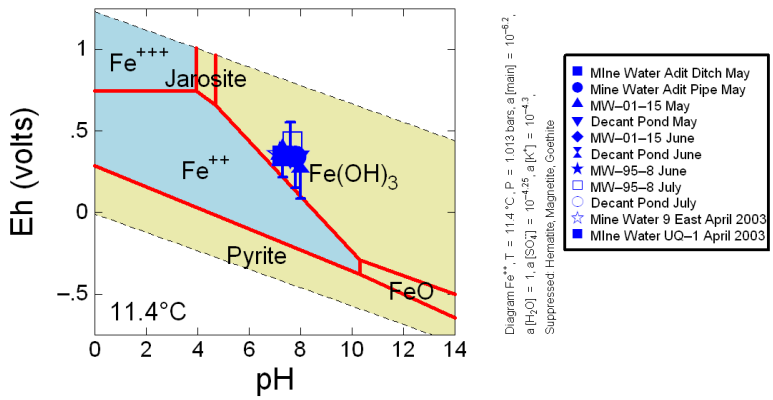


FIGURE 19. EH-PH DIAGRAM FOR IRON (ACTIVITY = $10^{-6.2}$ WITH SULFATE (ACTIVITY = $10^{-4.25}$) AND POTASSIUM (ACTIVITY=$10^{-4.3}$), GOETHITE SUPPRESSED



These diagrams illustrate that all of the Troy Mine waters are in the goethite or ferric hydroxide stability field. Formation and stability of goethite and ferric hydroxide is favored by:

1. Higher Eh (more oxidizing);
2. Higher pH; and
3. Higher iron concentrations.

Jarosite is only stable at relatively low pH and high sulfate conditions such as might occur in acid rock drainage. Given the lack of acid rock drainage and neutral pH of water at the Troy Mine, jarosite formation is not likely to form in the decant pond or the groundwater. Attenuation of metals by co-precipitation or adsorption is favored by conditions that lead to precipitation and stability of iron oxide and hydroxide minerals. Conditions that might lead to a reduction in metal attenuation effectiveness due to the lack of stability of iron oxide or hydroxide sorbent phases include lower Eh (more reducing) and acidic (lower pH) conditions.

5.6.6 Lead

Cerussite ($PbCO_3$) is the only lead mineral that is saturated or nearly saturated in mine water, decant water, and groundwater. Stability and solubility of cerussite is defined by a system containing copper, hydrogen (pH) and carbonate. Because the stability and solubility of cerussite is not directly dependent on Eh for the Eh range of interest, bicarbonate activity is shown on the y-axis instead of Eh. Solubility diagrams showing lead solubility as a function of pH in the presence of bicarbonate for the range of lead activities ($10^{-7.5}$ to $10^{-8.4}$) and bicarbonate activities ($10^{-2.6}$ to $10^{-3.2}$) present in water at the Troy Mine are shown in Figures 20 and 21. The pH and bicarbonate concentrations of decant pond water, and groundwater are plotted on the diagrams for reference. These diagrams illustrate that formation of cerussite is favored by:

1. Higher bicarbonate silica concentrations;
2. Higher pH; and
3. Higher lead concentrations.

Attenuation of lead by the mechanism of lead carbonate mineral formation would be impaired by acidic (low pH) conditions or low dissolved bicarbonate concentrations. If waters were to become acidic, the attenuation of lead by the formation of lead carbonate minerals would be reduced. If this condition were to occur, an effective mitigation would be to take actions (e.g. addition of a base such as lime or limestone) to raise the pH and bicarbonate of the water and restore the attenuation mechanism.

FIGURE 20. LEAD ACTIVITY-PH DIAGRAM WITH BICARBONATE ACTIVITY = $10^{-2.6}$

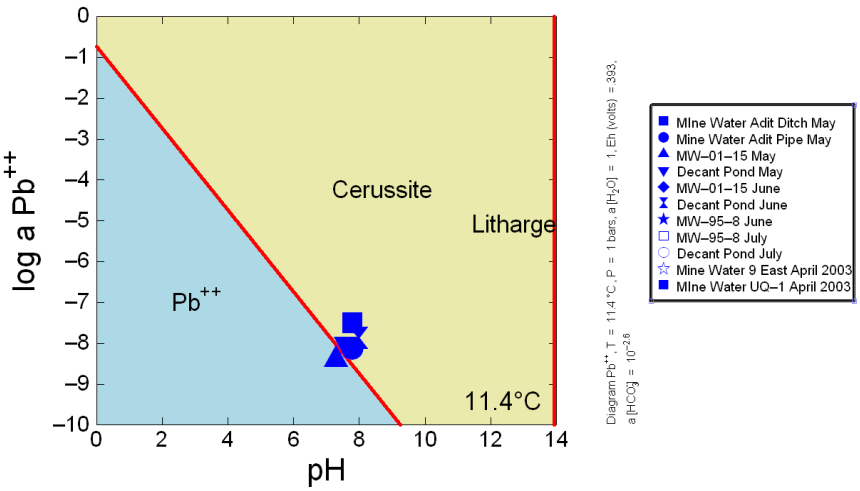
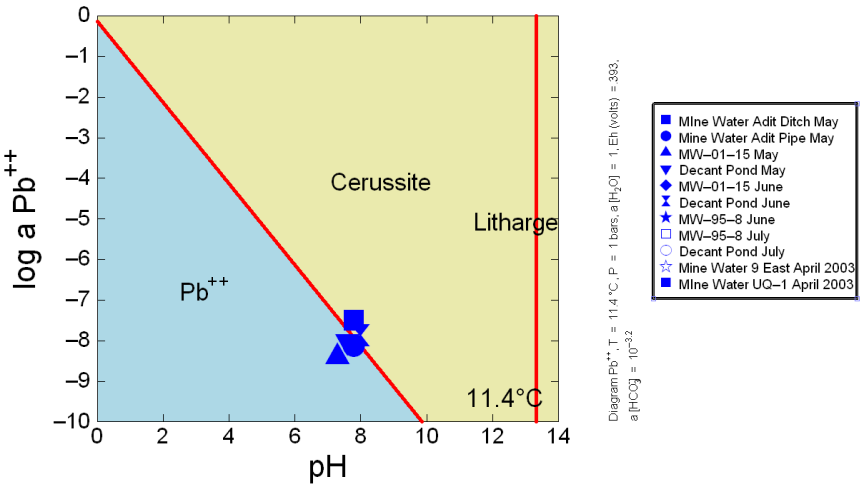


FIGURE 21. LEAD ACTIVITY-PH DIAGRAM WITH BICARBONATE ACTIVITY = $10^{-3.2}$



5.6.7 Manganese

Manganese minerals that are saturated or nearly saturated in mine water, decant water, and groundwater include manganese oxides (hausmannite (Mn_3O_4) and pyrolusite (MnO_2)) and the manganese carbonate mineral rhodochrosite ($MnCO_3$). These minerals are defined by a system containing manganese, oxygen (Eh), hydrogen (pH) and carbonate.

Solubility diagrams showing manganese solubility as a function of pH in the presence of bicarbonate for the range of bicarbonate activities ($10^{-2.6}$ to $10^{-3.2}$) present in water at the Troy Mine and the average field measured Eh (393 millivolts) are shown in Figures 22 and 23. Because the stability and solubility of the manganese minerals is not very sensitive to Eh for the Eh range of interest, bicarbonate activity is shown on the y-axis instead of Eh. The pH and bicarbonate concentrations of mine water, decant pond water, and groundwater are plotted on the diagrams for reference. These diagrams illustrate that formation and stability of manganese oxide minerals is favored by:

1. Higher pH; and
2. Higher manganese concentrations.

FIGURE 22. MANGANESE-pH DIAGRAM WITH BICARBONATE (ACTIVITY = $10^{-2.6}$)

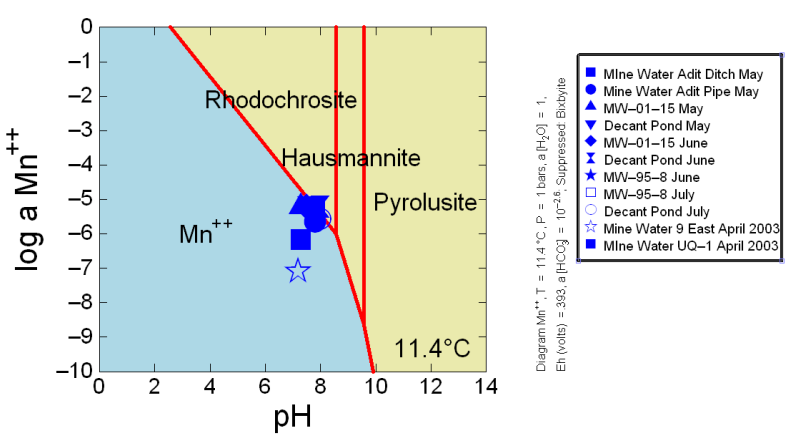
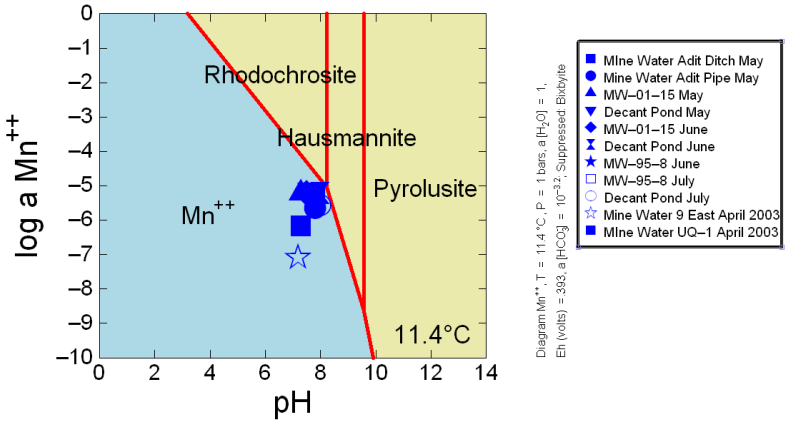


FIGURE 23. MANGANESE-pH DIAGRAM WITH BICARBONATE (ACTIVITY = $10^{-3.2}$)



Formation and stability of manganese carbonate minerals is favored by:

1. Higher bicarbonate silica concentrations;
2. Higher pH; and
3. Higher manganese concentrations.

Attenuation of metals by co-precipitation or adsorption is favored by conditions that lead to precipitation and stability of manganese oxide and hydroxide minerals. Conditions that might lead to a reduction in metal attenuation effectiveness by this attenuation mechanism include conditions of lower Eh (more reducing), lower pH (more acidic), and lower bicarbonate concentration. If this condition were to occur, an effective mitigation would be to take actions (e.g. addition of a base such as lime or limestone) to raise the pH and bicarbonate of the water and restore the attenuation mechanism.

6.0 SUMMARY SITE MODEL FOR NATURAL ATTENUATION

The summary site model for natural attenuation at the Troy Mine is that metals are attenuated (removed) from water by a combination of mineral precipitation, co-precipitation with other metals, and adsorption by various solid materials including iron and manganese oxides and hydroxides, clays, and organic matter. Field and laboratory testing, supported by geochemical equilibrium modeling, evidence the removal of copper and lead from water (i.e., attenuation) by precipitation of copper and lead minerals in sediments beneath the decant pond. Table 11 summarizes the minerals formed and the geochemical controls on the stability and solubility of copper and lead minerals.

Field and laboratory testing and geochemical modeling also evidence the removal of arsenic, antimony, copper, lead and uranium from water (i.e., attenuation) by co-precipitation or adsorption of these metals with iron and/or manganese minerals. Table 12 summarizes the geochemical controls on the stability of iron and manganese minerals. The extent of sorption of trace metals in groundwater is largely controlled by the following factors:

1. Groundwater pH;
2. Metal concentration in solution;
3. The quantity of sorbent material (principally hydrous ferric and manganese oxides, organic matter, and clays) within the aquifer; and
4. The concentration of competing ions and metal-complexing ions in solution.

TABLE 11. SUMMARY OF FACTORS AFFECTING METAL ATTENUATION BY MINERAL PRECIPITATION

Metal	Minerals	Geochemical Conditions Affecting Stability/Solubility	Factors Enhancing Attenuation	Factors Reducing Attenuation
Copper	Copper oxides (tenorite, ferrite-Cu, delafossite)	Redox: high Eh/oxygen preferred	Equilibration with atmospheric oxygen	Consumption of oxygen by organic material decomposition or sulfide minerals
		pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
	Copper carbonate (malachite)	pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
		Bicarbonate: high Bicarbonate preferred	Dissolution of carbonate rocks and minerals Equilibration with CO_2 in atmosphere	
	Copper silicates (chrysocolla)	pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
		Silica: high silica preferred	Equilibration with silicate minerals	
	Copper hydroxysulfates (brochantite)	pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
		High sulfate	Sulfide mineral oxidation Dissolution of sulfate minerals (e.g. gypsum)	
Lead	Lead carbonate (cerussite)	pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
		Bicarbonate: high Bicarbonate preferred	Dissolution of carbonate rocks and minerals Equilibration with CO_2 in atmosphere	

TABLE 12. SUMMARY OF FACTORS AFFECTING METAL ATTENUATION BY CO-PRECIPITATION OR ADSORPTION WITH IRON AND MANGANESE MINERALS

Metal	Minerals	Geochemical Conditions Affecting Stability/Solubility	Factors Enhancing Attenuation	Factors Reducing Attenuation
Iron	Iron oxides ($Fe(OH)_3$, goethite, ferrite-Cu, delafossite)	Redox: high Eh/oxygen preferred	Equilibration with atmospheric oxygen	Consumption of oxygen by organic material decomposition or sulfide minerals
		pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
Manganese	Manganese carbonate (rhodochrosite)	pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation
		Bicarbonate: high Bicarbonate preferred	Dissolution of carbonate rocks and minerals Equilibration with CO_2 in atmosphere	
	Manganese oxides (hausmannite, pyrolusite)	Redox: high Eh/oxygen preferred	Equilibration with atmospheric oxygen	Consumption of oxygen by organic material decomposition or sulfide minerals
		pH: high pH preferred	Buffering by carbonate rocks and minerals (e.g. calcite, limestone)	Sulfide mineral oxidation

7.0 EVALUATION OF LONGEVITY OF NATURAL ATTENUATION MECHANISMS

As described in the preceding sections, the active attenuation mechanisms for metals at the Troy tailing impoundment site include the precipitation of metallic minerals from water and the adsorption of metals onto precipitated minerals (iron and possibly manganese oxides and hydroxides) present in sediments beneath the decant pond. The expected duration of the geochemical conditions and capacity of aquifer sediment for attenuation is described in this section.

The longevity of the natural attenuation mechanisms is dependent on the duration of the geochemical conditions conducive to attenuation and to the capacity of the tailing impoundment/aquifer sediments to continue to uptake metals. The mineral precipitation and co-precipitation mechanisms are expected to last indefinitely or in perpetuity as long as geochemical conditions remain similar to current conditions. The adsorption mechanisms are conservatively estimated to last a minimum of 600 years.

7.1 ATTENUATION BY MINERAL PRECIPITATION

Although there are numerous metals and minerals of interest, the conditions necessary for continuation of attenuation are similar for most of these and are:

1. Neutral or alkaline pH;
2. Oxidizing redox conditions (moderate to high Eh);
3. Presence of moderate amounts of silica; and
4. Presence of moderate amounts of bicarbonate

An additional condition that only applies to sulfate minerals is:

1. Presence of moderate amounts of sulfate.

However, sulfate minerals are likely a minor attenuation mechanism given the generally low sulfate concentrations present and will not be discussed further. The durations or longevities of the primary attenuation conditions are presented below.

7.2 NEUTRAL TO ALKALINE PH

There is nearly 30 years of water quality data demonstrating that mine water is consistently neutral in pH (Parametrix, 2008). Additionally, acid-base accounting tests and long-term laboratory testing with humidity cells indicates that waste rock, ore, and tailings from the Troy Mine are not acid-generating but rather are acid-neutralizing (i.e., contain an excess of alkaline materials (MDEQ and USFS, 2001; Maxim, 2003)). Therefore, mine water pH is expected to remain near neutral to alkaline in perpetuity, and pH conditions are not expected to limit the longevity of attenuation mechanisms.

The pH of mine water, decant pond water, and groundwater are controlled by reactions between atmospheric gas (carbon dioxide) and the various rocks and minerals that the water contacts. As described in the Process Model for Geochemical Equilibrium Modeling (Section 5.1), meteoric water dissolves carbon dioxide from the atmosphere (forming carbonic acid) and becomes mildly acidic. Meteoric waters become neutral to alkaline from reaction with soils and rocks, particularly carbonate minerals and rocks that buffer the water. Although the oxidation of sulfide minerals in the underground mine releases small amounts of sulfuric acid to the water, the amount of acid released is small relative to the buffering capacity of the mine water, and mine water remains near neutral in pH.

7.3 OXIDIZING REDOX CONDITIONS

The dissolved oxygen content and redox condition (Eh) of mine water, decant pond water, and groundwater are controlled by reactions between atmospheric gas (oxygen), the various rocks and minerals that the water contacts, and decomposition of organic matter. As described in the Process Model for Geochemical Equilibrium Modeling (Section 5.1), meteoric water dissolves oxygen from the atmosphere and becomes well oxygenated. During infiltration/percolation of rainfall and groundwater to the mine workings the amount of oxygen in mine water is reduced, first by soil biological activity and later by reaction with

sulfide minerals present in the ore and waste rock. In the mine workings and during disposal of mine water in the decant pond, water is once again exposed to abundant atmospheric oxygen which raises the Eh or redox condition of the water and results in the formation of oxide minerals.

As the supply of oxygen in the atmosphere is essentially limitless, oxygen does not pose a limit to the longevity of the attenuation mechanisms as long as 1) the waters continue to receive ample exposure to the atmosphere; and 2) materials/chemicals other than metals do not consume excess amounts of oxygen. Other potential oxygen consumers are sulfide minerals and organic carbon such as plant material.

As described above for pH, oxidation of sulfide minerals in the mine is relatively slow and produces minor amounts of sulfate and acid. No change in the future rate of sulfide mineral oxidation is anticipated. Therefore, oxidation of sulfide minerals is not expected to affect the duration and longevity of attenuation mechanisms.

Currently the amount of organic carbon in mine water and decant pond sediments is low to moderate. The decant pond was dewatered in 2004 and pond bottom sediments were found to be primarily sand and silt with some interbedded layers of organic materials that appeared to be primarily algae and other very fine organic particles, with the occasional leaf or stick (see photos in Land and Water (2004)). Under these current conditions there is sufficient oxygen in the water and sediments to oxidize metals in the presence of this organic material and there is no predicted limit to the duration or longevity of the attenuation mechanism. However, if pond conditions were to change such that large amounts of organic matter were present, then excessive oxygen consumption by the decay of organic matter could result in redox conditions such that the precipitation of oxide and hydroxide minerals is limited (i.e., low Eh). Therefore, monitoring and management actions should include monitoring of pond sediments for redox conditions and carbon content, and if needed, removal of excessive organic material from the pond bottom.

7.3.1 Dissolved Silica

Silica is abundant in nature as silicates are the primary rock-forming minerals in the earth's crust. Silicate minerals are particularly abundant in and around the Troy Mine in the form of quartz and quartzite rocks, which are nearly pure silica. Moreover, tailings are predominately fine-grained quartz and sediments in the decant pond contain significant tailings material. Silica is dissolved in mine water by interaction of groundwater and mine water with silicate minerals. Given the overwhelming abundance of silica in general and in the Troy Mine and tailings impoundment in particular, the supply of dissolved silica is essentially limitless and the supply of silica does not pose a limit to the longevity of the attenuation mechanisms.

7.3.2 Dissolved Bicarbonate

The dissolved bicarbonate content of mine water, decant pond water, and groundwater are controlled by reactions between atmospheric gas (carbon dioxide), the various rocks and minerals that the water contacts, and decomposition of organic matter.

As described in the Process Model for Geochemical Equilibrium Modeling (Section 5.1), meteoric water dissolves carbon dioxide from the atmosphere, forming carbonic acid (H_2CO_3) and bicarbonate (HCO_3^-). During infiltration/percolation of rainfall and groundwater to the mine workings the amount of bicarbonate in mine water is increased, by soil biological activity and by dissolution of carbonate minerals in the ore and waste rock. Given the abundance of carbon dioxide gas in nature and carbonate rocks in the Troy Mine and tailings impoundment, the supply of dissolved bicarbonate is essentially limitless and bicarbonate does not pose a limit to the longevity of the attenuation mechanisms.

Bicarbonate concentrations of decant pond water have increased since the mine re-start in 2005. This increase is believed to be related to the higher carbonate mineral content of the ore zone that is currently being mined and milled, relative to the entire mine workings. Therefore, it is likely that bicarbonate concentrations of decant water will decrease to concentrations similar to the interim closure period after final mine closure. Decreases in bicarbonate concentrations of this magnitude are not expected to limit attenuation as

evidence shows that metal attenuation was effective at these lower concentrations during the interim shutdown period.

7.4 ATTENUATION BY ADSORPTION TO MINERALS AND SEDIMENTS

Attenuation of metals to minerals and organic matter in sediments beneath the decant pond and in the underlying aquifer is dependent on the presence of solid sorbent phases (e.g. minerals such as $Fe(OH)_3$, clay minerals, and organic matter) and appropriate water chemistry (primarily pH). The extent, duration and longevity of sorption of trace metals in groundwater are largely controlled by the following factors:

1. Groundwater pH;
2. The quantity of sorbent material (principally hydrous ferric and manganese oxides, organic matter, and clays) within decant pond and aquifer sediments; and
3. The concentration of competing ions in solution.

Site-specific evidence of the longevity of the adsorption mechanisms is provided by the 30-year operating life of the decant pond disposal system. Groundwater quality data from monitoring wells within 100 to 150 of the decant pond demonstrate that metals are effectively attenuated over this short distance, and have been for over 30 years. In comparison the decant pond is located approximately 3,000 feet from Lake Creek, a distance 20 times greater than the current transport distance of the metals. At a minimum, it is estimated that greater than 600 years of adsorption attenuation capacity remain in the shortest potential flow path to Lake Creek. This estimate is based on the following assumptions and calculations:

1. Mine water concentrations are expected to remain similar to current and past levels.
2. The adsorption capacity of sediments in the flow path between the decant pond and the adjacent monitoring wells is similar to the capacity of sediments in the flow path between the monitoring wells and Lake Creek.
3. There are not significant processes providing a sustainable supply of fresh sorbent material. This assumption is known to be false but is made to simplify the calculation

and provide a conservative estimate of adsorption life. Organic matter will continue to be replenished by deposition of algae and detritus in the pond. Groundwater containing high concentrations of iron is known to exist between the tailing impoundment and Lake Creek. Geochemical modeling and laboratory testing demonstrate that this iron provides an effective source of iron oxide and hydroxides for co-precipitation and adsorption of metals (CDM, 2010).

4. The adsorption capacity of sediments in the flow path from the pond to the adjacent monitoring wells (150 feet flow path) is at least 30 years, and likely greater as it has not been depleted yet. To be conservative, the adsorption capacity of the sediments is calculated to be 30 years of attenuation per 150 feet of flow. Stated differently, the attenuation front would be calculated to move toward Lake Creek at the rate of 5 feet/year or less.
5. The time required to deplete the adsorption capacity in the shortest potential flow path between the monitoring wells and Lake Creek (a distance of 2,850 feet) is:

2,850 feet x (30 years attenuation/150 feet) = 570 years;
or approximately 600 years.

It is important to note that this estimate is only for the adsorption attenuation mechanism. As described in Section 7.3, the mineral precipitation mechanism is expected to last indefinitely.

7.4.1 Water pH

As described in Section 7.1.1, there is nearly 30 years of water quality data demonstrating that mine water is consistently neutral in pH (Parametrix, 2008). Additionally, acid-base accounting tests and long-term laboratory testing with humidity cells indicates that waste rock, ore, and tailings from the Troy Mine are not acid-generating but rather are acid-neutralizing (i.e., contain an excess of alkaline materials) (MDEQ and USFS, 2001; Maxim, 2003). Therefore, mine water pH is expected to remain near neutral to alkaline in perpetuity, and pH conditions are not expected to limit the longevity of the adsorption attenuation mechanism.

7.4.2 Quantity of Sorbent Material

The quantities of inorganic sorbent materials within the aquifer are very large and are not expected to be exhausted. Iron and manganese are the fourth and twelfth most abundant elements in the earth's crust and the average rock contains about 5 percent iron and about 0.1 percent manganese. Although a portion of the iron and manganese occurs in forms such as silicate minerals that are not strong sorbent materials, the amount of iron and manganese oxide and hydroxides in the aquifer is still very large. Moreover, the supply of fresh iron and manganese oxides and hydroxides is continually replenished by the precipitation of iron and manganese minerals from mine water and groundwater near the decant pond. As demonstrated by geochemical modeling and field and laboratory testing by CDM (2010), there is an additional supplemental source of iron and manganese oxides downgradient of the tailing impoundment toe ponds. Groundwater near the impoundment toe naturally contains high levels of dissolved iron and manganese. Should metal-bearing water from the decant pond migrate to this area, mixing of the two groundwaters would result in the formation of fresh iron and manganese oxide/hydroxide minerals and that would adsorb and attenuate metals. This process has been demonstrated to occur in laboratory jar tests (CDM, 2010).

The quantities of organic matter in the aquifer and infiltration area sediments is likely to be low, probably less than 1 percent based on visual estimates of decant pond sediments. The organic matter that is present in the decant ponds was naturally deposited by wind and water transport of detrital material such as leaves and small pieces of tree branches and by the growth and subsequent death and deposition of algae on the pond surface. These processes are expected to continue after mine closure. Deposition of organic matter in the pond may be increased after full reclamation of the tailing impoundment surface as there will be much greater vegetative cover of the impoundment and a larger source of leaves, twigs, etc. Thus, organic matter is a renewable source of sorbent material that will not be depleted.

7.4.3 Concentration of Competing Ions

Adsorption may be viewed as an electrostatic reaction between a charge surface (the sorbent) and the charged ions in water (Cu^{++}, etc.). In some cases, there may be specific sites on the surface that are more suited for one species than another, so that ions may be seen as

"competing" for adsorption sites. A simple classic case of competing ions is the ion exchange reaction occurring in a home water softener where calcium in water reacts with zeolite minerals so that adsorbed sodium ions are forced off the zeolites and into water, while calcium ions take the adsorption sites formerly occupied by sodium. At low concentrations of ions in water (dilute solutions) competition between ions is low as there are a large number of adsorption sites relative to the number of ions desiring sites. Conversely, competition is high at high ionic concentrations.

If the quality of the disposal water were to change such that the total ionic content (e.g. total dissolved solids or TDS) or dissolved metal concentrations were to increase greatly, adsorption could be limited for some species. However, given the dilute nature of the disposal waters and groundwater (total dissolved solids generally less than 400 mg/L) the concentrations of ions in water are relatively low at present and are expected to decrease further after the cessation of mining and milling due the absence of potassium and sodium-containing milling reagents (see Section 2.3 for discussion of common ion trends). Moreover, mine water metal concentrations have been fairly consistent for over 30 years and are not expected to increase in the future.

Competition between ions is not expected to limit the duration or longevity of the adsorption attenuation mechanism, with a few possible exceptions as described in Section 3.3 and summarized as follows:

- Dissolved phosphate competes with arsenic for adsorption sites, and thus high levels of dissolved phosphate may suppress arsenic adsorption and limit arsenic attenuation. Phosphate concentrations in mine water are expected to remain low. One possible source of phosphate to the decant pond would be from fertilizer used during reclamation. Excessive phosphate fertilizer use should be avoided.
- Calcium, magnesium and trace metals (primarily zinc) compete with cadmium for adsorption sites, and thus high levels of these constituents may suppress cadmium adsorption.

- Uranium adsorption is shown to be greatly reduced in water with high carbonate concentrations due to the formation of uranium carbonate complexes that are poorly sorbed. Bicarbonate concentrations are expected to be reduced from current levels after final mine closure. Bicarbonate concentrations of decant pond water have increased since the mine re-start in 2005 (see Section 2.3). This increase is believed to be related to the higher carbonate mineral content of the ore zone that is currently being mined and milled, relative to the entire mine workings. Therefore, it is likely that bicarbonate concentrations of decant water will decrease to concentrations similar to the interim closure period after final mine closure.

Increased concentrations of ions and dissolved organic species can in some cases increase metal adsorption effectiveness. This occurs when the ions or organics form complexes with metals and the complexed form of the metal has a higher adsorption affinity than the uncomplexed metal ion. A notable example of this is copper, which adsorbs better in high ionic strength solutions, especially in water containing dissolved organic chemicals such as humic acid.

8.0 MANAGEMENT PRACTICES AND MONITORING TO VERIFY CONTINUED EFFECTIVENESS OF METAL ATTENUATION

Potential monitoring and management practices that would help ensure the continued effectiveness of metal attenuation by maintaining the geochemical conditions that are conducive to attenuation are described in this Section. The goal of monitoring and management practices would be to maintain the following current conditions at the tailing impoundment:

1. Neutral or alkaline pH;
2. Oxidizing redox conditions (moderate to high Eh);
3. Presence of moderate amounts of dissolved silica;
4. Presence of moderate amounts of bicarbonate; and
5. Presence of low to moderate amounts of organic material.

8.1 MONITORING

Monitoring activities to assess ongoing conditions related to metals attenuation should include continued monitoring of the water quality of mine water, decant pond water, and groundwater near the decant pond and conditions in the decant pond. Water monitoring parameters critical to attenuation include pH, redox (Eh and dissolved oxygen), dissolved silica, bicarbonate, and dissolved metals. The infiltration site should be monitored for excessive build up of organic matter that may reduce oxygen levels and change redox conditions in the groundwater system.

8.2 MANAGEMENT PRACTICES

Management practices should be aimed at maintaining the existing geochemical conditions by:

1. Maintaining exposure of disposal water to atmospheric oxygen and carbon dioxide;
2. Avoiding excessive use of phosphate fertilizer for reclamation (high levels of dissolved phosphate may suppress arsenic adsorption and limit arsenic attenuation);

3. Maintaining pH by monitoring or mitigation; and
4. Maintaining the decant pond/infiltration site as an aerobic environment by monitoring and if necessary removing excessive organic material that may build up.

8.3 POTENTIAL CORRECTIVE ACTIONS

Corrective actions could be done if needed to adjust or maintain geochemical conditions to maintain or enhance metal attenuation. Corrective actions could include:

1. Actions to raise pH
    a. Add alkaline material to mine water and/or decant pond.
2. Actions to maintain oxidizing conditions
    a. Remove organic matter from pond bottom;
    b. Aeration of water; and
    c. Addition of a chemical oxidant.
3. Actions to raise dissolved silica
    a. Increase exposure to fine-grained silica material (e.g. place tailings in transport path or in pond bottom); and
    b. Raise pH to increase silica solubility.
4. Actions to raise bicarbonate
    a. Add carbonate material (crushed or powdered limestone) to mine water and/or decant pond.

9.0 SUMMARY AND CONCLUSIONS

Mine water and tailings impoundment water have been infiltrated to the groundwater system at the Troy Mine tailings impoundment for over 30 years without appreciable transport of metals in groundwater away from the infiltration pond (decant pond). The lack of transport of metals in groundwater is due to natural attenuation of metals in the sediments beneath the infiltration pond and in the groundwater aquifer. Field evidence for natural attenuation of metals is provided by the sampling and analysis of water and soil samples in the vicinity of the tailings impoundment infiltration pond and from laboratory testing.

Water quality data shows that the concentrations of chemical parameters that are not attenuated (e.g. chemically conservative parameters such as nitrate) are similar between the mine water/decant pond water and the underlying groundwater. This similarity in concentrations indicates that mine water is not appreciably diluted in the groundwater system in close proximity to the infiltration pond. In contrast, the concentrations of metal parameters are much lower in the groundwater than in the mine water/decant pond, indicating that metal parameters are attenuated (removed) in the groundwater system.

Analyses of sediments in the subsurface of the decant pond reveal that metals are enriched in the sediments, indicating that the metals attenuated/removed from groundwater are retained on the sediments. Microscopic and electron microprobe examination of sediments document the occurrence of secondary copper minerals (i.e., non-ore forming minerals) in the sediments. These secondary minerals form by precipitation of copper from mine water. Geochemical equilibrium modeling confirms that copper, iron, lead, and manganese minerals are oversaturated in mine water and are favored to form from mine water.

9.1 EFFECTIVENESS AND LONGEVITY OF MONITORED NATURAL ATTENUATION

The effectiveness of natural attenuation in reducing the concentrations of metals in mine water disposed at the Try tailing impoundment has been proven by extensive field, laboratory and modeling evidence. Disposal of mine water and/or decant water (a mixture of tailings

water, mine water and natural precipitation) at the tailing impoundment has been conducted for over 30 years with no detection of increased metal concentrations in Lake Creek or in groundwater near Lake Creek. Monitoring of groundwater in wells very close to the decant pond (within 150 feet) demonstrate the rapid removal of metals over relatively short distances.

The longevity of the natural attenuation mechanisms is dependent on the duration of the geochemical conditions conducive to attenuation and to the capacity of the decant pond/aquifer sediments to continue to uptake metals. The mineral precipitation and co-precipitation mechanisms are expected to last indefinitely or in perpetuity as long as geochemical conditions remain similar to current conditions. The adsorption mechanisms are conservatively estimated to last a minimum of 600 years.

9.2 ANTIMONY

Antimony concentrations are relatively low in mine water, ranging from <0.003 mg/L to 0.016 mg/L since 1999. Historically, decant water concentrations were similar to mine water but since the mine restart in 2005 antimony concentrations have ranged up to 0.062 mg/L in decant pond water. After the cessation of mining, mine disposal water is expected to be similar to current mine water (<0.003 to 0.016 mg/L).

The scientific literature documents that antimony attenuation occurs primarily by the adsorption of antimony by iron oxides and hydroxides. This effect was demonstrated for Troy Mine waters in a water mixing test by CDM (2010). Mixing of mine water and decant pond water with groundwater from the vicinity of the tailing impoundment resulted in the precipitation of iron and manganese oxides/hydroxides from the mixed waters and the concurrent removal of up to 59 percent of the antimony. Groundwater monitoring data from wells within 150 feet of the decant pond also demonstrates that antimony concentrations are reduced to about 50 percent of the decant pond water in the shallowest groundwater (0.032 mg/L in well MW-01-15). In deeper groundwater (well MW-95-8), antimony concentrations are further attenuated to 0.005 mg/L, a greater than 90 percent reduction.

9.3 ARSENIC

Arsenic concentrations in mine water and decant pond water are very low (0.001 to 0.008 mg/L) and are reduced further by attenuation mechanisms such that arsenic is not detectable in groundwater in the monitoring wells adjacent the decant pond (<0.001 to <0.003 mg/L). Literature reports and site-specific evidence suggests that the primary mechanism of arsenic attenuation is co-precipitation and adsorption to iron and manganese oxide/hydroxide minerals. Geochemical modeling of mine water and decant pond water suggests that pure arsenic mineral phases (i.e., phases containing only arsenic and no other metals) are not expected to precipitate from mine water, decant pond water, and groundwater. Laboratory tests by CDM (2010) in which mine water and decant pond water were mixed with ambient groundwater containing high concentrations of iron demonstrate that arsenic is attenuated simultaneously with the precipitation of iron and manganese oxide/hydroxide solid phases.

9.4 CADMIUM

Cadmium concentrations in decant pond water and mine water are low, typically <0.001 to 0.002 mg/L, and are probably similar to ambient cadmium concentrations in surface water and groundwater in the area. For comparison, Hem (1985, p. 142) estimates the median concentration of cadmium in surface water in the United States to be 0.001 mg/L. Because the cadmium concentrations in water are so low and are often unmeasurable, little is known about cadmium behavior in water at the Troy Mine. In the mine water, decant pond water, and groundwater laboratory mixing tests (CDM, 2010), cadmium concentrations in mine water and decant pond water were not detected at a detection limit of 0.00008 mg/L (i.e., <0.08 parts per billion). Cadmium attenuation could not be determined in these tests because of the extremely low and unmeasurable concentrations.

Cadmium concentrations in nearby groundwater are similar to decant pond water suggesting that little attenuation occurs over the short transport distance between the pond and the monitoring wells. If significantly higher concentrations of cadmium were to occur in mine disposal water after mine closure, it is likely that cadmium would be attenuated at these higher concentrations as cadmium attenuation by mineral precipitation/co-precipitation and adsorption as described in the literature (see Section 3.4).

9.5 COPPER

Copper concentrations ranged from 0.044 to 0.17 mg/L during the interim mine shutdown period of 2000 through 2004 and are expected to be similar after final mine closure. The fate of copper disposed in the decant pond and the attenuation of copper has been extensively studied (Cannon Microprobe (2003), Land Water Consulting (2004), CDM (2010)) by many methods including:

- Groundwater monitoring that demonstrates that copper concentrations are greatly reduced in close proximity to the decant pond;
- Microscopic and electron microprobe identification of secondary copper minerals that are formed within the sediments beneath the decant pond;
- Chemical analyses of sediments beneath the decant pond that demonstrate enrichment in copper by the attenuation mechanisms; and
- Sequential extraction analyses of sediments beneath the decant pond that demonstrate the fractionation of copper in solid phases formed by the attenuation mechanisms.

These studies demonstrate the effectiveness of the natural attenuation of copper in limiting the transport of copper in the groundwater system.

9.6 LEAD

Lead concentrations in mine water are very low (<0.002 to 0.003 during the interim shutdown period; 0.002 to 0.008 mg/L in 2009). Lead concentrations are significantly attenuated and reduced in groundwater adjacent the decant pond as the highest measured groundwater concentration is only 0.0011 mg/L. For comparison, the Montana Groundwater Quality Standard is an order of magnitude higher than groundwater concentration, 0.015 mg/L.

The attenuation of lead is most likely by adsorption and the precipitation of lead minerals from mine water. The scientific literature documents that adsorption and mineral precipitation are common methods of lead attenuation. Geochemical modeling of Troy mine

water, decant pond, and groundwater indicates that the waters are saturated or nearly saturated with cerussite ($PbCO_3$), meaning that precipitation of cerussite and removal of lead from solution is favored. The adsorption effect was demonstrated for Troy Mine waters in a water mixing test by CDM (2010). Mixing of mine water and decant pond water with groundwater from the vicinity of the tailing impoundment resulted in the precipitation of iron and manganese oxides/hydroxides from the mixed waters and the concurrent attenuation of lead concentrations to less than detectable amounts (<0.0005 mg/L).

9.7 MERCURY

Mercury has not been detected in mine water, decant pond water, or groundwater at the Troy Mine. The scientific literature documents that mercury is commonly attenuated by adsorption onto iron and manganese oxide minerals, clays, and organic matter. If significantly higher concentrations of mercury were to occur in mine disposal water after mine closure, it is likely that mercury would be attenuated by these mechanisms.

9.8 SILVER

Silver has not been detected in mine water, decant pond water, or groundwater at the Troy Mine. The scientific literature documents that silver is commonly attenuated by adsorption onto iron and manganese oxide minerals and clays. If significantly higher concentrations of silver were to occur in mine disposal water after mine closure, it is likely that silver would be attenuated by these mechanisms.

9.9 URANIUM

Uranium concentrations are low in mine water (ranging from <0.0003 to 0.0013 mg/L in 2009). For comparison the Montana Groundwater Quality Standard is significantly higher at 0.03 mg/L. Uranium is typically attenuated in groundwater by adsorption mechanisms, in particular by adsorption to iron and manganese oxides. This effect was demonstrated for Troy Mine waters in a test by CDM (2010) in which mixing of mine water and decant pond water with groundwater from the vicinity of the tailing impoundment resulted in the precipitation of iron and manganese oxides/hydroxides from the mixed waters and the concurrent removal of up to 85 percent of the uranium.

At the Troy Mine decant pond, attenuation of uranium is demonstrated by reductions in uranium concentrations as water flows from the decant pond to the adjacent groundwater monitoring wells. Uranium concentrations are reduced by approximately 30 percent during transport to the closest monitoring well (approximately 100 feet lateral distance) and further reduced by 85 percent during flow to the next closest well (approximately 150 feet lateral distance).

10.0 REFERENCES

Bethke, CM, 2008. Geochemical and Biogeochemical Reaction Modeling, 2nd edition. Cambridge University Press, Cambridge. 543 pp.

Camp, Dresser & McKee (CDM), 2010. Troy Mine Copper Attenuation Study – Secondary Processes. Final Draft Report. March 18, 2010. Prepared for Montana Department of Environmental Quality.

Cannon Microprobe, 2003. Electron Microprobe and Scanning Electron Microscope Analysis of DP-2 Decant Pond Sediments. November 25, 2003.

Crane, M.J.; JL Sharpe, and PA Williams, 2001. Formation of Chrysocolla and Secondary Copper Phosphates in the Highly Weathered Supergene Zones of Some Australian Deposits. Records of the Australian Museum (2001) Vol. 53: 49–56.

Ford, R.G., and D.L. Sparks, 2000. The nature of Zn precipitates formed in the presence of pyrophyllite. Env. Sci. Technol. 34:2479-2483.

Gatehouse, S., DW Russel and JC Van Moort, 1977. Sequential soil analysis in exploration geochemistry. Journal of Geochemical Exploration, 8:483-494.

Genesis Inc., 2006. Genesis Incorporated Troy Mine Revised Reclamation Plan. Revised March 2006.

Hem J. D., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. Water-Supply Paper 2254, U.S. Geological Survey, Reston, VA, 1985.

Hydrometrics, Inc., 2000. Mine Water Fate and Transport Study Plan. Prepared for Genesis Inc./Sterling Mining Company. September, 2000.

Hydrometrics, Inc., 2001. Mine Water Plume Location and Identification Phase 1 Results and Phase 2 & 3 Workplan. Prepared for Genesis Inc./Sterling Mining Company. October, 2001

Hydrometrics, Inc., 2009. Proposed Scope of Work for Copper Attenuation Study Addendum. Prepared for Genesis Inc. January 23, 2009.

Langmuir, D., 1997a. Aqueous environmental chemistry. Upper Saddle River, NJ: Prentice-Hall. 600 pp.

Langmuir, D, P. Chrostowski, B. Vigneault and R. Chaney, 2004. Issue Paper on the Environmental Chemistry of Metals. Submitted to USEPA Risk Assessment Forum, August 2004.

Land and Water Consulting, 2004. Assessment of Fate and Transport of Copper in Decant Pond Disposal System – Troy Mine. Prepared for Revett Mining Company. January 2004.

Lindberg, R.D. and D.D. Runnells, 1984. Ground water redox reactions: An analysis of equilibrium state applied to Eh measurements and geochemical modeling. Science. v.225. p. 925-927.

Lawrence Livermore National Laboratory, 2006. Thermodynamic database: thermo.com.V8.R6. Modified March 28, 2006. Database distributed with Geochemist's Workbench software (RockWare, 2010).

Maxim Technologies, 2003. Rock Creek Project 2003 Geochemistry Review. Prepared for USFS Kootenai National Forest. May 2003.

McMahon, P.B., Chapelle, F.H., 2008. Redox Processes and Water Quality of Selected Principal Aquifers, Ground Water, vol. 46(2), 259-271.

Montana Dept. of Environmental Quality and US Forest Service, 2001. Final Environmental Impact Statement – Rock Creek Project. September 2001.

Parametrix, 2008. Final Annual Report – Year 22; Comprehensive Water Quality Monitoring Program for Streams Adjacent to Genesis, Inc. – Troy Mine: Analysis of Spring 1986 through Fall 2006 Samples. Prepared for Genesis Inc. and MDEQ. January 2008.

RockWare, 2010. The Geochemist's Workbench, Release 8.0.7. Copyright by Craig M. Bethke and The Board of Trustees of the University of Illinois.

Summit Envirosolutions, 1999. Site Instrumentation Status Report Troy Tailings Impoundment, Lincoln County, Montana.

US Environmental Protection Agency, 1979. Water-related Environmental Fate of 129 Priority Pollutants, Volume 1 and 2. EPA 440/4-79-029a.

US Environmental Protection Agency, 1991. Mine Site Visit Report – Asarco/Troy Mine.

US Environmental Protection Agency, 1999. Understanding Variation in Partition Coefficient, K_d, Values – Volume 2 - Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium. EPA 402-R-99-004B. August 1999.

US Environmental Protection Agency, 2004. Understanding Variation in Partition Coefficient, K_d, Values – Volume III – Review of Geochemistry and Available Kd Values for Americium, Arsenic, Curium, Iodine, Neptunium, Radium, and Technetium. EPA 402-R-04-002C. July 2004.

US Environmental Protection Agency, 2007a. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 1 and 2. EPA/600/R-07/139. October 2007.

US Environmental Protection Agency, 2007b. Metal Attenuation Processes at Mining Sites EPA/600/R-07/092. September 2007

Westall, J., 2002. Geochemical Equilibrium and the Interpretation of Eh in Workshop on Monitoring Oxidation-Reduction Processes for Ground-water Restoration. Workshop Summary. Dallas, Texas – April 25-27, 2000. EPA/600/R-02/002. January 2002

APPENDIX A

WATER QUALITY SAMPLE SUMMARIES AND LAB REPORTS

Hydrometrics, Inc.
consulting scientists and engineers

262 Burlington
Missoula, MT 59801
(406) 543-3660
Fax: (406) 721-4916
www.hydrometrics.com

May 15, 2009

MEMO TO FILE: Troy Mine (Genesis Mine) Copper Attenuation Samples.

Six of the eight proposed sites for collecting Copper attenuation samples and data were sampled on May 12 – 14, 2009. Seven samples (six sites plus a duplicate) were shipped from the mine site to Energy Laboratories in Billings, MT on May 14, 2009.

Two of the monitor wells proposed for sampling, MW01-16 and MW95-8, were not sampled. MW01-16 was dry. MW95-8 was not accessible because a new surface riser had been added to it when the tailings cell divider dike was raised and access to the well had not been reestablished.

Sites that were sampled include MW95-4, MW95-5, MW01-15, the Service Adit Ditch, Service Adit Pipe, and the decant pond. The Service Adit Ditch, Service Adit Pipe, and Decant samples were all grab samples. Monitor well samples were collected using a rediflo pump. Wells were purged at flow rates less than 0.1 gpm and routed through a flow through cell where groundwater parameters (pH, conductivity, dissolved oxygen, temperature, and oxidation-reduction potential) were measured. Samples were taken when the groundwater parameters stabilized per Hydrometrics standard operating procedure HF-SOP-11. In one case (MW95-4) the oxidation-reduction potential appeared to still be climbing when the sample was taken, however the other parameters had stabilized when the sample was taken.

Sampling field data sheets are attached.

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Ray MINE
Project Code:
Sample Team Member(s): LJ | PK
Laboratory Used: ELI

Site Designation: MW 95-4
Sample Code Number:
Sample Date: 5/12/09
Sample Time: 10:30 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

		Comments
well volume formula:	V = (TD-SWL)x(Dia.^{2}) / 25	
TD (ft):	17.7	
SWL (ft):	10.2	no access/pumping
Casing Diameter (I.D.")	2"	
Water Volume (V) (gal):	1.2	
x 3=(gal.)	3.6	
Actual Vol. Removed (gal.)	2+/-	
Water Level Recovery:	slow moderate (rapid)	

Site Conditions

New Site: Yes (No) Photo taken: Yes No
Site Type: DRY surface water process water (monitoring well) domestic well adit seep spring– other:
Weather Conditions: calm (breeze) windy no precip. (rain) snow clear p. cloudy overcast
Air Temperature: °C 55 °F

For Surface Water Samples

~~Flow Method: Marsh McBirney Volumetric Flume Weir Estimate~~
~~Other Flow or Description:~~
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes
1059	-21.3	0.12	6.36	254	—	5.87	
1046	-26.2	0.15	7.39	286	—	7.02	
1100	13.6	0.18	7.38	347	—	7.43	
1105	38.7	0.19	7.70	358	—	7.70	
1110	45.4	0.20	7.79	367	—	7.80	
1115	32.7	0.18	7.31	374		~~7.29~~	7.93

Turbidity: (circle) clear moderate (slight) very

Sample Method: (describe) grab composite (pump) bailer other
200 FLO 0.1 gpm

Field Parameters

	Sample	Duplicate
ORP (mV)	32.7	
DO (mg/l)	0.18	
pH	7.31	
SC (µmhos/cm)	374	
Turbidity (ntu)	—	
H_2O Tmp. (°C)	7.93	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cond Alk Cl, Fe, SAR, Al	
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	Diss MET	
1	250 ml	(F) or UF	HCl	Hg	
1	250 ml	F or (UF)	HNO_3	Total Rec MET	
1	250 ml	F or (UF)	H_2SO_4	Nitr-NO3 -Sc	
1	250 ml	F or (UF)	NaOH-ZnOAc	Sulfide	
1	500 ml	F or (UF)	H_3PO_4	C	
	ml	F or UF			

Comments: 2 in tubing, 1 filter

Sample Team Member Signature: Larry M Johnson

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Way MIUE
Project Code:
Sample Team Member(s): LJ | RK
Laboratory Used: EL

Site Designation: M495 X3
Sample Code Number:
Sample Date: 5/12/09
Sample Time: 13:45 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Time:

Site Conditions

New Site: Yes (No) Photo taken: Yes No
Site Type: DRY surface water process water (monitoring well) domestic well adit seep spring-- other:
Weather Conditions: calm (breeze) windy no precip. (rain) snow clear (p. cloudy) overcast
Air Temperature: °C 55 °F

For Groundwater Samples

well volume formula: V = (TD-SWL)x(Dia.^{2}) / 25 — Comments

TD (ft): 13.40 (sounded)
SWL (ft): 7.25 no access/pumping
Casing Diameter (I.D.") 2
Water Volume (V) (gal): 1
x 3=(gal.) 3
Actual Vol. Removed (gal.) 2.5
Water Level Recovery: slow moderate rapid

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization Start Pump @ 13:10

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes
1319	167.7	1.86	6.10	78	—	6.98	
1330	175.2	1.00	5.99	75	—	8.10	
1335	177.9	1.76	5.[illegible]	74		8.21	
1343	179.51	1.77	6.04	72	—	8.8	

Turbidity: (circle) clear (slight) (moderate) very

Sample Method: (describe) grab composite (pump) bailer other
Low Flow Pump ~0.1 gpm

Field Parameters

	Sample	Duplicate
ORP (mV)	179.51	
DO (mg/l)	1.77	
pH	6.04	
SC (µmhos/cm)	72	
Turbidity (ntu)	—	
H_2O Tmp. (°C)	8.8	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cond. M+, Fl, Fe, SO4, Alk	
1	500 ml	F or (UF)	—	TDS	P, pH
1	250 ml	(F) or UF	HNO_3	Diss MET	
1	250 ml	(F) or UF	HCl	Hg	
1	250 ml	F or (UF)	HNO_3	Tot Rec MET	
1	250 ml	F or (UF)	H_2SO_4	N	
1	250 ml	F or (UF)	NaOH+ZnOAc	Sulfide	
1	500 ml	F or (UF)	H_3PO_4	C	
	ml	F or UF			

Comments: 20' tubing, 1 filter

Sample Team Member Signature: Larry M Johnson

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Ivy Mine
Project Code:
Sample Team Member(s): LJ/PK
Laboratory Used: GCI

Site Designation: Adit Pipe
Sample Code Number:
Sample Date: 5/12/09
Sample Time: 3:15 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

well volume formula: $V = \frac{(TD-SWL)x(Dia.^2)}{25}$ — Comments

TD (ft):
SWL (ft): — no access/pumping
Casing Diameter (I.D.")
Water Volume (V) (gal):
x 3=(gal.)
Actual Vol. Removed (gal.)
Water Level Recovery: slow moderate rapid

Site Conditions

New Site: Yes (No) Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well (adit) seep
spring– other:
Weather Conditions: calm (breeze) windy
no precip. (rain) snow
clear p. cloudy (overcast)
Air Temperature: °C 57 °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear slight (moderate) very

Sample Method: (grab) composite pump bailer other
(describe)

Field Parameters

	Sample	Duplicate
ORP (mV)	174.2	
DO (mg/l)	4.11	
pH	7.52	
SC (µmhos/cm)	245	
Turbidity (ntu)		
H_2O Tmp. (°C)	6.37	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cond. Alk, Cl, Fe	
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	Diss Met	
1	250 ml	(F) or UF	HCl	HCl	Hg
1	250 ml	F or (UF)	HNO_3	Total Met	
1	250 ml	F or (UF)	H_2SO_4	N	
1	250 ml	F or (UF)	NaOH	NaOH	Sulfide
1	500 ml	F or (UF)	H_3PO_4	H_3PO_4	C
	ml	F or UF			

Comments:

Sample Team Member Signature: Lam H Sohn

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: TROY MINE
Project Code:
Sample Team Member(s): LJ/PK
Laboratory Used: ZL

Site Designation: ADIT DITCH
Sample Code Number:
Sample Date: 5/12/09
Sample Time: 3:30 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Time:

For Groundwater Samples

well volume formula: V = (TD-SWL)x(Dia.^{2}) / 25 — Comments

TD (ft):
SWL (ft): — no access/pumping
Casing Diameter (I.D.")
Water Volume (V) (gal):
x 3=(gal.)
Actual Vol. Removed (gal.)
Water Level Recovery: slow moderate rapid

Site Conditions

New Site: Yes (No) Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well (adit) seep
spring– other:
Weather Conditions: calm (breeze) windy
no precip. (rain) snow
clear p. cloudy overcast
Air Temperature: °C 55 °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes
3:30	182.7	10.75	7.53	146		5.25	

Turbidity: (circle) clear slight (moderate) (very)

Sample Method: (describe) (grab) composite pump bailer other

Field Parameters

	Sample	Duplicate
ORP (mV)	182.7	
DO (mg/l)	10.75	
pH	7.53	
SC (µmhos/cm)	146	
Turbidity (ntu)		
H_2O Tmp. (°C)	5.25	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cond	M^+, Alk, Fl, Fe
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	Diss.	Met
1	250 ml	(F) or UF	HCl	HCl	Hg
1	250 ml	F or (UF)	HNO_3	HNO_3	Ca, Mg, M^+
1	250 ml	F or (UF)	H_2SO_4	H_2SO_4	N
1	250 ml	F or (UF)	NaOH	Sulfide	
1	500 ml	F or (UF)	H_3PO_4	Cr+	
	ml	F or UF			

Comments:

Sample Team Member Signature: [signature]

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Ray Mine
Project Code:
Sample Team Member(s): LS / GH PK
Laboratory Used: BL

Site Designation: MW-0115
Sample Code Number:
Sample Date: 5/13/09
Sample Time: 15:10 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

well volume formula:	V = (TD-SWL)x(Dia.^{2}) / 25	Comments
TD (ft):	~~43.9~~ 53.25	
SWL (ft):	~~53~~ 43.9	no access/pumping
Casing Diameter (I.D.")	2"	
Water Volume (V) (gal):	1.5	
x 3=(gal.)	4.5	
Actual Vol. Removed (gal.)		
Water Level Recovery:	slow moderate rapid	

Site Conditions

New Site: Yes (No) Photo taken: Yes No
Site Type: (DRY) surface water process water
monitoring well domestic well adit seep
spring-- other:
Weather Conditions: calm (breeze) windy
no precip. rain (snow)
clear p. cloudy (overcast)
Air Temperature: °C 40°F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes
1426	185.7	3.80	7.18	390	—	8.69	
1449	181.8	3.49	7.26	390	—	9.97	
1501	180.9	4.98	7.30	390	—	10.9	
1510	183	5.17	7.24	390	—	10.85	

Turbidity: (circle) clear moderate (slight) very

Sample Method: (describe) grab composite (pump) bailer other
<0.1 gpm

Field Parameters

	Sample	Duplicate
ORP (mV)	183	
DO (mg/l)	5.17	
pH	7.24	
SC (µmhos/cm)	390	
Turbidity (ntu)		
H_2O Tmp. (°C)	10.85	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cond.	Alt
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO3	DISS.	Alt
1	250 ml	(F) or UF	HCl	Hg	
1	250 ml	F or (UF)	HNO3	Fe -	TOTAL
1	250 ml	F or (UF)	H2SO4	N	
1	250 ml	F or (UF)	NaOH	S	
1	500 ml	F or (UF)	H3PO4	Cr	
	ml	F or UF			

Comments: Set Pump @ 50': 60' hose, 1 filter
Start Purge @ 14:15

Sample Team Member Signature: [signature]

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Troy Mine
Project Code:
Sample Team Member(s): LJ/AK
Laboratory Used: EL

Site Designation: RECAUT 1
Sample Code Number:
Sample Date: 5/14/2009
Sample Time: 8:30 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #: RECAUT 2
Duplicate Sample Time: 8:45

For Groundwater Samples

well volume formula:	V = (TD-SWL)x(Dia.^{2}) / 25	Comments
TD (ft):		
SWL (ft):		no access/pumping
Casing Diameter (I.D.")		
Water Volume (V) (gal):		
x 3=(gal.)		
Actual Vol. Removed (gal.)		
Water Level Recovery:	slow moderate rapid	

Site Conditions

New Site: Yes (No) Photo taken: Yes (No)

Site Type: DRY surface water process water monitoring well domestic well adit seep spring other: Recaut Road

Weather Conditions: calm (breeze) windy; no precip. (rain) snow; clear p. cloudy overcast

Air Temperature: °C 40 °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate

Other Flow or Description:

Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear slight (moderate) very

Sample Method: (describe) (grab) composite pump bailer other

Field Parameters

	Sample	Duplicate
ORP (mV)	179.5	179.5
DO (mg/l)	8.19	8.19
pH	7.43	7.43
SC (µmhos/cm)	394	394
Turbidity (ntu)		
H_2O Tmp. (°C)	9.5	9.5
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1+1	500 ml	F or (UF)	—	Conduct	MF
1+1	500 ml	F or (UF)	—	TDS	
1+1	250 ml	(F) or UF	HNO_3	DISS	MF
1+1	250 ml	(F) or UF	HCl	Hg	
1+1	250 ml	F or (UF)	HNO_3	~~Fe~~	TOTAL Fe
1+1	250 ml	F or (UF)	H_2SO_4	N	
1+1	250 ml	F or (UF)	NaOH	S	
1+1	500 ml	F or (UF)	H_3PO_4	Cr	
	ml	F or UF			

Comments: Filter from Recaut pond #1 from pump/dif Resandat.

Sample Team Member Signature: [signature]

Page 1 of 1

ENERGY LABORATORIES, INC. * 1120 S 27th St * PO Box 30916 * Billings, MT 59107-0916
Toll Free 800.735.4489 * 406.252.6325 * FAX 406.252.6069 * eli@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-001
Client Sample ID: MW 95-4

Report Date: 05/29/09
Collection Date: 05/12/09 10:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	6.5	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	445	umhos/cm		1		A2510 B	05/18/09 15:51 / nlh
Solids, Total Dissolved TDS @ 180 C	292	mg/L		10		A2540 C	05/18/09 16:15 / afb
INORGANICS							
Alkalinity, Total as CaCO3	77	mg/L		4		A2320 B	05/18/09 22:56 / ehb
Bicarbonate as HCO3	94	mg/L		4		A2320 B	05/18/09 22:56 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 22:56 / ehb
Chloride	1	mg/L		1		E300.0	05/20/09 20:08 / kh
Sulfate	111	mg/L		1		E300.0	05/20/09 20:08 / kh
Fluoride	ND	mg/L		0.1		A4500-F C	05/18/09 22:56 / ehb
Sulfide	0.22	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	108	mg/L		1		A2340 B	05/19/09 16:20 / rls
Sodium Adsorption Ratio (SAR)	0.53			0.01		Calculation	05/19/09 16:20 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	4.8	mg/L	D	0.8		A5310 C	05/20/09 11:12 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.72	mg/L		0.05		E350.1	05/19/09 10:48 / sam
Nitrogen, Nitrate+Nitrite as N	0.02	mg/L		0.01		E353.2	05/18/09 14:27 / bls
Phosphorus, Orthophosphate as P	0.014	mg/L	LH	0.005		E365.1	05/19/09 15:49 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:30 / eli-c
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.8	05/19/09 17:32 / aje
Antimony	ND	mg/L		0.003		E200.8	05/19/09 17:32 / aje
Arsenic	0.002	mg/L		0.001		E200.8	05/19/09 17:32 / aje
Barium	0.114	mg/L		0.005		E200.8	05/19/09 17:32 / aje
Beryllium	ND	mg/L		0.001		E200.8	05/19/09 17:32 / aje
Cadmium	0.00093	mg/L		0.00008		E200.8	05/19/09 17:32 / aje
Calcium	29	mg/L		1		E200.7	05/19/09 16:20 / tao
Chromium	0.002	mg/L		0.001		E200.8	05/19/09 17:32 / aje
Copper	ND	mg/L		0.001		E200.8	05/19/09 17:32 / aje
Iron	7.84	mg/L		0.05		E200.7	05/19/09 16:20 / tao
Iron, Ferrous	7.84	mg/L		0.05		E200.7	05/19/09 16:20 / tao
Lead	ND	mg/L		0.0005		E200.8	05/19/09 17:32 / aje
Magnesium	8	mg/L		1		E200.7	05/19/09 16:20 / tao
Manganese	2.43	mg/L		0.005		E200.7	05/19/09 16:20 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-001
Client Sample ID: MW 95-4

Report Date: 05/29/09
Collection Date: 05/12/09 10:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:20 / tao
Potassium	17	mg/L		1		E200.7	05/19/09 16:20 / tao
Selenium	0.003	mg/L		0.001		E200.8	05/19/09 17:32 / aje
Silicon	21.7	mg/L		0.1		E200.7	05/20/09 13:06 / tao
Silica	46.4	mg/L		0.2		E200.7	05/20/09 13:06 / tao
Silver	ND	mg/L		0.0005		E200.8	05/19/09 17:32 / aje
Sodium	13	mg/L		1		E200.7	05/19/09 16:20 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 17:32 / aje
Uranium	ND	mg/L		0.0003		E200.8	05/19/09 17:32 / aje
Zinc	ND	mg/L		0.01		E200.8	05/19/09 17:32 / aje
METALS, TOTAL							
Iron, Ferric	3.46	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	11.3	mg/L		0.05		E200.7	05/21/09 11:56 / tao
FIELD PARAMETERS							
Field pH, su	7.3	s.u.				FIELD	05/12/09 10:30 / ---
Field Temperature, C	8.0	C				FIELD	05/12/09 10:30 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-002
Client Sample ID: MW 95-5

Report Date: 05/29/09
Collection Date: 05/12/09 13:45
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	5.9	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	82	umhos/cm		1		A2510 B	05/19/09 11:13 / nlh
Solids, Total Dissolved TDS @ 180 C	97	mg/L		10		A2540 C	05/19/09 15:29 / afb
INORGANICS							
Alkalinity, Total as CaCO3	31	mg/L		4		A2320 B	05/18/09 23:04 / ehb
Bicarbonate as HCO3	38	mg/L		4		A2320 B	05/18/09 23:04 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:04 / ehb
Chloride	ND	mg/L		1		E300.0	05/20/09 20:43 / kh
Sulfate	3	mg/L		1		E300.0	05/20/09 20:43 / kh
Fluoride	ND	mg/L		0.1		A4500-F C	05/18/09 23:04 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	20	mg/L		1		A2340 B	05/19/09 16:24 / rls
Sodium Adsorption Ratio (SAR)	0.51			0.01		Calculation	05/19/09 16:24 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	2.4	mg/L		0.5		A5310 C	05/20/09 11:23 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	ND	mg/L		0.05		E350.1	05/19/09 10:51 / sam
Nitrogen, Nitrate+Nitrite as N	0.09	mg/L		0.01		E353.2	05/18/09 14:28 / bls
Phosphorus, Orthophosphate as P	0.016	mg/L	LH	0.005		E365.1	05/19/09 15:52 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:32 / eli-c
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	05/19/09 16:24 / tao
Antimony	ND	mg/L		0.003		E200.8	05/19/09 18:30 / aje
Arsenic	ND	mg/L		0.001		E200.8	05/19/09 18:30 / aje
Barium	0.016	mg/L		0.005		E200.8	05/19/09 18:30 / aje
Beryllium	ND	mg/L		0.001		E200.8	05/19/09 18:30 / aje
Cadmium	0.00089	mg/L		0.00008		E200.8	05/19/09 18:30 / aje
Calcium	6	mg/L		1		E200.7	05/19/09 16:24 / tao
Chromium	0.003	mg/L		0.001		E200.8	05/19/09 18:30 / aje
Copper	0.002	mg/L		0.001		E200.8	05/19/09 18:30 / aje
Iron	0.18	mg/L		0.05		E200.7	05/19/09 16:24 / tao
Iron, Ferrous	0.18	mg/L		0.05		E200.7	05/19/09 16:24 / tao
Lead	ND	mg/L		0.0005		E200.8	05/19/09 18:30 / aje
Magnesium	1	mg/L		1		E200.7	05/19/09 16:24 / tao
Manganese	0.457	mg/L		0.005		E200.7	05/19/09 16:24 / tao

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
H - Analysis performed past recommended holding time.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
L - Lowest available reporting limit for the analytical methoc used.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-002
Client Sample ID: MW 95-5

Report Date: 05/29/09
Collection Date: 05/12/09 13:45
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:24 / tao
Potassium	5	mg/L		1		E200.7	05/19/09 16:24 / tao
Selenium	0.001	mg/L		0.001		E200.8	05/20/09 14:06 / aje
Silicon	28.4	mg/L		0.1		E200.7	05/20/09 13:18 / tao
Silica	60.8	mg/L		0.2		E200.7	05/20/09 13:18 / tao
Silver	ND	mg/L		0.0005		E200.8	05/19/09 18:30 / aje
Sodium	5	mg/L		1		E200.7	05/19/09 16:24 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 18:30 / aje
Uranium	ND	mg/L		0.0003		E200.8	05/19/09 18:30 / aje
Zinc	ND	mg/L		0.01		E200.8	05/19/09 18:30 / aje
METALS, TOTAL							
Iron, Ferric	0.20	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	0.38	mg/L		0.05		E200.7	05/21/09 12:00 / tao
FIELD PARAMETERS							
Field pH, su	6.04	s.u.				FIELD	05/12/09 13:45 / ---
Field Temperature, C	8.8	C				FIELD	05/12/09 13:45 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-003
Client Sample ID: Adit Pipe

Report Date: 05/29/09
Collection Date: 05/12/09 15:15
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.8	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	269	umhos/cm		1		A2510 B	05/18/09 15:56 / nlh
Solids, Total Dissolved TDS @ 180 C	156	mg/L		10		A2540 C	05/18/09 16:21 / afb
INORGANICS							
Alkalinity, Total as CaCO3	79	mg/L		4		A2320 B	05/18/09 23:12 / ehb
Bicarbonate as HCO3	96	mg/L		4		A2320 B	05/18/09 23:12 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:12 / ehb
Chloride	ND	mg/L		1		E300.0	05/20/09 20:55 / kh
Sulfate	17	mg/L		1		E300.0	05/20/09 20:55 / kh
Fluoride	ND	mg/L		0.1		A4500-F C	05/18/09 23:12 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	107	mg/L		1		A2340 B	05/19/09 16:28 / rls
Sodium Adsorption Ratio (SAR)	0.18			0.01		Calculation	05/19/09 16:28 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	ND	mg/L		0.5		A5310 C	05/20/09 11:33 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	2.33	mg/L		0.05		E350.1	05/19/09 10:52 / sam
Nitrogen, Nitrate+Nitrite as N	7.99	mg/L	D	0.02		E353.2	05/18/09 14:29 / bls
Phosphorus, Orthophosphate as P	0.096	mg/L	LH	0.005		E365.1	05/19/09 15:53 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:34 / eli-c
METALS, DISSOLVED							
Aluminum	0.09	mg/L		0.03		E200.7	05/19/09 16:28 / tao
Antimony	0.015	mg/L		0.003		E200.8	05/19/09 18:37 / aje
Arsenic	0.002	mg/L		0.001		E200.8	05/19/09 18:37 / aje
Barium	0.070	mg/L		0.005		E200.8	05/19/09 18:37 / aje
Beryllium	ND	mg/L		0.001		E200.7	05/19/09 16:28 / tao
Cadmium	0.00220	mg/L		0.00008		E200.8	05/19/09 18:37 / aje
Calcium	32	mg/L		1		E200.7	05/19/09 16:28 / tao
Chromium	ND	mg/L		0.001		E200.8	05/19/09 18:37 / aje
Copper	0.041	mg/L		0.001		E200.8	05/19/09 18:37 / aje
Iron	0.05	mg/L		0.05		E200.7	05/19/09 16:28 / tao
Iron, Ferrous	0.05	mg/L		0.05		E200.7	05/19/09 16:28 / tao
Lead	0.0021	mg/L		0.0005		E200.8	05/19/09 18:37 / aje
Magnesium	7	mg/L		1		E200.7	05/19/09 16:28 / tao
Manganese	0.163	mg/L		0.005		E200.7	05/19/09 16:28 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-003
Client Sample ID: Adit Pipe

Report Date: 05/29/09
Collection Date: 05/12/09 15:15
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:28 / tao
Potassium	2	mg/L		1		E200.7	05/19/09 16:28 / tao
Selenium	0.003	mg/L		0.001		E200.8	05/20/09 14:33 / aje
Silicon	3.6	mg/L		0.1		E200.8	05/20/09 14:33 / aje
Silica	7.7	mg/L		0.2		E200.8	05/20/09 14:33 / aje
Silver	ND	mg/L		0.0005		E200.8	05/19/09 18:37 / aje
Sodium	4	mg/L		1		E200.7	05/19/09 16:28 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 18:37 / aje
Uranium	0.0013	mg/L		0.0003		E200.8	05/19/09 18:37 / aje
Zinc	ND	mg/L		0.01		E200.8	05/19/09 18:37 / aje
METALS, TOTAL							
Iron, Ferric	4.24	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	4.29	mg/L		0.05		E200.7	05/21/09 12:04 / tao
FIELD PARAMETERS							
Field pH, su	7.52	s.u.				FIELD	05/12/09 15:15 / ---
Field Temperature, C	6.04	C				FIELD	05/12/09 15:15 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-004
Client Sample ID: Adit Ditch

Report Date: 05/29/09
Collection Date: 05/12/09 15:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.8	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	169	umhos/cm		1		A2510 B	05/18/09 15:55 / nlh
Solids, Total Dissolved TDS @ 180 C	96	mg/L		10		A2540 C	05/18/09 16:20 / afb
INORGANICS							
Alkalinity, Total as CaCO3	42	mg/L		4		A2320 B	05/18/09 23:20 / ehb
Bicarbonate as HCO3	52	mg/L		4		A2320 B	05/18/09 23:20 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:20 / ehb
Chloride	ND	mg/L		1		E300.0	05/20/09 21:06 / kh
Sulfate	17	mg/L		1		E300.0	05/20/09 21:06 / kh
Fluoride	ND	mg/L		0.1		A4500-F C	05/18/09 23:20 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	57	mg/L		1		A2340 B	05/19/09 16:39 / rls
Sodium Adsorption Ratio (SAR)	0.20			0.01		Calculation	05/19/09 16:39 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	ND	mg/L		0.5		A5310 C	05/20/09 11:42 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	1.59	mg/L		0.05		E350.1	05/19/09 10:54 / sam
Nitrogen, Nitrate+Nitrite as N	3.22	mg/L		0.01		E353.2	05/18/09 14:31 / bls
Phosphorus, Orthophosphate as P	0.051	mg/L	LH	0.005		E365.1	05/19/09 15:54 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	5	ng/L		5		E245.7	05/27/09 17:36 / eli-c
METALS, DISSOLVED							
Aluminum	0.06	mg/L		0.03		E200.7	05/19/09 16:39 / tao
Antimony	0.008	mg/L		0.003		E200.8	05/19/09 18:44 / aje
Arsenic	0.001	mg/L		0.001		E200.8	05/19/09 18:44 / aje
Barium	0.065	mg/L		0.005		E200.8	05/19/09 18:44 / aje
Beryllium	ND	mg/L		0.001		E200.8	05/19/09 18:44 / aje
Cadmium	0.00087	mg/L		0.00008		E200.8	05/19/09 18:44 / aje
Calcium	17	mg/L		1		E200.7	05/19/09 16:39 / tao
Chromium	ND	mg/L		0.001		E200.8	05/19/09 18:44 / aje
Copper	0.084	mg/L		0.001		E200.8	05/19/09 18:44 / aje
Iron	ND	mg/L		0.05		E200.7	05/19/09 16:39 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	05/19/09 16:39 / tao
Lead	0.0080	mg/L		0.0005		E200.8	05/19/09 18:44 / aje
Magnesium	3	mg/L		1		E200.7	05/19/09 16:39 / tao
Manganese	0.312	mg/L		0.005		E200.7	05/19/09 16:39 / tao

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
H - Analysis performed past recommended holding time.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
L - Lowest available reporting limit for the analytical methoc used.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-004
Client Sample ID: Adit Ditch

Report Date: 05/29/09
Collection Date: 05/12/09 15:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:39 / tao
Potassium	2	mg/L		1		E200.7	05/19/09 16:39 / tao
Selenium	0.001	mg/L		0.001		E200.8	05/20/09 14:40 / aje
Silicon	4.4	mg/L		0.1		E200.8	05/20/09 14:40 / aje
Silica	9.5	mg/L		0.2		E200.8	05/20/09 14:40 / aje
Silver	ND	mg/L		0.0005		E200.8	05/19/09 18:44 / aje
Sodium	3	mg/L		1		E200.7	05/19/09 16:39 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 18:44 / aje
Uranium	ND	mg/L		0.0003		E200.8	05/19/09 18:44 / aje
Zinc	ND	mg/L		0.01		E200.8	05/19/09 18:44 / aje
METALS, TOTAL							
Iron, Ferric	8.51	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	8.51	mg/L		0.05		E200.7	05/21/09 12:08 / tao
FIELD PARAMETERS							
Field pH, su	7.53	s.u.				FIELD	05/12/09 15:30 / ---
Field Temperature, C	5.25	C				FIELD	05/12/09 15:30 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-005
Client Sample ID: MW-01-15

Report Date: 05/29/09
Collection Date: 05/13/09 15:20
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.3	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	424	umhos/cm		1		A2510 B	05/18/09 15:57 / nlh
Solids, Total Dissolved TDS @ 180 C	256	mg/L		10		A2540 C	05/18/09 16:23 / afb
INORGANICS							
Alkalinity, Total as CaCO3	83	mg/L		4		A2320 B	05/18/09 23:28 / ehb
Bicarbonate as HCO3	102	mg/L		4		A2320 B	05/18/09 23:28 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:28 / ehb
Chloride	4	mg/L		1		E300.0	05/20/09 21:18 / kh
Sulfate	31	mg/L		1		E300.0	05/20/09 21:18 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	05/18/09 23:28 / ehb
Sulfide	0.05	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	71	mg/L		1		A2340 B	05/19/09 16:43 / rls
Sodium Adsorption Ratio (SAR)	1.66			0.01		Calculation	05/19/09 16:43 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	1.6	mg/L		0.5		A5310 C	05/20/09 11:53 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.83	mg/L		0.05		E350.1	05/19/09 10:55 / sam
Nitrogen, Nitrate+Nitrite as N	16.8	mg/L	D	0.02		E353.2	05/18/09 14:32 / bls
Phosphorus, Orthophosphate as P	0.073	mg/L	LH	0.005		E365.1	05/19/09 15:55 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:38 / eli-c
METALS, DISSOLVED							
Aluminum	0.04	mg/L		0.03		E200.8	05/19/09 18:51 / aje
Antimony	0.032	mg/L		0.003		E200.8	05/19/09 18:51 / aje
Arsenic	ND	mg/L		0.001		E200.8	05/19/09 18:51 / aje
Barium	0.101	mg/L		0.005		E200.8	05/19/09 18:51 / aje
Beryllium	ND	mg/L		0.001		E200.7	05/19/09 16:43 / tao
Cadmium	0.00090	mg/L		0.00008		E200.8	05/19/09 18:51 / aje
Calcium	22	mg/L		1		E200.7	05/19/09 16:43 / tao
Chromium	0.002	mg/L		0.001		E200.8	05/19/09 18:51 / aje
Copper	0.068	mg/L		0.001		E200.8	05/19/09 18:51 / aje
Iron	0.06	mg/L		0.05		E200.7	05/19/09 16:43 / tao
Iron, Ferrous	0.06	mg/L		0.05		E200.7	05/19/09 16:43 / tao
Lead	0.0011	mg/L		0.0005		E200.8	05/19/09 18:51 / aje
Magnesium	4	mg/L		1		E200.7	05/19/09 16:43 / tao
Manganese	0.455	mg/L		0.005		E200.7	05/19/09 16:43 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

ENERGY LABORATORIES, INC. * 1120 S 27th St * PO Box 30916 * Billings, MT 59107-0916
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-005
Client Sample ID: MW-01-15

Report Date: 05/29/09
Collection Date: 05/13/09 15:20
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:43 / tao
Potassium	22	mg/L		1		E200.7	05/19/09 16:43 / tao
Selenium	ND	mg/L		0.001		E200.8	05/19/09 18:51 / aje
Silicon	5.1	mg/L		0.1		E200.7	05/20/09 13:34 / tao
Silica	11.0	mg/L		0.2		E200.7	05/20/09 13:34 / tao
Silver	ND	mg/L		0.0005		E200.8	05/19/09 18:51 / aje
Sodium	32	mg/L		1		E200.7	05/19/09 16:43 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 18:51 / aje
Uranium	0.0020	mg/L		0.0003		E200.8	05/19/09 18:51 / aje
Zinc	0.01	mg/L		0.01		E200.7	05/19/09 16:43 / tao
METALS, TOTAL							
Iron, Ferric	3.31	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	3.37	mg/L		0.05		E200.7	05/21/09 12:12 / tao
FIELD PARAMETERS							
Field pH, su	7.24	s.u.				FIELD	05/13/09 15:20 / ---
Field Temperature, C	10.85	C				FIELD	05/13/09 15:20 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-006
Client Sample ID: Decant 1

Report Date: 05/29/09
Collection Date: 05/14/09 08:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.6	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	427	umhos/cm		1		A2510 B	05/18/09 16:00 / nlh
Solids, Total Dissolved TDS @ 180 C	305	mg/L		10		A2540 C	05/18/09 16:26 / afb
INORGANICS							
Alkalinity, Total as CaCO3	82	mg/L		4		A2320 B	05/18/09 23:36 / ehb
Bicarbonate as HCO3	99	mg/L		4		A2320 B	05/18/09 23:36 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:36 / ehb
Chloride	4	mg/L		1		E300.0	05/20/09 21:30 / kh
Sulfate	33	mg/L		1		E300.0	05/20/09 21:30 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	05/18/09 23:36 / ehb
Sulfide	0.04	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	59	mg/L		1		A2340 B	05/19/09 16:47 / rls
Sodium Adsorption Ratio (SAR)	1.73			0.01		Calculation	05/19/09 16:47 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	1.6	mg/L		0.5		A5310 C	05/20/09 12:04 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	6.0	mg/L	D	0.1		E350.1	05/21/09 10:47 / sam
Nitrogen, Nitrate+Nitrite as N	17.6	mg/L	D	0.02		E353.2	05/18/09 14:33 / bls
Phosphorus, Orthophosphate as P	0.134	mg/L	LH	0.005		E365.1	05/19/09 15:56 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:40 / eli-c
METALS, DISSOLVED							
Aluminum	0.11	mg/L		0.03		E200.8	05/19/09 18:58 / aje
Antimony	0.046	mg/L		0.003		E200.8	05/19/09 18:58 / aje
Arsenic	0.002	mg/L		0.001		E200.8	05/19/09 18:58 / aje
Barium	0.097	mg/L		0.005		E200.8	05/19/09 18:58 / aje
Beryllium	ND	mg/L		0.001		E200.8	05/19/09 18:58 / aje
Cadmium	0.00089	mg/L		0.00008		E200.8	05/19/09 18:58 / aje
Calcium	17	mg/L		1		E200.7	05/19/09 16:47 / tao
Chromium	ND	mg/L		0.001		E200.8	05/19/09 18:58 / aje
Copper	0.028	mg/L		0.001		E200.8	05/19/09 18:58 / aje
Iron	0.06	mg/L		0.05		E200.7	05/19/09 16:47 / tao
Iron, Ferrous	0.06	mg/L		0.05		E200.7	05/19/09 16:47 / tao
Lead	0.0026	mg/L		0.0005		E200.8	05/19/09 18:58 / aje
Magnesium	4	mg/L		1		E200.7	05/19/09 16:47 / tao
Manganese	0.554	mg/L		0.005		E200.7	05/19/09 16:47 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
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L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-006
Client Sample ID: Decant 1

Report Date: 05/29/09
Collection Date: 05/14/09 08:30
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:47 / tao
Potassium	27	mg/L		1		E200.7	05/19/09 16:47 / tao
Selenium	0.001	mg/L		0.001		E200.8	05/20/09 15:15 / aje
Silicon	4.0	mg/L		0.1		E200.8	05/20/09 15:15 / aje
Silica	8.5	mg/L		0.2		E200.8	05/20/09 15:15 / aje
Silver	ND	mg/L		0.0005		E200.8	05/19/09 18:58 / aje
Sodium	31	mg/L		1		E200.7	05/19/09 16:47 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 18:58 / aje
Uranium	0.0029	mg/L		0.0003		E200.8	05/19/09 18:58 / aje
Zinc	ND	mg/L		0.01		E200.8	05/19/09 18:58 / aje
METALS, TOTAL							
Iron, Ferric	2.96	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	3.02	mg/L		0.05		E200.7	05/21/09 12:24 / tao
FIELD PARAMETERS							
Field pH, su	7.45	s.u.				FIELD	05/14/09 08:30 / ---
Field Temperature, C	9.5	C				FIELD	05/14/09 08:30 / ---

Report Definitions:
RL - Analyte reporting limit.
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MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-007
Client Sample ID: Decant

Report Date: 05/29/09
Collection Date: 05/14/09 08:45
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.7	s.u.		0.1		A4500-H B	05/18/09 14:52 / nlh
Conductivity	429	umhos/cm		1		A2510 B	05/18/09 16:01 / nlh
Solids, Total Dissolved TDS @ 180 C	314	mg/L		10		A2540 C	05/18/09 16:27 / afb
INORGANICS							
Alkalinity, Total as CaCO3	82	mg/L		4		A2320 B	05/18/09 23:59 / ehb
Bicarbonate as HCO3	100	mg/L		4		A2320 B	05/18/09 23:59 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	05/18/09 23:59 / ehb
Chloride	4	mg/L		1		E300.0	05/21/09 00:01 / kh
Sulfate	33	mg/L		1		E300.0	05/21/09 00:01 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	05/18/09 23:59 / ehb
Sulfide	0.10	mg/L		0.04		A4500 S-D	05/19/09 09:30 / afb
Hardness as CaCO3	59	mg/L		1		A2340 B	05/19/09 16:51 / rls
Sodium Adsorption Ratio (SAR)	1.76			0.01		Calculation	05/19/09 16:51 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	1.6	mg/L		0.5		A5310 C	05/20/09 12:16 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	6.0	mg/L	D	0.1		E350.1	05/21/09 10:48 / sam
Nitrogen, Nitrate+Nitrite as N	19.4	mg/L	D	0.02		E353.2	05/18/09 14:34 / bls
Phosphorus, Orthophosphate as P	0.169	mg/L	LH	0.005		E365.1	05/19/09 15:57 / mlm
- The sample was received after the holding time had expired for Orthophosphat.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5		E245.7	05/27/09 17:44 / eli-c
METALS, DISSOLVED							
Aluminum	0.12	mg/L		0.03		E200.7	05/19/09 16:51 / tao
Antimony	0.047	mg/L		0.003		E200.8	05/19/09 19:05 / aje
Arsenic	0.002	mg/L		0.001		E200.8	05/19/09 19:05 / aje
Barium	0.099	mg/L		0.005		E200.8	05/19/09 19:05 / aje
Beryllium	ND	mg/L		0.001		E200.7	05/19/09 16:51 / tao
Cadmium	0.00091	mg/L		0.00008		E200.8	05/19/09 19:05 / aje
Calcium	17	mg/L		1		E200.7	05/19/09 16:51 / tao
Chromium	ND	mg/L		0.001		E200.8	05/19/09 19:05 / aje
Copper	0.024	mg/L		0.001		E200.8	05/19/09 19:05 / aje
Iron	ND	mg/L		0.05		E200.7	05/19/09 16:51 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	05/19/09 16:51 / tao
Lead	0.0016	mg/L		0.0005		E200.8	05/19/09 19:05 / aje
Magnesium	4	mg/L		1		E200.7	05/19/09 16:51 / tao
Manganese	0.543	mg/L		0.005		E200.7	05/19/09 16:51 / tao

Report Definitions:

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QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Copper Attenuation - Scott Mason, Hydrometrics
Lab ID: B09051541-007
Client Sample ID: Decant

Report Date: 05/29/09
Collection Date: 05/14/09 08:45
DateReceived: 05/18/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	05/19/09 16:51 / tao
Potassium	27	mg/L		1		E200.7	05/19/09 16:51 / tao
Selenium	ND	mg/L		0.001		E200.8	05/20/09 15:22 / aje
Silicon	3.9	mg/L		0.1		E200.8	05/20/09 15:22 / aje
Silica	8.3	mg/L		0.2		E200.8	05/20/09 15:22 / aje
Silver	ND	mg/L		0.0005		E200.8	05/19/09 19:05 / aje
Sodium	31	mg/L		1		E200.7	05/19/09 16:51 / tao
Thallium	ND	mg/L		0.0002		E200.8	05/19/09 19:05 / aje
Uranium	0.0030	mg/L		0.0003		E200.8	05/19/09 19:05 / aje
Zinc	ND	mg/L		0.01		E200.7	05/19/09 16:51 / tao
METALS, TOTAL							
Iron, Ferric	2.95	mg/L		0.03		Calculation	05/27/09 09:16 / rls
METALS, TOTAL RECOVERABLE							
Iron	2.95	mg/L		0.05		E200.7	05/21/09 12:28 / tao
FIELD PARAMETERS							
Field pH, su	7.45	s.u.				FIELD	05/14/09 08:45 / ---
Field Temperature, C	9.5	C				FIELD	05/14/09 08:45 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

Hydrometrics, Inc.
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June 10, 2009

MEMO TO FILE
RE: COPPER ATTENUATION SAMPLING – TROY MINE

Three samples were taken to provide additional data for the copper attenuation modeling of the tailing facility at the Genesis Mine (Troy Mine). One set of samples was collected from each of the monitor wells MW01-15 and MW95-8. Monitor well MW01-16 was also checked and found to be dry. The third sample was taken from the Decant Pond. Sample field sheets are attached.

Recovery rates in both of sampled wells (MW01-15 and MW95-8) were moderate to slow within the screened interval, but full recovery is extremely slow. Well MW01-15 didn't produce enough water to maintain SWL while pumping at a rate of <0.1 gpm. Details of the purging and sampling of the wells are included below.

Samples were shipped to Energy Labs in Billings with a request for a rush turnaround.

Monitor Well MW01-15

The original completion notes for this well indicate a total well depth of 45 feet with screen from 30 to 40 feet below the ground surface. A lift has been put on the tailing divider dike on which the well is located since the well was installed. The sounded depth for the well is 53.25 feet with a 1.5 foot stick up, implying the screen is now at about 37 to 47 feet. Static water level (SWL) in the well was 44.54. The Rediflo pump was set at 50 feet. Initial pumping of the well at approximately 0.25 gpm drew the SWL to 50.5 feet. The SWL recovered to 44.7 feet in 42 minutes. The well was pumped down and allowed to recover five times yielding approximately 3.5 gallons. Initial recovery rates after purging the well were up to one foot of SWL recovery in four minutes. Recovery rates significantly declined after 2 to 2.5 feet of SWL recovery.

The sample was taken under low flow (<0.1 gpm) conditions. The SWL in the well was drawn down approximately 2 feet while sampling. Field parameters were taken after the sample was taken because it was not known if the well could be pumped long enough to allow stabilization of field parameters before the sample was taken without drawing the SWL down to the pump.

Monitor Well MW95-8

Completion notes for this well indicate a total depth of 54.5 feet with the screen at 48 to 53 feet (presumably below ground surface). The sounded depth of the well was 64.18

feet, reflecting additional casing added to the well because of a lift being put on the divider dike where the well is located. The initial SWL was 50.06 feet. Approximately 3.5 gallons of water were purged with a bailer, drawing the SWL down to 59 feet. The well was left to recover overnight and recovered to 51.0 feet. Another 2 gallons were bailed, drawing the SWL down to a SWL of 59.0 feet. The pump was put in the well at a depth of 60 feet, in preparation for sampling. SWL was measured at 58.25 after installing the pump. SWL showed no recovery after 2.5 hours. Pump was pulled from the well due to a lack of water in the well and poor recovery and a sample was taken using a bailer. SWL at initiation of bailing for the sample was 58.27 feet, and taking the sample drew the well down to 59.24 feet. Well recovered to 59.01 feet in ten minutes after taking the sample.

Monitoring Well MW01-16

Completion notes for this well indicate a total depth of 42 feet with screen from 32 to 42 feet. The well was sounded to a depth of 42.88 feet and was dry.

Decant Pond

A sample from the decant pond was taken from a point adjacent to the access ramp to the pump dock. The pumps were not running at the time of sampling.

Sampling MW01-15: Decant pond in background. Irrigation well visible on far left side of decant pond.

Monitor Well MW01-16

MW01-16 next to dike road, looking toward M95-8 on dike road on far side of decant pond

Monitor Well MW01-16. Looking back toward MW00-15

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: TR01
Project Code:
Sample Team Member(s): LS/PK
Laboratory Used: ECI

Site Designation: MW 58
Sample Code Number:
Sample Date: 6/8/09
Sample Time: 12:15 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

		Comments
well volume formula:	V = (TD-SWL)x(Dia.^{2}) / 25	
TD (ft):	~~60.18~~ 64.18	
SWL (ft):	~~50.60~~ 50.06	no access/pumping
Casing Diameter (I.D.")	2"	
Water Volume (V) (gal):	2.3	
x 3=(gal.)	6.8	
Actual Vol. Removed (gal.)	5.5	
Water Level Recovery:	slow moderate rapid	

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other:
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump (bailer) other

Field Parameters

	Sample	Duplicate
ORP (mV)	128.8	
DO (mg/l)	4.52	
pH	7.57	
SC (µmhos/cm)	532	
Turbidity (ntu)		
H_2O Tmp. (°C)	10.2	
Color	LLR	
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	COND	Mt, Alk, Fe
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	DISS. Mt	
1	250 ml	(F) or UF	HCl	Hg	
1	250 ml	F or (UF)	HNO_3	TOT Mt	
1	250 ml	F or (UF)	H_2SO_4	SO4	
1	250 ml	F or (UF)	H_2O_4	Sulfate	
1	500 ml	F or (UF)	H_2SO_4	CN	
	ml	~~F or UF~~			

Comments: Bailed ~3.5 gal : SWL → 59.00 : LET WELL SET OVERNITE → SWL 59.00 after 1 bailer : BAILED TO ~51' - let set for 2.5 hours → ND
Recovery: Run pump → SWL @ 58.27 : TOOK SAMPLE → SWL 59.24
WAIT 10 MIN SWL → 59.01

Sample Team Member Signature: [signature]

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Ray Mine
Project Code:
Sample Team Member(s): LJ/PK
Laboratory Used: ALI

Site Designation: MW-01-15
Sample Code Number:
Sample Date: 6/2/09
Sample Time: 17:00 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

		Comments
well volume formula:	V = (TD-SWL)x(Dia.^{2}) / 25	
TD (ft):	53.25*	
SWL (ft):	44.54	no access/pumping
Casing Diameter (I.D.")	2	
Water Volume (V) (gal):	1.4	
x 3=(gal.)	4.2	
Actual Vol. Removed (gal.)	3.5	
Water Level Recovery:	slow moderate rapid	

Site Conditions

New Site: Yes (No) Photo taken: Yes (No)
Site Type: DRY surface water process water (monitoring well) domestic well adit seep spring– other:
Weather Conditions: calm (breeze) windy (no precip.) rain snow clear p. cloudy (overcast)
Air Temperature: °C 50 °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes
16:31	154.4	3.86	7.85	431	—	8.70	
16:34	153.0	3.79	7.56	423	—	8.79	
17:08	127.9	5.10	7.66	424	—	14.10	*AFTER
17:11	142.6	4.35	7.31	421	—	15.69	SMPLING

Turbidity: (circle) (clear) slight moderate very

Sample Method: (describe) grab composite (pump) bailer other
RECIRC

Field Parameters

	Sample	Duplicate
ORP (mV)	127.9	
DO (mg/l)	4.35	
pH	7.31	
SC (µmhos/cm)	421	
Turbidity (ntu)	—	
H_2O Tmp. (°C)	14.10	
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	Cat. Mt, Alk, Fe, Fl	
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	DISS Mt	
1	250 ml	(F) or UF	HCl	Hg	
1	250 ml	F or (UF)	HNO_3	TOTAL Mt	
1	250 ml	F or (UF)	H_2SO_4	SO4	Mt's
1	250 ml	F or (UF)	NaOH	S	
1	500 ml	F or (UF)	H_3PO_4	Cl	
	ml	F or UF			

Comments: *Some additional csg has been added since construction; Pumped @ 0.25 gpm; drawdown SWL to 50'; pump set @ 50'; 12:28 12:28 13:10 well recov to 44.7; drawdown to 44.9' 13:13; pumped to 50.0; SWL 3 times = 3.5 gal; pumping @ <<0.10 gpm; SWL comes up or is steady

Sample Team Member Signature: [signature]

Page 1 of 1

15:06 47.6 → 46.6 = 15:10 ⇒ lft vacuum | 4 min.

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: TRO4
Project Code:
Sample Team Member(s): LS/DK
Laboratory Used: ECL

Site Designation: MW 58
Sample Code Number:
Sample Date: 6/8/09
Sample Time: 12:15 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

well volume formula: V = (TD-SWL)x(Dia.^{2}) / 25

		Comments
TD (ft):	~~60.18~~ 64.18	
SWL (ft):	~~50.40~~ 50.06	no access/pumping
Casing Diameter (I.D.")	2"	
Water Volume (V) (gal):	2.3	
x 3=(gal.)	6.8	
Actual Vol. Removed (gal.)		
Water Level Recovery:	slow moderate rapid	

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other:
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump (bailer) other

Field Parameters

	Sample	Duplicate
ORP (mV)	128.8	
DO (mg/l)	4.52	
pH	7.57	
SC (µmhos/cm)	532	
Turbidity (ntu)		
H_2O Tmp. (°C)	10.2	
Color	CLR	
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or (UF)	—	COND	Mt, [illegible] Fe
1	500 ml	F or (UF)	—	TDS	
1	250 ml	(F) or UF	HNO_3	DISS. Mt.	
1	250 ml	(F) or UF	HCl	Hg	
	250 ml	F or (UF)	HNO_3	TOT [illegible]	
1	250 ml	F or (UF)	H_2SO_4	SO_4	
1	250 ml	F or (UF)	H_2O_4	Sulfate	
1	500 ml	F or (UF)	H_2SO_4	Cr	
	ml	~~F or (UF)~~			

Comments: Bailed ~3.5 gal : SW → 54.00 : LET HRS SET OVERNIGHT → SWL [illegible] 0.05 after 1 bailer : BAILED TO ~51' - let set for 2.5 HOURS → NO RECOVERY : RUN PUMP → SWL @ 58.27 : TURN SAMPLE → SWL 59.27 WAIT 10 MIN SWL → 59.01

Sample Team Member Signature: [signature]

Page 1 of 1

Hydrometrics, Inc.

STANDARD OPERATING PROCEDURE
WATER SAMPLING FORM
HF-FORM-430

Consulting Scientists and Engineers

Site Designation: MW01-16
Sample Code Number:
Sample Date: 6/8/09
Sample Time: 12:50 (military)

Project Name: Roof
Project Code:
Sample Team Member(s): CS/RK
Laboratory Used:

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

well volume formula: $V = \frac{(TD-SWL)x(Dia.^2)}{25}$

Comments

TD (ft): 42.88
SWL (ft): 742.88
no access/pumping
Casing Diameter (I.D.") 2"
Water Volume (V) (gal):
x 3=(gal.)
Actual Vol. Removed (gal.)
Water Level Recovery: slow moderate rapid

Site Conditions

New Site: Yes No
Photo taken: Yes No
Site Type: DRY surface water process water monitoring well domestic well adit seep spring other:

Weather Conditions: calm breeze windy no precip. rain snow clear p. cloudy overcast

Air Temperature: °C 53 °F

For Surface Water Samples

Flow Method: ~~Marsh-McBirney~~ Volumetric Flume Weir Estimate
Other Flow or Description:

Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump bailer other

Field Parameters

	Sample	Duplicate
ORP (mV)		
DO (mg/l)		
pH		
SC (µmhos/cm)		
Turbidity (ntu)		
H_2O Tmp. (°C)		
Color		
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			

NO SAMPLE

Comments: WELL DRY AT 42.88 - TD

Sample Team Member Signature: [signature]

Page 1 of 1

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: Ral
Project Code:
Sample Team Member(s): L & PK
Laboratory Used: ECL

Site Designation: DECANT
Sample Code Number: —
Sample Date: 6/9/09
Sample Time: 0935 (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #:
Duplicate Sample Time:

For Groundwater Samples

well volume formula: $V = \frac{(TD-SWL)x(Dia.^2)}{25}$ — Comments

TD (ft):
SWL (ft): no access/pumping
Casing Diameter (I.D.")
Water Volume (V) (gal):
x 3=(gal.)
Actual Vol. Removed (gal.)
Water Level Recovery: slow moderate rapid

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other: DECANT POND
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C 60 °F

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description:
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction Potential (mV)	Dissolved Oxygen (mg/l)	pH	S.C. (µmhos/cm)	Turbidity (n.t.u.)	Temperature (°C)	Additional Parameters or Notes

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump bailer other

Field Parameters

	Sample	Duplicate
ORP (mV)	125.4	
DO (mg/l)	6.86	
pH	6.92	
SC (µmhos/cm)	442	
Turbidity (ntu)	—	
H_2O Tmp. (°C)	15.1	
Color	WHITE	
Other:		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
1	500 ml	F or UF	—		COLLIFORM
1	500 ml	F or UF	—		TDS
1	250 ml	F or UF	HNO_3	DISS MET	
1	250 ml	F or UF	HCl	Hg	
1	250 ml	F or UF	HNO_3	TOTAL	MET
1	250 ml	F or UF	H_2SO_4	NUTS	
1	250 ml	F or UF	$NaOH$	S	
1	500 ml	F or UF	H_3PO_4	CN	
	ml	F or UF			

Comments: SAMPLE FROM PUMP DOCK - PUMPS NOT RUNNING

Sample Team Member Signature: [signature]

Page 1 of 1

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5/5/2009/1:15 PM

Hydrometrics, Inc.
Consulting Scientists and Engineers

STANDARD OPERATING PROCEDURE
INSTRUMENT CALIBRATION FORM
HF-FORM-500

Project Name: TRCC/ MWE

Project Number:

Date: 6/3/09

Personnel: LJ / PK

Weather Conditions:

calm | breeze | windy
no precip | rain | snow
clear | p. cloudy | overcast

Air Temperature:
°F 50 °C

pH

Meter Type:
SN:

Time	Buffer	Temperature	Reading (Temp Corrected)
11:52	4	18.5	4.00
11:55	7	18.1	7.00
	10		
Calibration check:			

Dissolved Oxygen

Meter Type:
SN:
Time: 11:47
Calibration Results: 9.12 mg/L

Specific Conductance

Meter Type: SN:

Time	Standard	Temperature	Reading (Temp Corrected)	Cell Factor
11:54	14.13	18	14.13	
Calibration check:				

Redox Potential (Eh)

Meter Type:
SN:
Electrode: Ag/AgCl
Other:
Time: 12:02
ZoBell Solution Potential (mV): 220
Temperature: 16.7

Turbidity

Meter Type: SN:
Standard: Reading:

PID/FID

Meter Type: SN:
Span Gas Type:

Time	Span Gas		Calibration Memory	Response Factor	Reading
	Gauge Pressure	Concentration			
Calibration Check:					

Notes/Additional Information:

Hydrometrics, Inc.
Consulting Scientists and Engineers

STANDARD OPERATING PROCEDURE
INSTRUMENT CALIBRATION FORM
HF-FORM-500

Project Name: TRCI

Project Number:

Date: 6/9/09

Personnel: LS

Weather Conditions:

calm	breeze	windy
no precip	rain	snow
clear	p. cloudy	overcast

Air Temperature:
°F °C

Dissolved Oxygen

Meter Type:
SN:
Time: 0844
Calibration Results: 10:47

Redox Potential (Eh)

Meter Type:
SN:
Electrode: Ag/AgCl
Other:
Time: 0858
ZoBell Solution Potential (mV): 220
Temperature: 8.9

pH

Meter Type:
SN:

Time	Buffer	Temperature	Reading (Temp Corrected)
0848	4	8.9	4.00
0852	7	8.6	7.00
	10		
Calibration check:			

Specific Conductance

Meter Type: SN:

Time	Standard	Temperature	Reading (Temp Corrected)	Cell Factor
	1415			
0855	1413	8.7	1414	
Calibration check:				

Turbidity

Meter Type: SN:
Standard: Reading:

PID/FID

Meter Type: SN:
Span Gas Type:

Time	Span Gas		Calibration Memory	Response Factor	Reading
	Gauge Pressure	Concentration			
Calibration Check:					

Notes/Additional Information:

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ANALYTICAL SUMMARY REPORT

July 31, 2009

Paul Kukay
Genesis Inc Troy Mine
PO Box 1660
Troy, MT 59935-1660

Workorder No.: B09072237 Quote ID: B1850 - Troy Mine Geochemical Modeling

Project Name: Cu Attenuation Study-Scott Mason Hydrometrics

Energy Laboratories Inc received the following 4 samples for Genesis Inc Troy Mine on 7/24/2009 for analysis.

Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
B09072237-001	MW-95-8	07/21/09 9:10	07/24/09	Aqueous	Metals by ICP/ICPMS, Dissolved Metals by ICP/ICPMS, Tot. Rec. Alkalinity Anions by ion chromatography Conductivity Carbon, Total Organic Mercury, Dissolved Field Parameters Fluoride Hardness as CaCO3 Iron, ferric Nitrogen, Ammonia Nitrogen, Nitrate + Nitrite pH Metals Preparation by EPA 200.2 Phosphorus, Orthophosphate as P Sodium Adsorption Ratio Solids, Total Dissolved Sulfide, Methylene Blue Colorimetric
B09072237-002	Decant Pond	07/21/09 10:15	07/24/09	Aqueous	Same As Above
B09072237-003	MW-01-15	07/21/09 12:50	07/24/09	Aqueous	Same As Above
B09072237-004	MW-00	07/21/09 13:10	07/24/09	Aqueous	Same As Above

Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

If you have any questions regarding these tests results, please call.

Report Approved By:

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800-735-4489 • 406-252-6325 • 406-252-6069 fax • eli@energylab.com

CLIENT: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Sample Delivery Group: B09072237

Date: *31-Jul-09*

CASE NARRATIVE

Tests Associated with Analyst identified as ELI-CA were subcontracted to Energy Laboratories Casper Branch, EPA Number WY00002.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-001
Client Sample ID: MW-95-8

Report Date: 07/31/09
Collection Date: 07/21/09 09:10
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.7	s.u.		0.1		A4500-H B	07/24/09 13:17 / nlh
Conductivity	534	umhos/cm		1		A2510 B	07/24/09 13:17 / nlh
Solids, Total Dissolved TDS @ 180 C	346	mg/L		10		A2540 C	07/24/09 15:41 / afb
INORGANICS							
Alkalinity, Total as CaCO3	139	mg/L		4		A2320 B	07/24/09 16:11 / ehb
Bicarbonate as HCO3	169	mg/L		4		A2320 B	07/24/09 16:11 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	07/24/09 16:11 / ehb
Chloride	4	mg/L		1		E300.0	07/27/09 18:07 / kh
Sulfate	41	mg/L		1		E300.0	07/27/09 18:07 / kh
Fluoride	0.1	mg/L		0.1		A4500-F C	07/24/09 16:11 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	07/24/09 12:15 / afb
Hardness as CaCO3	204	mg/L		1		A2340 B	07/27/09 11:58 / rls
Sodium Adsorption Ratio (SAR)	0.78			0.01		Calculation	07/27/09 11:58 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	ND	mg/L		0.5		A5310 C	07/28/09 15:58 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	ND	mg/L		0.05		E350.1	07/24/09 15:18 / sam
Nitrogen, Nitrate+Nitrite as N	22.1	mg/L	D	0.03		E353.2	07/24/09 14:28 / bls
Phosphorus, Orthophosphate as P	ND	mg/L	LH	0.005		E365.1	07/24/09 12:22 / sam
- The sample was received after the holding time had expired for Ortho Phosphate.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5.0		E245.7	07/30/09 15:08 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.8	07/27/09 21:03 / jjw
Antimony	ND	mg/L		0.003		E200.8	07/27/09 21:03 / jjw
Arsenic	ND	mg/L		0.001		E200.8	07/27/09 21:03 / jjw
Barium	0.135	mg/L		0.005		E200.7	07/27/09 11:58 / tao
Beryllium	ND	mg/L		0.001		E200.7	07/27/09 11:58 / tao
Cadmium	0.00148	mg/L		0.00008		E200.8	07/27/09 21:03 / jjw
Calcium	68	mg/L		1		E200.7	07/27/09 11:58 / tao
Chromium	ND	mg/L		0.001		E200.8	07/27/09 21:03 / jjw
Copper	0.007	mg/L		0.001		E200.8	07/27/09 21:03 / jjw
Iron	ND	mg/L		0.05		E200.7	07/27/09 11:58 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	07/27/09 11:58 / tao
Lead	ND	mg/L		0.0005		E200.8	07/27/09 21:03 / jjw
Magnesium	8	mg/L		1		E200.7	07/27/09 11:58 / tao
Manganese	ND	mg/L		0.005		E200.7	07/27/09 11:58 / tao

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-001
Client Sample ID: MW-95-8

Report Date: 07/31/09
Collection Date: 07/21/09 09:10
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	07/27/09 11:58 / tao
Potassium	8	mg/L		1		E200.7	07/27/09 11:58 / tao
Selenium	0.002	mg/L		0.001		E200.8	07/27/09 21:03 / jjw
Silicon	5.4	mg/L		0.1		E200.7	07/27/09 11:58 / tao
Silica	11.7	mg/L		0.2		E200.7	07/27/09 11:58 / tao
Silver	ND	mg/L		0.0005		E200.8	07/27/09 21:03 / jjw
Sodium	26	mg/L		1		E200.7	07/27/09 11:58 / tao
Thallium	ND	mg/L		0.0002		E200.8	07/27/09 21:03 / jjw
Uranium	0.0005	mg/L		0.0003		E200.8	07/27/09 21:03 / jjw
Zinc	ND	mg/L		0.01		E200.7	07/27/09 11:58 / tao
METALS, TOTAL							
Iron, Ferric	6.94	mg/L		0.05		Calculation	07/29/09 16:23 / mep
METALS, TOTAL RECOVERABLE							
Iron	6.94	mg/L		0.05		E200.8	07/27/09 21:10 / jjw
FIELD PARAMETERS							
Field pH, su	6.85	s.u.				FIELD	07/21/09 09:10 / ---
Field Temperature, C	10.32	C				FIELD	07/21/09 09:10 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-002
Client Sample ID: Decant Pond

Report Date: 07/31/09
Collection Date: 07/21/09 10:15
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	8.0	s.u.		0.1		A4500-H B	07/24/09 13:22 / nlh
Conductivity	398	umhos/cm		1		A2510 B	07/24/09 13:22 / nlh
Solids, Total Dissolved TDS @ 180 C	255	mg/L		10		A2540 C	07/24/09 15:40 / afb
INORGANICS							
Alkalinity, Total as CaCO3	81	mg/L		4		A2320 B	07/24/09 16:36 / ehb
Bicarbonate as HCO3	99	mg/L		4		A2320 B	07/24/09 16:36 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	07/24/09 16:36 / ehb
Chloride	4	mg/L		1		E300.0	07/27/09 18:19 / kh
Sulfate	42	mg/L		1		E300.0	07/27/09 18:19 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	07/24/09 16:36 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	07/24/09 12:15 / afb
Hardness as CaCO3	76	mg/L		1		A2340 B	07/27/09 12:05 / rls
Sodium Adsorption Ratio (SAR)	1.34			0.01		Calculation	07/27/09 12:05 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	0.9	mg/L		0.5		A5310 C	07/28/09 16:09 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.14	mg/L		0.05		E350.1	07/24/09 15:19 / sam
Nitrogen, Nitrate+Nitrite as N	13.6	mg/L	D	0.03		E353.2	07/24/09 14:29 / bls
Phosphorus, Orthophosphate as P	0.006	mg/L	LH	0.005		E365.1	07/24/09 12:23 / sam
- The sample was received after the holding time had expired for Ortho Phosphate.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5.0		E245.7	07/30/09 15:10 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	07/27/09 12:05 / tao
Antimony	0.062	mg/L		0.003		E200.8	07/27/09 21:17 / jjw
Arsenic	0.005	mg/L		0.001		E200.8	07/27/09 21:17 / jjw
Barium	0.111	mg/L		0.005		E200.7	07/27/09 12:05 / tao
Beryllium	ND	mg/L		0.001		E200.7	07/27/09 12:05 / tao
Cadmium	0.00097	mg/L		0.00008		E200.8	07/27/09 21:17 / jjw
Calcium	22	mg/L		1		E200.7	07/27/09 12:05 / tao
Chromium	ND	mg/L		0.001		E200.8	07/27/09 21:17 / jjw
Copper	0.013	mg/L		0.001		E200.8	07/27/09 21:17 / jjw
Iron	ND	mg/L		0.05		E200.7	07/27/09 12:05 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	07/27/09 12:05 / tao
Lead	ND	mg/L		0.0005		E200.8	07/27/09 21:17 / jjw
Magnesium	5	mg/L		1		E200.7	07/27/09 12:05 / tao
Manganese	0.209	mg/L		0.005		E200.7	07/27/09 12:05 / tao

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-002
Client Sample ID: Decant Pond

Report Date: 07/31/09
Collection Date: 07/21/09 10:15
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	ND	mg/L		0.01		E200.7	07/27/09 12:05 / tao
Potassium	26	mg/L		1		E200.7	07/27/09 12:05 / tao
Selenium	0.002	mg/L		0.001		E200.8	07/27/09 21:17 / jjw
Silicon	6.3	mg/L		0.1		E200.7	07/27/09 12:05 / tao
Silica	13.5	mg/L		0.2		E200.7	07/27/09 12:05 / tao
Silver	ND	mg/L		0.0005		E200.8	07/27/09 21:17 / jjw
Sodium	27	mg/L		1		E200.7	07/27/09 12:05 / tao
Thallium	ND	mg/L		0.0002		E200.8	07/27/09 21:17 / jjw
Uranium	0.0029	mg/L		0.0003		E200.8	07/27/09 21:17 / jjw
Zinc	ND	mg/L		0.01		E200.7	07/27/09 12:05 / tao
METALS, TOTAL							
Iron, Ferric	0.55	mg/L		0.05		Calculation	07/29/09 16:23 / mep
METALS, TOTAL RECOVERABLE							
Iron	0.55	mg/L		0.05		E200.7	07/28/09 17:30 / tao
FIELD PARAMETERS							
Field pH, su	7.66	s.u.				FIELD	07/21/09 10:15 / ---
Field Temperature, C	20.9	C				FIELD	07/21/09 10:15 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-003
Client Sample ID: MW-01-15

Report Date: 07/31/09
Collection Date: 07/21/09 12:50
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.3	s.u.		0.1		A4500-H B	07/24/09 13:24 / nlh
Conductivity	418	umhos/cm		1		A2510 B	07/24/09 13:24 / nlh
Solids, Total Dissolved TDS @ 180 C	239	mg/L		10		A2540 C	07/24/09 15:40 / afb
INORGANICS							
Alkalinity, Total as CaCO3	95	mg/L		4		A2320 B	07/24/09 16:44 / ehb
Bicarbonate as HCO3	115	mg/L		4		A2320 B	07/24/09 16:44 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	07/24/09 16:44 / ehb
Chloride	4	mg/L		1		E300.0	07/27/09 18:54 / kh
Sulfate	41	mg/L		1		E300.0	07/27/09 18:54 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	07/24/09 16:44 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	07/24/09 12:15 / afb
Hardness as CaCO3	82	mg/L		1		A2340 B	07/27/09 12:09 / rls
Sodium Adsorption Ratio (SAR)	1.49			0.01		Calculation	07/27/09 12:09 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	0.9	mg/L		0.5		A5310 C	07/28/09 16:19 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.19	mg/L		0.05		E350.1	07/24/09 15:20 / sam
Nitrogen, Nitrate+Nitrite as N	14.1	mg/L	D	0.03		E353.2	07/24/09 14:30 / bls
Phosphorus, Orthophosphate as P	0.010	mg/L	LH	0.005		E365.1	07/24/09 12:24 / sam
- The sample was received after the holding time had expired for Ortho Phosphate.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5.0		E245.7	07/30/09 15:12 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	07/27/09 12:09 / tao
Antimony	0.026	mg/L		0.003		E200.8	07/27/09 21:31 / jjw
Arsenic	ND	mg/L		0.001		E200.8	07/27/09 21:31 / jjw
Barium	0.106	mg/L		0.005		E200.7	07/27/09 12:09 / tao
Beryllium	ND	mg/L		0.001		E200.7	07/27/09 12:09 / tao
Cadmium	0.00193	mg/L		0.00008		E200.8	07/27/09 21:31 / jjw
Calcium	25	mg/L		1		E200.7	07/27/09 12:09 / tao
Chromium	0.002	mg/L		0.001		E200.8	07/27/09 21:31 / jjw
Copper	0.007	mg/L		0.001		E200.8	07/27/09 21:31 / jjw
Iron	0.06	mg/L		0.05		E200.7	07/27/09 12:09 / tao
Iron, Ferrous	0.06	mg/L		0.05		E200.7	07/27/09 12:09 / tao
Lead	ND	mg/L		0.0005		E200.8	07/27/09 21:31 / jjw
Magnesium	5	mg/L		1		E200.7	07/27/09 12:09 / tao
Manganese	0.491	mg/L		0.005		E200.7	07/27/09 12:09 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-003
Client Sample ID: MW-01-15

Report Date: 07/31/09
Collection Date: 07/21/09 12:50
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	0.01	mg/L		0.01		E200.7	07/27/09 12:09 / tao
Potassium	22	mg/L		1		E200.7	07/27/09 12:09 / tao
Selenium	0.002	mg/L		0.001		E200.8	07/27/09 21:31 / jjw
Silicon	5.8	mg/L		0.1		E200.7	07/27/09 12:09 / tao
Silica	12.3	mg/L		0.2		E200.7	07/27/09 12:09 / tao
Silver	ND	mg/L		0.0005		E200.8	07/27/09 21:31 / jjw
Sodium	31	mg/L		1		E200.7	07/27/09 12:09 / tao
Thallium	ND	mg/L		0.0002		E200.8	07/27/09 21:31 / jjw
Uranium	0.0020	mg/L		0.0003		E200.8	07/27/09 21:31 / jjw
Zinc	ND	mg/L		0.01		E200.7	07/27/09 12:09 / tao
METALS, TOTAL							
Iron, Ferric	6.40	mg/L		0.05		Calculation	07/29/09 16:23 / mep
METALS, TOTAL RECOVERABLE							
Iron	6.46	mg/L		0.05		E200.8	07/27/09 22:05 / jjw
FIELD PARAMETERS							
Field pH, su	7.21	s.u.				FIELD	07/21/09 12:50 / ---
Field Temperature, C	22.1	C				FIELD	07/21/09 12:50 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-004
Client Sample ID: MW-00 duplicate of MW-01-15

Report Date: 07/31/09
Collection Date: 07/21/09 13:10
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.4	s.u.		0.1		A4500-H B	07/24/09 13:26 / nlh
Conductivity	414	umhos/cm		1		A2510 B	07/24/09 13:26 / nlh
Solids, Total Dissolved TDS @ 180 C	248	mg/L		10		A2540 C	07/24/09 15:44 / afb
INORGANICS							
Alkalinity, Total as CaCO3	94	mg/L		4		A2320 B	07/24/09 16:52 / ehb
Bicarbonate as HCO3	115	mg/L		4		A2320 B	07/24/09 16:52 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	07/24/09 16:52 / ehb
Chloride	4	mg/L		1		E300.0	07/27/09 19:05 / kh
Sulfate	42	mg/L		1		E300.0	07/27/09 19:05 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	07/24/09 16:52 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	07/24/09 12:15 / afb
Hardness as CaCO3	86	mg/L		1		A2340 B	07/27/09 12:37 / rls
Sodium Adsorption Ratio (SAR)	1.43			0.01		Calculation	07/27/09 12:37 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	0.7	mg/L		0.5		A5310 C	07/28/09 16:29 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.12	mg/L		0.05		E350.1	07/24/09 15:22 / sam
Nitrogen, Nitrate+Nitrite as N	12.8	mg/L	D	0.03		E353.2	07/24/09 14:31 / bls
Phosphorus, Orthophosphate as P	0.012	mg/L	LH	0.005		E365.1	07/24/09 12:25 / sam
- The sample was received after the holding time had expired for Ortho Phosphate.							
METALS - DISSOLVED							
Mercury	ND	ng/L		5.0		E245.7	07/30/09 15:14 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	07/27/09 12:37 / tao
Antimony	0.026	mg/L		0.003		E200.8	07/28/09 12:50 / jjw
Arsenic	ND	mg/L		0.001		E200.8	07/28/09 12:50 / jjw
Barium	0.115	mg/L		0.005		E200.7	07/27/09 12:37 / tao
Beryllium	ND	mg/L		0.001		E200.7	07/27/09 12:37 / tao
Cadmium	0.00137	mg/L		0.00008		E200.8	07/28/09 12:50 / jjw
Calcium	26	mg/L		1		E200.7	07/27/09 12:37 / tao
Chromium	0.003	mg/L		0.001		E200.8	07/28/09 12:50 / jjw
Copper	0.012	mg/L		0.001		E200.8	07/28/09 12:50 / jjw
Iron	0.06	mg/L		0.05		E200.7	07/27/09 12:37 / tao
Iron, Ferrous	0.06	mg/L		0.05		E200.7	07/27/09 12:37 / tao
Lead	0.0014	mg/L		0.0005		E200.8	07/27/09 22:12 / jjw
Magnesium	5	mg/L		1		E200.7	07/27/09 12:37 / tao
Manganese	0.516	mg/L		0.005		E200.7	07/27/09 12:37 / tao

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics
Lab ID: B09072237-004
Client Sample ID: MW-00

Report Date: 07/31/09
Collection Date: 07/21/09 13:10
DateReceived: 07/24/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Nickel	0.01	mg/L		0.01		E200.7	07/27/09 12:37 / tao
Potassium	23	mg/L		1		E200.7	07/27/09 12:37 / tao
Selenium	0.002	mg/L		0.001		E200.8	07/27/09 22:12 / jjw
Silicon	6.1	mg/L		0.1		E200.7	07/27/09 12:37 / tao
Silica	13.1	mg/L		0.2		E200.7	07/27/09 12:37 / tao
Silver	ND	mg/L		0.0005		E200.8	07/28/09 12:50 / jjw
Sodium	31	mg/L		1		E200.7	07/27/09 12:37 / tao
Thallium	ND	mg/L		0.0002		E200.8	07/27/09 22:12 / jjw
Uranium	0.0021	mg/L		0.0003		E200.8	07/27/09 22:12 / jjw
Zinc	ND	mg/L		0.01		E200.7	07/27/09 12:37 / tao
METALS, TOTAL							
Iron, Ferric	1.87	mg/L		0.05		Calculation	07/29/09 16:23 / mep
METALS, TOTAL RECOVERABLE							
Iron	1.93	mg/L		0.05		E200.8	07/27/09 22:19 / jjw
FIELD PARAMETERS							
Field pH, su	7.28	s.u.				FIELD	07/21/09 13:10 / ---
Field Temperature, C	18.56	C				FIELD	07/21/09 13:10 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A2320 B									Batch: R133312
Sample ID: MB	Method Blank				Run: MAN-TECH_090724B				07/24/09 15:11
Alkalinity, Total as CaCO3	ND	mg/L	4						
Bicarbonate as HCO3	ND	mg/L	4						
Carbonate as CO3	ND	mg/L	4						
Sample ID: LCS	Laboratory Control Sample				Run: MAN-TECH_090724B				07/24/09 15:17
Alkalinity, Total as CaCO3	97.4	mg/L	4.0	97	90	110			
Sample ID: B09072237-001AMS	Sample Matrix Spike				Run: MAN-TECH_090724B				07/24/09 16:19
Alkalinity, Total as CaCO3	262	mg/L	4.0	93	80	120			
Sample ID: B09072237-001AMSD	Sample Matrix Spike Duplicate				Run: MAN-TECH_090724B				07/24/09 16:28
Alkalinity, Total as CaCO3	256	mg/L	4.0	88	80	120	2.5	20	
Method: A2510 B									Batch: R133226
Sample ID: SC 150	Laboratory Control Sample				Run: PHSC _101-B_090724A				07/24/09 09:00
Conductivity	156	umhos/cm	1.0	104	90	110			
Sample ID: SC 5000	Laboratory Control Sample				Run: PHSC _101-B_090724A				07/24/09 09:02
Conductivity	4930	umhos/cm	1.0	99	90	110			
Sample ID: B09072235-002ADUP	Sample Duplicate				Run: PHSC _101-B_090724A				07/24/09 13:20
Conductivity	472	umhos/cm	1.0				1.1	10	
Method: A2540 C									Batch: TDS090724B
Sample ID: MBLK3	Method Blank				Run: CPA124S_090724B				07/24/09 15:38
Solids, Total Dissolved TDS @ 180 C	ND	mg/L	10						
Sample ID: LFB3	Laboratory Fortified Blank				Run: CPA124S_090724B				07/24/09 15:39
Solids, Total Dissolved TDS @ 180 C	1100	mg/L	10	99	90	110			
Sample ID: B09072237-001A MS	Sample Matrix Spike				Run: CPA124S_090724B				07/24/09 15:42
Solids, Total Dissolved TDS @ 180 C	2350	mg/L	10	101	80	120			
Sample ID: B09072237-001A MSD	Sample Matrix Spike Duplicate				Run: CPA124S_090724B				07/24/09 15:42
Solids, Total Dissolved TDS @ 180 C	2360	mg/L	10	101	80	120	0.5	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A4500 S-D								Analytical Run: SPEC_090724A	
Sample ID: ICV1_090724A	Initial Calibration Verification Standard							07/24/09 09:00	
Sulfide	0.190	mg/L	0.040	95	90	110			
Method: A4500 S-D								Batch: 090724A-SULFIDE-MB-W	
Sample ID: B09072120-001DMS	Sample Matrix Spike				Run: SPEC_090724A			07/24/09 09:00	
Sulfide	0.192	mg/L	0.040	82	70	130			
Sample ID: B09072120-001DMSD	Sample Matrix Spike Duplicate				Run: SPEC_090724A			07/24/09 09:00	
Sulfide	0.195	mg/L	0.040	84	70	130	1.8	30	
Sample ID: MBLK1_090724A	Method Blank				Run: SPEC_090724A			07/24/09 09:00	
Sulfide	ND	mg/L	0.02						
Sample ID: LFB1_090724A	Laboratory Fortified Blank				Run: SPEC_090724A			07/24/09 09:00	
Sulfide	0.190	mg/L	0.040	93	70	130			
Method: A4500-F C								Analytical Run: MAN-TECH_090724B	
Sample ID: ICV	Initial Calibration Verification Standard							07/24/09 15:30	
Fluoride	1.01	mg/L	0.10	101	90	110			
Method: A4500-F C								Batch: R133312	
Sample ID: MB	Method Blank				Run: MAN-TECH_090724B			07/24/09 15:24	
Fluoride	ND	mg/L	0.05						
Sample ID: LFB	Laboratory Fortified Blank				Run: MAN-TECH_090724B			07/24/09 15:27	
Fluoride	0.960	mg/L	0.10	96	90	110			
Sample ID: B09072237-001AMS	Sample Matrix Spike				Run: MAN-TECH_090724B			07/24/09 16:19	
Fluoride	1.08	mg/L	0.10	97	80	120			
Sample ID: B09072237-001AMSD	Sample Matrix Spike Duplicate				Run: MAN-TECH_090724B			07/24/09 16:28	
Fluoride	1.07	mg/L	0.10	96	80	120	0.9	10	
Method: A4500-H B								Batch: R133226	
Sample ID: pH 4	Laboratory Control Sample				Run: PHSC _101-B_090724A			07/24/09 08:56	
pH	4.06	s.u.	0.10	101	97	103			
Sample ID: pH 7	Laboratory Control Sample				Run: PHSC _101-B_090724A			07/24/09 08:57	
pH	7.08	s.u.	0.10	101	98	102			
Sample ID: B09072235-002ADUP	Sample Duplicate				Run: PHSC _101-B_090724A			07/24/09 13:20	
pH	7.91	s.u.	0.10				0.3	10	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: A5310 C								Analytical Run: SUB-C121564	
Sample ID: ICV-23206	Initial Calibration Verification Standard							07/28/09 09:44	
Organic Carbon, Dissolved (DOC)	10.4	mg/L	0.10	104	90	110			
Method: A5310 C								Batch: C_R121564	
Sample ID: MBLK	Method Blank				Run: SUB-C121564			07/28/09 15:00	
Organic Carbon, Total (TOC)	0.05	mg/L	0.04						
Sample ID: C09070914-002AMS	Sample Matrix Spike				Run: SUB-C121564			07/28/09 16:40	
Organic Carbon, Total (TOC)	9.10	mg/L	0.50	98	85	115			
Sample ID: C09070914-002AMSD	Sample Matrix Spike Duplicate				Run: SUB-C121564			07/28/09 16:51	
Organic Carbon, Total (TOC)	9.25	mg/L	0.50	101	85	115	1.7	10	
Sample ID: LCS-5085	Laboratory Control Sample				Run: SUB-C121564			07/28/09 17:02	
Organic Carbon, Total (TOC)	10.1	mg/L	0.50	100	90	110			
Method: E245.7								Batch: C_23241	
Sample ID: QCS-23241	Quality Control Sample				Run: SUB-C121686			07/30/09 14:16	
Mercury	22.8	ng/L	5.0	91	90	110			
Sample ID: MB-23241	Method Blank				Run: SUB-C121686			07/30/09 14:31	
Mercury	1	ng/L	1						
Sample ID: LCS-23241	Laboratory Control Sample				Run: SUB-C121686			07/30/09 14:34	
Mercury	22.9	ng/L	5.0	87	85	115			
Sample ID: C09070682-001CMS	Sample Matrix Spike				Run: SUB-C121686			07/30/09 14:44	
Mercury	13.6	ng/L	5.0	112	63	111			S
Sample ID: C09070682-001CMSD	Sample Matrix Spike Duplicate				Run: SUB-C121686			07/30/09 14:46	
Mercury	12.8	ng/L	5.0	104	63	111	6.1	18	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

S - Spike recovery outside of advisory limits.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-001
Client Sample ID: MW-01-15

Report Date: 06/22/09
Collection Date: 06/08/09 17:00
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.5	s.u.		0.1		A4500-H B	06/12/09 12:17 / kh
Conductivity	405	umhos/cm		1		A2510 B	06/12/09 12:17 / kh
Solids, Total Dissolved TDS @ 180 C	247	mg/L		10		A2540 C	06/12/09 16:23 / afb
INORGANICS							
Alkalinity, Total as CaCO3	85	mg/L		4		A2320 B	06/12/09 17:22 / ehb
Bicarbonate as HCO3	104	mg/L		4		A2320 B	06/12/09 17:22 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	06/12/09 17:22 / ehb
Chloride	4	mg/L		1		E300.0	06/15/09 16:31 / kh
Sulfate	41	mg/L		1		E300.0	06/15/09 16:31 / kh
Fluoride	0.3	mg/L		0.1		A4500-F C	06/15/09 15:32 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	06/15/09 09:30 / afb
Hardness as CaCO3	78	mg/L		1		A2340 B	06/15/09 13:02 / rls
Sodium Adsorption Ratio (SAR)	1.57			0.01		Calculation	06/15/09 13:02 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	0.8	mg/L		0.5		A5310 C	06/17/09 11:37 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	3.64	mg/L		0.05		E350.1	06/13/09 12:43 / sam
Nitrogen, Nitrate+Nitrite as N	14.5	mg/L	D	0.02		E353.2	06/15/09 14:28 / bls
Phosphorus, Orthophosphate as P	0.025	mg/L	LH	0.005		E365.1	06/13/09 13:56 / mlm
METALS - DISSOLVED							
Mercury	ND	ng/L		10		E245.7	06/19/09 11:32 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	06/15/09 13:02 / tao
Antimony	0.029	mg/L		0.003		E200.8	06/15/09 20:43 / jjw
Arsenic	ND	mg/L		0.001		E200.8	06/15/09 20:43 / jjw
Barium	0.107	mg/L		0.005		E200.7	06/15/09 13:02 / tao
Beryllium	ND	mg/L		0.001		E200.7	06/15/09 13:02 / tao
Cadmium	0.00136	mg/L		0.00008		E200.8	06/15/09 20:43 / jjw
Calcium	23	mg/L		1		E200.7	06/15/09 13:02 / tao
Chromium	ND	mg/L		0.001		E200.8	06/15/09 20:43 / jjw
Copper	0.009	mg/L		0.001		E200.8	06/15/09 20:43 / jjw
Iron	ND	mg/L		0.05		E200.7	06/15/09 13:02 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	06/15/09 13:02 / tao
Lead	ND	mg/L		0.0005		E200.8	06/15/09 20:43 / jjw
Magnesium	5	mg/L		1		E200.7	06/15/09 13:02 / tao
Manganese	0.467	mg/L		0.005		E200.7	06/15/09 13:02 / tao
Nickel	ND	mg/L		0.01		E200.7	06/15/09 13:02 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-001
Client Sample ID: MW-01-15

Report Date: 06/22/09
Collection Date: 06/08/09 17:00
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Potassium	23	mg/L		1		E200.7	06/15/09 13:02 / tao
Selenium	0.002	mg/L		0.001		E200.8	06/15/09 20:43 / jjw
Silicon	5.3	mg/L		0.1		E200.7	06/15/09 13:02 / tao
Silica	11.4	mg/L		0.2		E200.7	06/15/09 13:02 / tao
Silver	ND	mg/L		0.0005		E200.8	06/15/09 20:43 / jjw
Sodium	32	mg/L		1		E200.7	06/15/09 13:02 / tao
Thallium	ND	mg/L		0.0002		E200.8	06/15/09 20:43 / jjw
Uranium	0.0018	mg/L		0.0003		E200.8	06/15/09 20:43 / jjw
Zinc	ND	mg/L		0.01		E200.7	06/15/09 13:02 / tao
METALS, TOTAL							
Iron, Ferric	0.17	mg/L		0.03		Calculation	06/18/09 10:52 / mep
METALS, TOTAL RECOVERABLE							
Iron	0.17	mg/L		0.05		E200.7	06/15/09 22:47 / tao
FIELD PARAMETERS							
Field pH, su	7.3	s.u.				FIELD	06/08/09 17:00 / ---
Field Temperature, C	14.1	C				FIELD	06/08/09 17:00 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-002
Client Sample ID: Decant Pond

Report Date: 06/22/09
Collection Date: 06/09/09 09:35
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	8.0	s.u.		0.1		A4500-H B	06/12/09 12:19 / kh
Conductivity	411	umhos/cm		1		A2510 B	06/12/09 12:19 / kh
Solids, Total Dissolved TDS @ 180 C	300	mg/L		10		A2540 C	06/12/09 16:25 / afb
INORGANICS							
Alkalinity, Total as CaCO3	83	mg/L		4		A2320 B	06/12/09 17:31 / ehb
Bicarbonate as HCO3	101	mg/L		4		A2320 B	06/12/09 17:31 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	06/12/09 17:31 / ehb
Chloride	4	mg/L		1		E300.0	06/15/09 16:42 / kh
Sulfate	45	mg/L		1		E300.0	06/15/09 16:42 / kh
Fluoride	0.2	mg/L		0.1		A4500-F C	06/15/09 15:35 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	06/15/09 09:30 / afb
Hardness as CaCO3	73	mg/L		1		A2340 B	06/15/09 13:10 / rls
Sodium Adsorption Ratio (SAR)	1.51			0.01		Calculation	06/15/09 13:10 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	1.2	mg/L		0.5		A5310 C	06/17/09 11:48 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	4.4	mg/L	D	0.1		E350.1	06/13/09 12:44 / sam
Nitrogen, Nitrate+Nitrite as N	14.5	mg/L	D	0.03		E353.2	06/15/09 12:40 / bls
Phosphorus, Orthophosphate as P	0.083	mg/L	LH	0.005		E365.1	06/13/09 13:59 / mlm
METALS - DISSOLVED							
Mercury	ND	ng/L		10		E245.7	06/19/09 11:38 / eli-ca
METALS, DISSOLVED							
Aluminum	0.18	mg/L		0.03		E200.7	06/15/09 13:10 / tao
Antimony	0.050	mg/L		0.003		E200.8	06/15/09 20:51 / jjw
Arsenic	0.002	mg/L		0.001		E200.8	06/15/09 20:51 / jjw
Barium	0.117	mg/L		0.005		E200.7	06/15/09 13:10 / tao
Beryllium	ND	mg/L		0.001		E200.7	06/15/09 13:10 / tao
Cadmium	0.00126	mg/L		0.00008		E200.8	06/15/09 20:51 / jjw
Calcium	21	mg/L		1		E200.7	06/15/09 13:10 / tao
Chromium	ND	mg/L		0.001		E200.8	06/15/09 20:51 / jjw
Copper	0.024	mg/L		0.001		E200.8	06/15/09 20:51 / jjw
Iron	0.05	mg/L		0.05		E200.7	06/15/09 13:10 / tao
Iron, Ferrous	0.05	mg/L		0.05		E200.7	06/15/09 13:10 / tao
Lead	0.0038	mg/L		0.0005		E200.8	06/15/09 20:51 / jjw
Magnesium	5	mg/L		1		E200.7	06/15/09 13:10 / tao
Manganese	0.458	mg/L		0.005		E200.7	06/15/09 13:10 / tao
Nickel	ND	mg/L		0.01		E200.7	06/15/09 13:10 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
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MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
H - Analysis performed past recommended holding time.

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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-002
Client Sample ID: Decant Pond

Report Date: 06/22/09
Collection Date: 06/09/09 09:35
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Potassium	28	mg/L		1		E200.7	06/15/09 13:10 / tao
Selenium	0.001	mg/L		0.001		E200.8	06/15/09 20:51 / jjw
Silicon	6.2	mg/L		0.1		E200.7	06/15/09 13:10 / tao
Silica	13.2	mg/L		0.2		E200.7	06/15/09 13:10 / tao
Silver	ND	mg/L		0.0005		E200.8	06/15/09 20:51 / jjw
Sodium	30	mg/L		1		E200.7	06/15/09 13:10 / tao
Thallium	ND	mg/L		0.0002		E200.8	06/15/09 20:51 / jjw
Uranium	0.0033	mg/L		0.0003		E200.8	06/15/09 20:51 / jjw
Zinc	ND	mg/L		0.01		E200.7	06/15/09 13:10 / tao
METALS, TOTAL							
Iron, Ferric	0.77	mg/L		0.03		Calculation	06/18/09 10:52 / mep
METALS, TOTAL RECOVERABLE							
Iron	0.82	mg/L		0.05		E200.7	06/16/09 20:42 / tao
FIELD PARAMETERS							
Field pH, su	6.92	s.u.				FIELD	06/09/09 09:35 / ---
Field Temperature, C	15.1	C				FIELD	06/09/09 09:35 / ---

Report Definitions:
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-003
Client Sample ID: MW 95-8

Report Date: 06/22/09
Collection Date: 06/09/09 12:15
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.6	s.u.		0.1		A4500-H B	06/12/09 12:22 / kh
Conductivity	540	umhos/cm		1		A2510 B	06/12/09 12:22 / kh
Solids, Total Dissolved TDS @ 180 C	353	mg/L		10		A2540 C	06/12/09 16:26 / afb
INORGANICS							
Alkalinity, Total as CaCO3	134	mg/L		4		A2320 B	06/12/09 17:39 / ehb
Bicarbonate as HCO3	163	mg/L		4		A2320 B	06/12/09 17:39 / ehb
Carbonate as CO3	ND	mg/L		4		A2320 B	06/12/09 17:39 / ehb
Chloride	4	mg/L		1		E300.0	06/15/09 17:17 / kh
Sulfate	36	mg/L		1		E300.0	06/15/09 17:17 / kh
Fluoride	0.1	mg/L		0.1		A4500-F C	06/15/09 15:38 / ehb
Sulfide	ND	mg/L		0.04		A4500 S-D	06/15/09 09:30 / afb
Hardness as CaCO3	203	mg/L		1		A2340 B	06/15/09 13:14 / rls
Sodium Adsorption Ratio (SAR)	0.77			0.01		Calculation	06/15/09 13:14 / rls
AGGREGATE ORGANICS (CONTRACT LAB WY00002)							
Organic Carbon, Total (TOC)	1.3	mg/L		0.5		A5310 C	06/17/09 12:00 / eli-ca
NUTRIENTS							
Nitrogen, Ammonia as N	0.77	mg/L		0.05		E350.1	06/13/09 12:46 / sam
Nitrogen, Nitrate+Nitrite as N	24.5	mg/L	D	0.03		E353.2	06/15/09 12:50 / bls
Phosphorus, Orthophosphate as P	ND	mg/L	LH	0.005		E365.1	06/13/09 14:00 / mlm
METALS - DISSOLVED							
Mercury	ND	ng/L		10		E245.7	06/19/09 11:40 / eli-ca
METALS, DISSOLVED							
Aluminum	ND	mg/L		0.03		E200.7	06/15/09 13:14 / tao
Antimony	0.005	mg/L		0.003		E200.8	06/15/09 20:58 / jjw
Arsenic	ND	mg/L		0.001		E200.8	06/15/09 20:58 / jjw
Barium	0.149	mg/L		0.005		E200.7	06/15/09 13:14 / tao
Beryllium	ND	mg/L		0.001		E200.7	06/15/09 13:14 / tao
Cadmium	0.00296	mg/L		0.00008		E200.8	06/15/09 20:58 / jjw
Calcium	68	mg/L		1		E200.7	06/15/09 13:14 / tao
Chromium	ND	mg/L		0.001		E200.8	06/15/09 20:58 / jjw
Copper	0.011	mg/L		0.001		E200.8	06/15/09 20:58 / jjw
Iron	ND	mg/L		0.05		E200.7	06/15/09 13:14 / tao
Iron, Ferrous	ND	mg/L		0.05		E200.7	06/15/09 13:14 / tao
Lead	ND	mg/L		0.0005		E200.8	06/15/09 20:58 / jjw
Magnesium	8	mg/L		1		E200.7	06/15/09 13:14 / tao
Manganese	ND	mg/L		0.005		E200.7	06/15/09 13:14 / tao
Nickel	ND	mg/L		0.01		E200.7	06/15/09 13:14 / tao

Report Definitions:

RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix interference.
L - Lowest available reporting limit for the analytical method used.
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ND - Not detected at the reporting limit.
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LABORATORY ANALYTICAL REPORT

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study (Scott Mason, Hydrometrics)
Lab ID: B09061251-003
Client Sample ID: MW 95-8

Report Date: 06/22/09
Collection Date: 06/09/09 12:15
DateReceived: 06/12/09
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
METALS, DISSOLVED							
Potassium	9	mg/L		1		E200.7	06/15/09 13:14 / tao
Selenium	0.004	mg/L		0.001		E200.8	06/15/09 20:58 / jjw
Silicon	5.2	mg/L		0.1		E200.7	06/15/09 13:14 / tao
Silica	11.1	mg/L		0.2		E200.7	06/15/09 13:14 / tao
Silver	ND	mg/L		0.0005		E200.8	06/15/09 20:58 / jjw
Sodium	25	mg/L		1		E200.7	06/15/09 13:14 / tao
Thallium	ND	mg/L		0.0002		E200.8	06/15/09 20:58 / jjw
Uranium	0.0005	mg/L		0.0003		E200.8	06/15/09 20:58 / jjw
Zinc	ND	mg/L		0.01		E200.8	06/15/09 20:58 / jjw
METALS, TOTAL							
Iron, Ferric	1.62	mg/L		0.03		Calculation	06/18/09 10:52 / mep
METALS, TOTAL RECOVERABLE							
Iron	1.62	mg/L		0.05		E200.7	06/16/09 20:50 / tao
FIELD PARAMETERS							
Field pH, su	7.57	s.u.				FIELD	06/09/09 12:15 / ---
Field Temperature, C	10.2	C				FIELD	06/09/09 12:15 / ---

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E300.0								Analytical Run: IC202-B_090727A	
Sample ID: ICV072709-11	Initial Calibration Verification Standard							07/27/09 12:19	
Chloride	24.1	mg/L	1.0	96	90	110			
Sulfate	103	mg/L	1.0	103	90	110			
Method: E300.0								Batch: R133371	
Sample ID: ICB072709-12	Method Blank				Run: IC202-B_090727A			07/27/09 12:30	
Chloride	ND	mg/L	0.03						
Sulfate	ND	mg/L	0.06						
Sample ID: LFB072709-13	Laboratory Fortified Blank				Run: IC202-B_090727A			07/27/09 12:42	
Chloride	22.8	mg/L	1.0	91	90	110			
Sulfate	101	mg/L	1.0	101	90	110			
Sample ID: B09072237-002AMS	Sample Matrix Spike				Run: IC202-B_090727A			07/27/09 18:30	
Chloride	28.0	mg/L	1.0	98	90	110			
Sulfate	152	mg/L	1.0	110	90	110			
Sample ID: B09072237-002AMSD	Sample Matrix Spike Duplicate				Run: IC202-B_090727A			07/27/09 18:42	
Chloride	28.4	mg/L	1.0	100	90	110	1.4	20	
Sulfate	154	mg/L	1.0	112	90	110	1.1	20	S
Method: E350.1								Analytical Run: FIA202-B_090724C	
Sample ID: ICV	Initial Calibration Verification Standard							07/24/09 13:23	
Nitrogen, Ammonia as N	5.52	mg/L	0.11	101	90	110			
Method: E350.1								Batch: R133268	
Sample ID: MBLK	Method Blank				Run: FIA202-B_090724C			07/24/09 13:24	
Nitrogen, Ammonia as N	ND	mg/L	0.02						
Sample ID: LFB	Laboratory Fortified Blank				Run: FIA202-B_090724C			07/24/09 13:26	
Nitrogen, Ammonia as N	1.03	mg/L	0.050	104	90	110			
Sample ID: B09072233-003BMS	Sample Matrix Spike				Run: FIA202-B_090724C			07/24/09 15:16	
Nitrogen, Ammonia as N	1.43	mg/L	0.050	104	90	110			
Sample ID: B09072233-003BMSD	Sample Matrix Spike Duplicate				Run: FIA202-B_090724C			07/24/09 15:17	
Nitrogen, Ammonia as N	1.43	mg/L	0.050	105	90	110	0.2	10	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

S - Spike recovery outside of advisory limits.

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E353.2								Analytical Run: FIA203-B_090724A	
Sample ID: ICV	Initial Calibration Verification Standard								07/24/09 08:53
Nitrogen, Nitrate+Nitrite as N	37.4	mg/L	0.032	106	90	110			
Method: E353.2									Batch: R133234
Sample ID: MBLK	Method Blank				Run: FIA203-B_090724A				07/24/09 08:54
Nitrogen, Nitrate+Nitrite as N	ND	mg/L	0.002						
Sample ID: LFB	Laboratory Fortified Blank				Run: FIA203-B_090724A				07/24/09 08:55
Nitrogen, Nitrate+Nitrite as N	1.00	mg/L	0.010	102	90	110			
Sample ID: B09072233-003BMS	Sample Matrix Spike				Run: FIA203-B_090724A				07/24/09 14:22
Nitrogen, Nitrate+Nitrite as N	0.979	mg/L	0.010	98	90	110			
Sample ID: B09072233-003BMSD	Sample Matrix Spike Duplicate				Run: FIA203-B_090724A				07/24/09 14:23
Nitrogen, Nitrate+Nitrite as N	0.981	mg/L	0.010	98	90	110	0.2	10	
Sample ID: B09071811-003AMS	Sample Matrix Spike				Run: FIA203-B_090724A				07/24/09 14:38
Nitrogen, Nitrate+Nitrite as N	0.971	mg/L	0.010	99	90	110			
Sample ID: B09071811-003AMSD	Sample Matrix Spike Duplicate				Run: FIA203-B_090724A				07/24/09 14:40
Nitrogen, Nitrate+Nitrite as N	0.980	mg/L	0.010	100	90	110	0.9	10	

Qualifiers:

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ND - Not detected at the reporting limit.

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800-735-4489 • 406-252-6325 • 406-252-6069 fax • eli@energylab.com

QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E365.1								Analytical Run: FIA202-B_090724B	
Sample ID: ICV	Initial Calibration Verification Standard							07/24/09 11:11	
Phosphorus, Orthophosphate as P	0.245	mg/L	0.0050	98	90	110			
Method: E365.1								Batch: R133252	
Sample ID: MBLK	Method Blank				Run: FIA202-B_090724B			07/24/09 11:14	
Phosphorus, Orthophosphate as P	ND	mg/L	0.005						
Sample ID: LFB	Laboratory Fortified Blank				Run: FIA202-B_090724B			07/24/09 11:15	
Phosphorus, Orthophosphate as P	0.0940	mg/L	0.0050	94	90	110			
Sample ID: B09072221-002AMS	Sample Matrix Spike				Run: FIA202-B_090724B			07/24/09 11:31	
Phosphorus, Orthophosphate as P	0.134	mg/L	0.0050	95	90	110			
Sample ID: B09072221-002AMSD	Sample Matrix Spike Duplicate				Run: FIA202-B_090724B			07/24/09 11:32	
Phosphorus, Orthophosphate as P	0.135	mg/L	0.0050	96	90	110	0.7	10	
Sample ID: B09072233-002AMS	Sample Matrix Spike				Run: FIA202-B_090724B			07/24/09 12:19	
Phosphorus, Orthophosphate as P	0.165	mg/L	0.0050	99	90	110			
Sample ID: B09072233-002AMSD	Sample Matrix Spike Duplicate				Run: FIA202-B_090724B			07/24/09 12:20	
Phosphorus, Orthophosphate as P	0.164	mg/L	0.0050	98	90	110	0.6	10	
Sample ID: B09072231-003AMS	Sample Matrix Spike				Run: FIA202-B_090724B			07/24/09 12:31	
Phosphorus, Orthophosphate as P	0.101	mg/L	0.0050	101	90	110			
Sample ID: B09072231-003AMSD	Sample Matrix Spike Duplicate				Run: FIA202-B_090724B			07/24/09 12:32	
Phosphorus, Orthophosphate as P	0.101	mg/L	0.0050	101	90	110	0	10	

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Batch: 40344
Sample ID: MB-40344	Method Blank				Run: ICP202-B_090728A				07/28/09 16:30
Iron	0.04	mg/L	0.008						
Sample ID: LCS5-40344	Laboratory Control Sample				Run: ICP202-B_090728A				07/28/09 16:34
Iron	2.61	mg/L	0.030	103	85	115			
Sample ID: B09072246-001BMS5	Sample Matrix Spike				Run: ICP202-B_090728A				07/28/09 17:45
Iron	15.1	mg/L	0.030		70	130			A
Sample ID: B09072246-001BMSD5	Sample Matrix Spike Duplicate				Run: ICP202-B_090728A				07/28/09 17:49
Iron	15.1	mg/L	0.030		70	130	0.3	20	A

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7								Analytical Run: ICP202-B_090727A	
Sample ID: ICV	Continuing Calibration Verification Standard								07/27/09 10:48
Aluminum	2.47	mg/L	0.10	99	95	105			
Barium	2.59	mg/L	0.10	104	95	105			
Beryllium	1.21	mg/L	0.010	96	95	105			
Calcium	24.2	mg/L	1.0	97	95	105			
Iron	2.60	mg/L	0.030	104	95	105			
Magnesium	25.2	mg/L	1.0	101	95	105			
Manganese	2.41	mg/L	0.010	96	95	105			
Nickel	2.60	mg/L	0.050	104	95	105			
Potassium	23.7	mg/L	1.0	95	95	105			
Silicon	5.08	mg/L	0.10	102	95	105			
Sodium	24.6	mg/L	1.0	98	95	105			
Zinc	2.55	mg/L	0.010	102	95	105			
Method: E200.7									Batch: R133358
Sample ID: MB-SPDIS090727A	Method Blank				Run: ICP202-B_090727A				07/27/09 10:13
Aluminum	ND	mg/L	0.008						
Barium	0.001	mg/L	0.0001						
Beryllium	0.0005	mg/L	9E-05						
Calcium	0.03	mg/L	0.009						
Iron	ND	mg/L	0.002						
Magnesium	0.01	mg/L	0.01						
Manganese	0.0005	mg/L	0.0003						
Nickel	ND	mg/L	0.002						
Potassium	ND	mg/L	0.01						
Silicon	ND	mg/L	0.01						
Sodium	ND	mg/L	0.03						
Zinc	0.002	mg/L	0.002						
Sample ID: LFB-SPDIS090727A	Laboratory Fortified Blank				Run: ICP202-B_090727A				07/27/09 10:16
Aluminum	5.05	mg/L	0.10	101	85	115			
Barium	0.972	mg/L	0.10	97	85	115			
Beryllium	0.484	mg/L	0.010	97	85	115			
Calcium	48.3	mg/L	1.0	97	85	115			
Iron	5.19	mg/L	0.030	104	85	115			
Magnesium	51.1	mg/L	1.0	102	85	115			
Manganese	4.83	mg/L	0.010	97	85	115			
Nickel	1.05	mg/L	0.050	105	85	115			
Potassium	50.4	mg/L	1.0	101	85	115			
Silicon	11.0	mg/L	0.10	110	85	115			
Sodium	49.4	mg/L	1.0	99	85	115			
Zinc	1.02	mg/L	0.010	102	85	115			

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7									Batch: R133358
Sample ID: B09072234-001BMS2	Sample Matrix Spike				Run: ICP202-B_090727A				07/27/09 11:51
Aluminum	4.79	mg/L	0.10	96	70	130			
Barium	1.04	mg/L	0.10	94	70	130			
Beryllium	0.461	mg/L	0.0010	92	70	130			
Calcium	82.9	mg/L	1.0	84	70	130			
Iron	4.95	mg/L	0.030	99	70	130			
Magnesium	107	mg/L	1.0	89	70	130			
Manganese	4.68	mg/L	0.010	94	70	130			
Nickel	1.01	mg/L	0.010	100	70	130			
Potassium	50.8	mg/L	1.0	99	70	130			
Silicon	14.7	mg/L	0.10	94	70	130			
Sodium	52.4	mg/L	1.0	98	70	130			
Zinc	0.981	mg/L	0.010	98	70	130			
Iron, Ferrous	4.95	mg/L	0.030	99	70	130			
Silica	31.4	mg/L	0.21	94	70	130			
Sample ID: B09072234-001BMSD2	Sample Matrix Spike Duplicate				Run: ICP202-B_090727A				07/27/09 11:55
Aluminum	4.84	mg/L	0.10	97	70	130	1	20	
Barium	1.03	mg/L	0.10	93	70	130	1.3	20	
Beryllium	0.465	mg/L	0.0010	93	70	130	0.9	20	
Calcium	83.6	mg/L	1.0	86	70	130	0.9	20	
Iron	5.03	mg/L	0.030	100	70	130	1.7	20	
Magnesium	109	mg/L	1.0	92	70	130	1.4	20	
Manganese	4.72	mg/L	0.010	94	70	130	0.8	20	
Nickel	1.01	mg/L	0.010	101	70	130	0.4	20	
Potassium	50.3	mg/L	1.0	98	70	130	1	20	
Silicon	14.9	mg/L	0.10	97	70	130	1.6	20	
Sodium	52.1	mg/L	1.0	98	70	130	0.6	20	
Zinc	0.988	mg/L	0.010	98	70	130	0.7	20	
Iron, Ferrous	5.03	mg/L	0.030	100	70	130	1.7	20	
Silica	31.9	mg/L	0.21	97	70	130	1.6	20	
Sample ID: B09072251-005BMS2	Sample Matrix Spike				Run: ICP202-B_090727A				07/27/09 13:02
Aluminum	4.86	mg/L	0.10	97	70	130			
Barium	1.45	mg/L	0.10	92	70	130			
Beryllium	0.471	mg/L	0.0010	94	70	130			
Calcium	123	mg/L	1.0	78	70	130			
Iron	109	mg/L	0.030		70	130			A
Magnesium	67.8	mg/L	1.0	94	70	130			
Manganese	6.98	mg/L	0.010	90	70	130			
Nickel	0.994	mg/L	0.010	98	70	130			
Potassium	51.9	mg/L	1.0	98	70	130			
Silicon	27.5	mg/L	0.10	92	70	130			
Sodium	70.7	mg/L	1.0	97	70	130			

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.7								Batch: R133358	
Sample ID: B09072251-005BMS2	Sample Matrix Spike				Run: ICP202-B_090727A			07/27/09 13:02	
Zinc	0.962	mg/L	0.010	96	70	130			
Iron, Ferrous	109	mg/L	0.030		70	130			A
Silica	58.8	mg/L	0.21	92	70	130			
Sample ID: B09072251-005BMSD2	Sample Matrix Spike Duplicate				Run: ICP202-B_090727A			07/27/09 13:05	
Aluminum	5.14	mg/L	0.10	103	70	130	5.6	20	
Barium	1.47	mg/L	0.10	95	70	130	1.6	20	
Beryllium	0.482	mg/L	0.0010	96	70	130	2.4	20	
Calcium	125	mg/L	1.0	83	70	130	1.7	20	
Iron	110	mg/L	0.030		70	130	1.3	20	A
Magnesium	69.3	mg/L	1.0	97	70	130	2.3	20	
Manganese	7.13	mg/L	0.010	93	70	130	2	20	
Nickel	1.05	mg/L	0.010	104	70	130	5.5	20	
Potassium	54.9	mg/L	1.0	104	70	130	5.6	20	
Silicon	28.0	mg/L	0.10	97	70	130	1.8	20	
Sodium	72.9	mg/L	1.0	102	70	130	3.2	20	
Zinc	1.01	mg/L	0.010	101	70	130	5.3	20	
Iron, Ferrous	110	mg/L	0.030		70	130	1.3	20	A
Silica	59.9	mg/L	0.21	97	70	130	1.8	20	
Method: E200.7								Analytical Run: ICP202-B_090728A	
Sample ID: ICV	Continuing Calibration Verification Standard							07/28/09 10:54	
Iron	2.57	mg/L	0.030	103	95	105			
Method: E200.8								Batch: 40344	
Sample ID: MB-40344	Method Blank				Run: ICPMS203-B_090727A			07/27/09 20:43	
Iron	0.08	mg/L	0.0008						
Sample ID: LCS5-40344	Laboratory Control Sample				Run: ICPMS203-B_090727A			07/27/09 20:50	
Iron	2.55	mg/L	0.030	99	85	115			
Sample ID: B09072246-001BMS5	Sample Matrix Spike				Run: ICPMS203-B_090727A			07/27/09 22:32	
Iron	15.7	mg/L	0.030		70	130			A
Sample ID: B09072246-001BMSD5	Sample Matrix Spike Duplicate				Run: ICPMS203-B_090727A			07/27/09 22:39	
Iron	15.8	mg/L	0.030		70	130	0.7	20	A

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
Project: Cu Attenuation Study-Scott Mason Hydrometrics

Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8							Analytical Run: ICPMS203-B_090727A		
Sample ID: QCS-090602A,090609B,0	Initial Calibration Verification Standard								07/27/09 19:40
Aluminum	0.245	mg/L	0.10	98	90	110			
Antimony	0.0480	mg/L	0.050	96	90	110			
Arsenic	0.0490	mg/L	0.0050	98	90	110			
Cadmium	0.0257	mg/L	0.0010	103	90	110			
Chromium	0.0500	mg/L	0.010	100	90	110			
Copper	0.0512	mg/L	0.010	102	90	110			
Iron	0.273	mg/L	0.030	107	90	110			
Lead	0.0493	mg/L	0.010	99	90	110			
Selenium	0.0497	mg/L	0.0050	99	90	110			
Silver	0.0261	mg/L	0.0050	104	90	110			
Thallium	0.0501	mg/L	0.10	100	90	110			
Uranium	0.0191	mg/L	0.0010	95	90	110			
Method: E200.8									Batch: R133351
Sample ID: LRB	Method Blank				Run: ICPMS203-B_090727A				07/27/09 11:55
Aluminum	0.005	mg/L	0.00010						
Antimony	ND	mg/L	1E-05						
Arsenic	ND	mg/L	2E-05						
Cadmium	ND	mg/L	4E-06						
Chromium	ND	mg/L	2E-05						
Copper	ND	mg/L	3E-05						
Lead	ND	mg/L	3E-06						
Selenium	ND	mg/L	4E-05						
Silver	3E-05	mg/L	9E-06						
Thallium	ND	mg/L	8E-06						
Uranium	ND	mg/L	2E-06						
Sample ID: LFB	Laboratory Fortified Blank				Run: ICPMS203-B_090727A				07/27/09 12:15
Aluminum	0.0530	mg/L	0.10	96	85	115			
Antimony	0.0496	mg/L	0.050	99	85	115			
Arsenic	0.0495	mg/L	0.0050	99	85	115			
Cadmium	0.0495	mg/L	0.0010	99	85	115			
Chromium	0.0499	mg/L	0.010	100	85	115			
Copper	0.0485	mg/L	0.010	97	85	115			
Lead	0.0497	mg/L	0.010	99	85	115			
Selenium	0.0487	mg/L	0.0050	97	85	115			
Silver	0.0191	mg/L	0.0050	95	85	115			
Thallium	0.0506	mg/L	0.10	101	85	115			
Uranium	0.0491	mg/L	0.0010	98	85	115			
Sample ID: B09072057-005CMS	Sample Matrix Spike				Run: ICPMS203-B_090727A				07/28/09 00:29
Aluminum	0.0942	mg/L	0.10	94	70	130			
Antimony	0.100	mg/L	0.0050	100	70	130			

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
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Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Batch: R133351
Sample ID: B09072057-005CMS	Sample Matrix Spike				Run: ICPMS203-B_090727A				07/28/09 00:29
Arsenic	0.101	mg/L	0.0050	101	70	130			
Cadmium	0.0988	mg/L	0.0010	99	70	130			
Chromium	0.102	mg/L	0.010	102	70	130			
Copper	0.156	mg/L	0.010	94	70	130			
Lead	0.101	mg/L	0.010	100	70	130			
Selenium	0.104	mg/L	0.0050	103	70	130			
Silver	0.0389	mg/L	0.0050	97	70	130			
Thallium	0.101	mg/L	0.0050	101	70	130			
Uranium	0.109	mg/L	0.0010	100	70	130			
Sample ID: B09072057-005CMSD	Sample Matrix Spike Duplicate				Run: ICPMS203-B_090727A				07/28/09 01:03
Aluminum	0.0933	mg/L	0.10	93	70	130		20	
Antimony	0.100	mg/L	0.0050	100	70	130	0.3	20	
Arsenic	0.102	mg/L	0.0050	102	70	130	1	20	
Cadmium	0.0982	mg/L	0.0010	98	70	130	0.6	20	
Chromium	0.0996	mg/L	0.010	100	70	130	2.2	20	
Copper	0.156	mg/L	0.010	94	70	130	0.3	20	
Lead	0.102	mg/L	0.010	100	70	130	0.4	20	
Selenium	0.102	mg/L	0.0050	101	70	130	2.2	20	
Silver	0.0385	mg/L	0.0050	96	70	130	1.1	20	
Thallium	0.101	mg/L	0.0050	101	70	130	0.6	20	
Uranium	0.109	mg/L	0.0010	101	70	130	0.3	20	

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QA/QC Summary Report

Client: Genesis Inc Troy Mine
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Report Date: 07/31/09
Work Order: B09072237

Analyte	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8								Analytical Run: ICPMS202-B_090728A	
Sample ID: QCS - 090602A,090609B,	Initial Calibration Verification Standard								07/28/09 09:41
Antimony	0.0465	mg/L	0.050	93	90	110			
Arsenic	0.0499	mg/L	0.0050	100	90	110			
Cadmium	0.0247	mg/L	0.0010	99	90	110			
Chromium	0.0493	mg/L	0.010	99	90	110			
Copper	0.0501	mg/L	0.010	100	90	110			
Silver	0.0258	mg/L	0.0050	103	90	110			
Method: E200.8									Batch: R133463
Sample ID: LRB	Method Blank				Run: ICPMS202-B_090728A				07/28/09 12:22
Antimony	ND	mg/L	5E-05						
Arsenic	ND	mg/L	3E-05						
Cadmium	ND	mg/L	1E-05						
Chromium	ND	mg/L	0.0002						
Copper	ND	mg/L	8E-05						
Silver	ND	mg/L	2E-05						
Sample ID: LFB	Laboratory Fortified Blank				Run: ICPMS202-B_090728A				07/28/09 12:26
Antimony	0.0507	mg/L	0.050	101	85	115			
Arsenic	0.0495	mg/L	0.0050	99	85	115			
Cadmium	0.0487	mg/L	0.0010	97	85	115			
Chromium	0.0477	mg/L	0.010	95	85	115			
Copper	0.0470	mg/L	0.010	94	85	115			
Silver	0.0175	mg/L	0.0050	88	85	115			
Sample ID: B09072234-001BMS	Sample Matrix Spike				Run: ICPMS202-B_090728A				07/28/09 12:38
Antimony	0.0512	mg/L	0.0050	100	70	130			
Arsenic	0.0519	mg/L	0.0050	100	70	130			
Cadmium	0.0488	mg/L	0.0010	97	70	130			
Chromium	0.0491	mg/L	0.010	97	70	130			
Copper	0.0493	mg/L	0.010	94	70	130			
Silver	0.0177	mg/L	0.0050	88	70	130			
Sample ID: B09072234-001BMSD	Sample Matrix Spike Duplicate				Run: ICPMS202-B_090728A				07/28/09 12:42
Antimony	0.0510	mg/L	0.0050	100	70	130	0.4	20	
Arsenic	0.0519	mg/L	0.0050	100	70	130	0.1	20	
Cadmium	0.0484	mg/L	0.0010	97	70	130	0.9	20	
Chromium	0.0491	mg/L	0.010	97	70	130	0.1	20	
Copper	0.0491	mg/L	0.010	94	70	130	0.3	20	
Silver	0.0180	mg/L	0.0050	90	70	130	1.7	20	

Qualifiers:

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Energy Laboratories Inc
Workorder Receipt Checklist

Genesis Inc Troy Mine

B09072237

Login completed by: Gina McCartney

Date and Time Received: 7/24/2009 9:00 AM

Reviewed by: Denise Ruby

Received by: lg

Reviewed Date: 7/24/2009 5:35:00 PM

Carrier name: Return-UPS Ground

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time?	Yes ☐	No ☑	
Container/Temp Blank temperature:	5°C On Ice		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☑	No ☐	Not Applicable ☐

Contact and Corrective Action Comments:

All samples for Ortho Phosphorus received past the 48 hour hold time. Analyze, per ELI's project manager.

ENERGY LABORATORIES

Chain of Custody and Analytical Request Record

Page ____ of ____

PLEASE PRINT- Provide as much information as possible.

Company Name: Genesis Inc - Troy Mine	Project Name, PWS, Permit, Etc. Cu Attenuation Study - Scott Mason Hydrometrics	Sample Origin State: Mont.	EPA/State Compliance: Yes ☐ No ☒
Report Mail Address: PO Box 1660 Troy, MT 59935	Contact Name: Paul Kukay Phone/Fax: 295-5882 x221	Email: PKukay@hotmail.com	Sampler: (Please Print) Kukay/Johnson
Invoice Address: Same	Invoice Contact & Phone: Same	Purchase Order:	Quote/Bottle Order: 1850

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

☐ DW ☐ A2LA
☐ GSA ☐ EDD/EDT (Electronic Data)
☐ POTW/WWTP Format: ____
☐ State: ____ ☐ LEVEL IV
☐ Other: ____ ☐ NELAC

Contact ELI prior to **RUSH** sample submittal for charges and scheduling – See Instruction Page

Comments:

Shipped by: Hand Delivered
Cooler ID(s):
Receipt Temp 5 °C
On Ice: Yes No
Custody Seal Y N
Bottles/Coolers B C
Intact Y N
Signature Match Y N

ANALYSIS REQUESTED: wyoming per Scott Mason's note: Scott Mason - Hydrometrics - Trace

	SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX (Number of Containers; Sample Type: A W S V B O; Air Water Soils/Solids Vegetation Bioassay Other)	SEE ATTACHED	Normal Turnaround (TAT)	RUSH	Comments	LABORATORY USE ONLY
1	MW-95-8	21 July 09	9:10am	W	X		X	pH 6.85 temp 10.32°C	B0907237-001
2	Decant Pond	"	10:15am	W	X		X	pH 7.66 temp 20.9°C	-002
3	MW-01-15	"	12:50pm	W	X		X	pH 7.21 temp 22.1°C	-003
4	MW-00	"	1:10pm	W	X		X	pH 7.28 temp 18.8°C	-004
5									
6									
7									
8									
9									
10									

Custody Record MUST be Signed

Relinquished by (print)	Date/Time	Signature	Received by (print)	Date/Time	Signature
Paul Kukay	22 July 09 8:00am	Paul D Kukay			

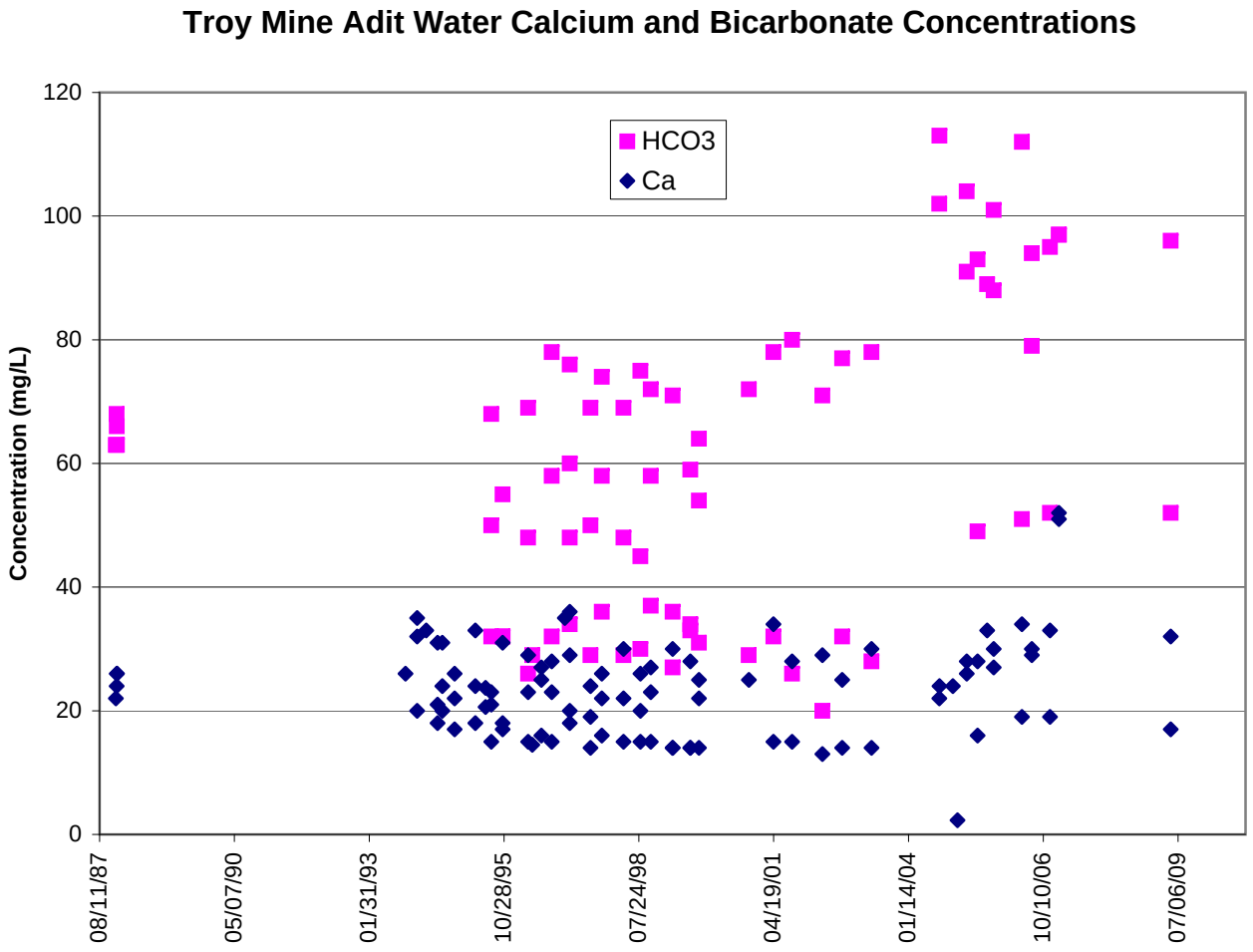
Received by Laboratory: 7-24-09 9:00

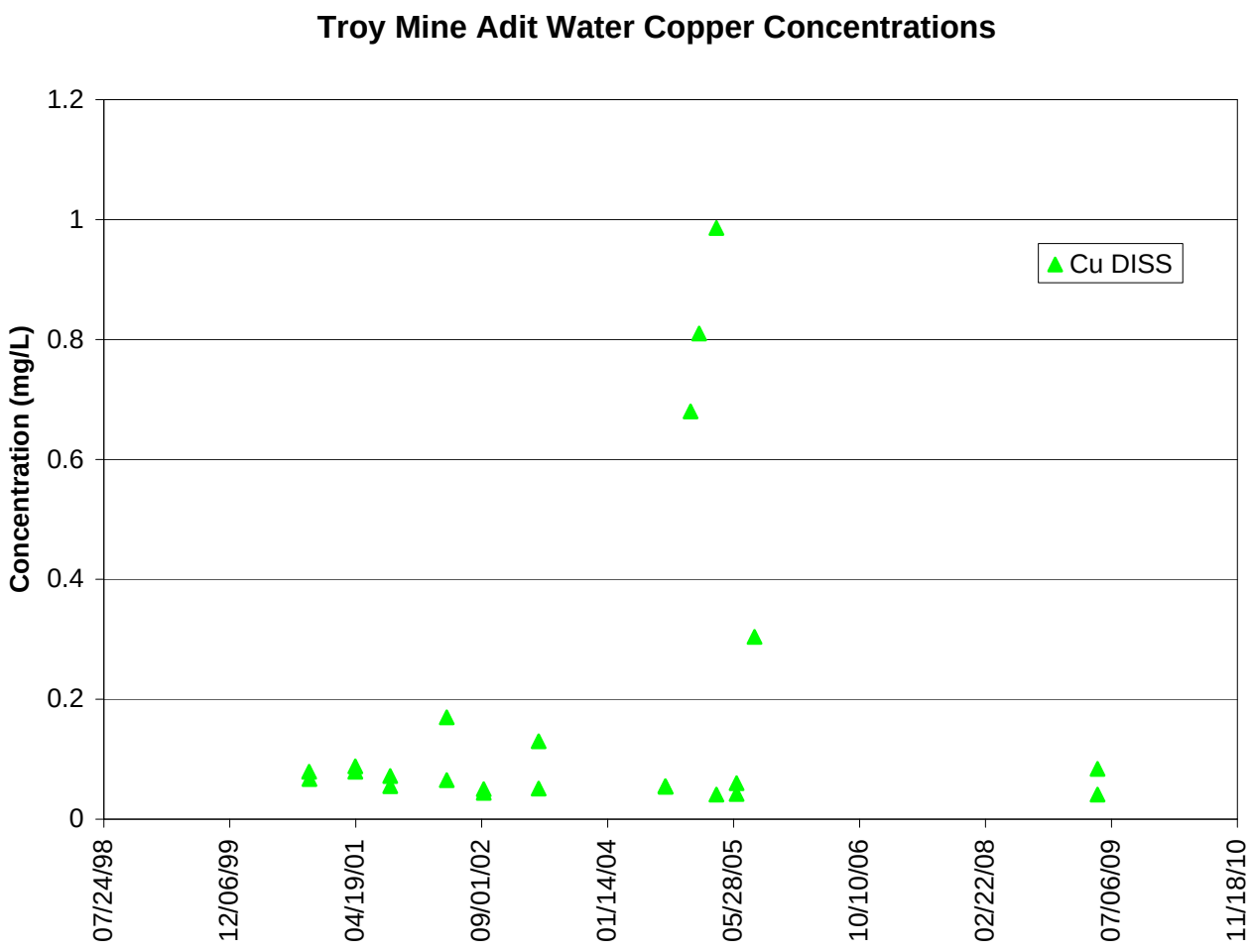
Sample Disposal: Return to Client: ____ Lab Disposal: ____

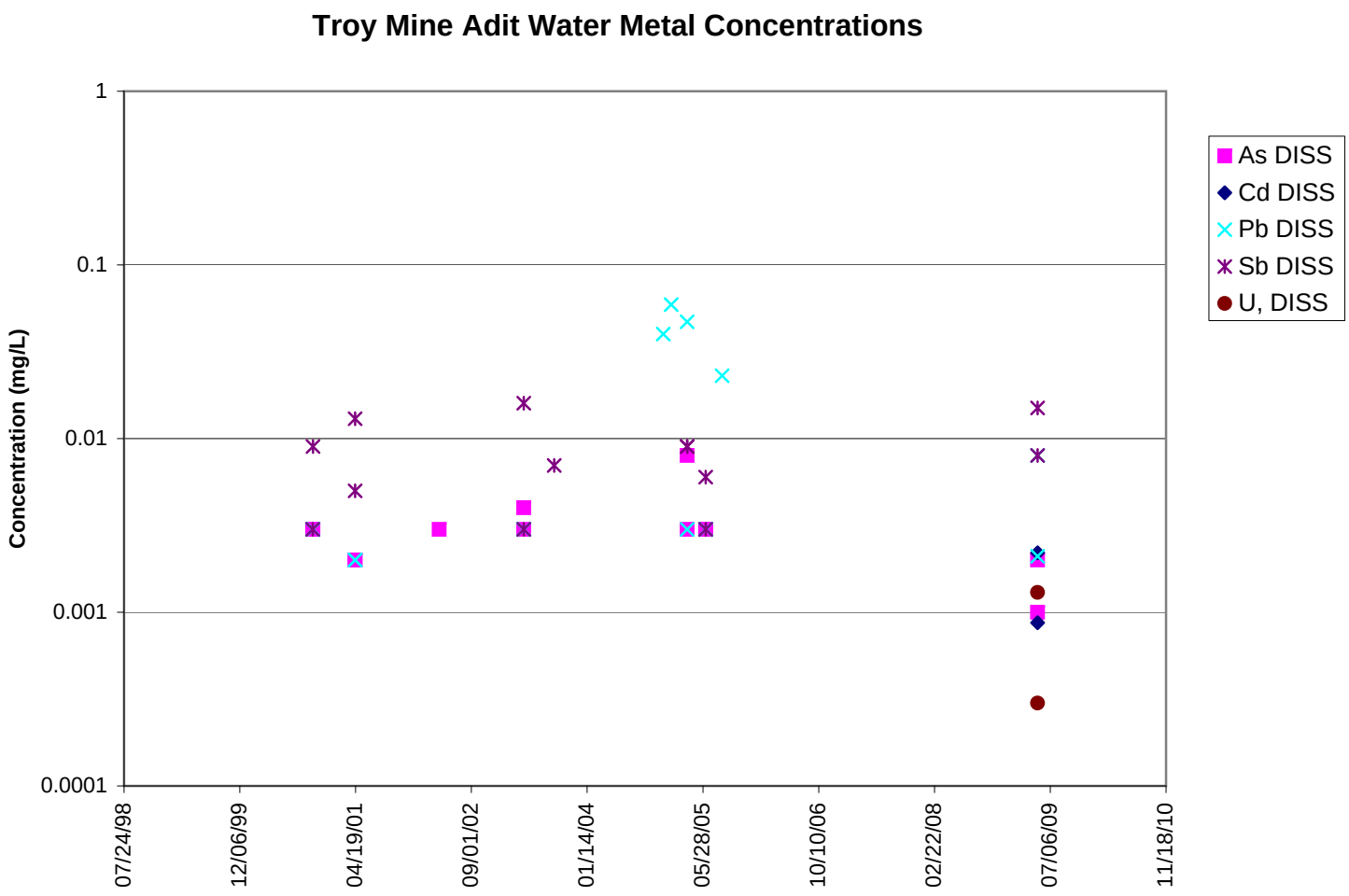
In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.
Visit our web site at www.energylab.com for additional information, downloadable fee schedule, forms, and links.

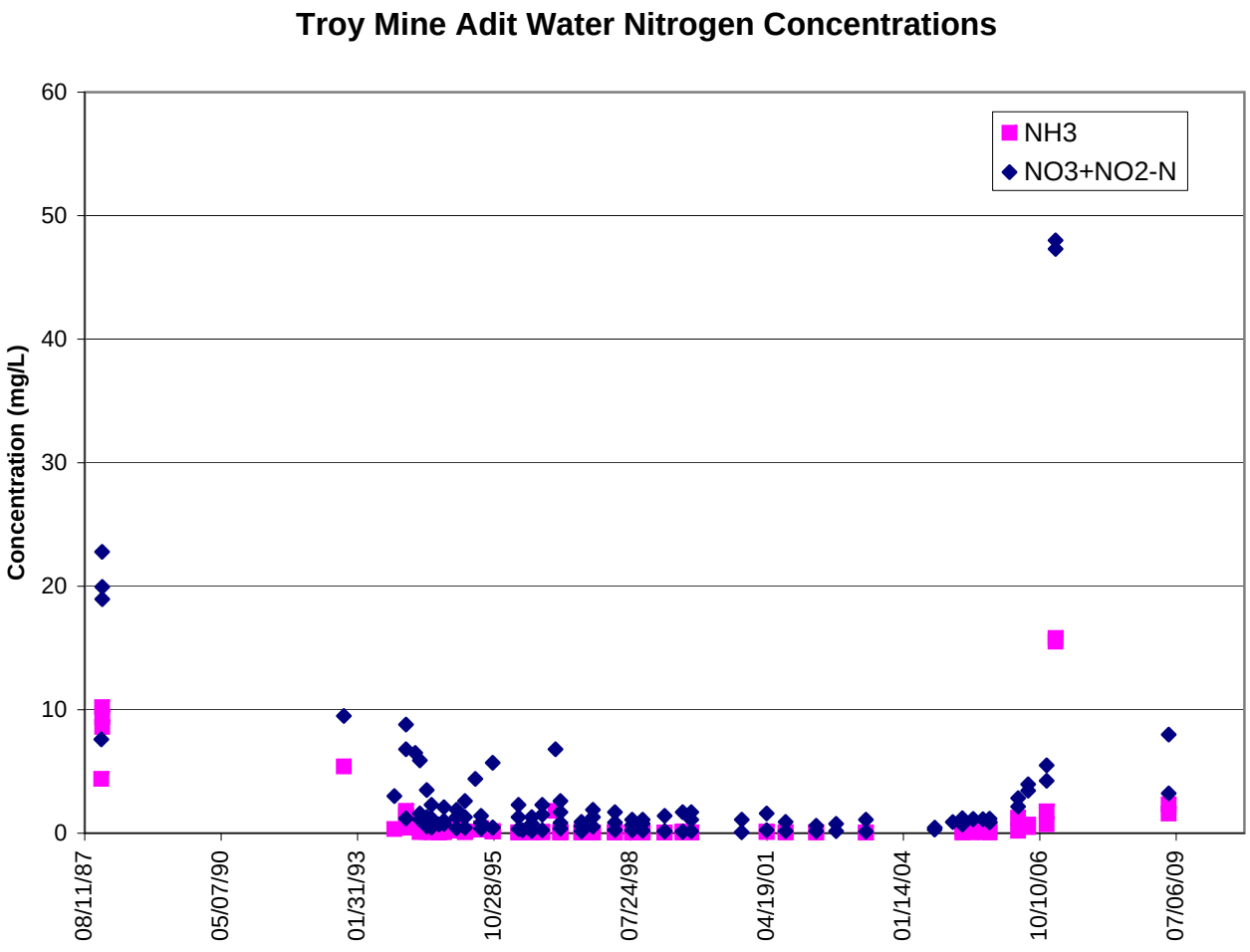
APPENDIX B

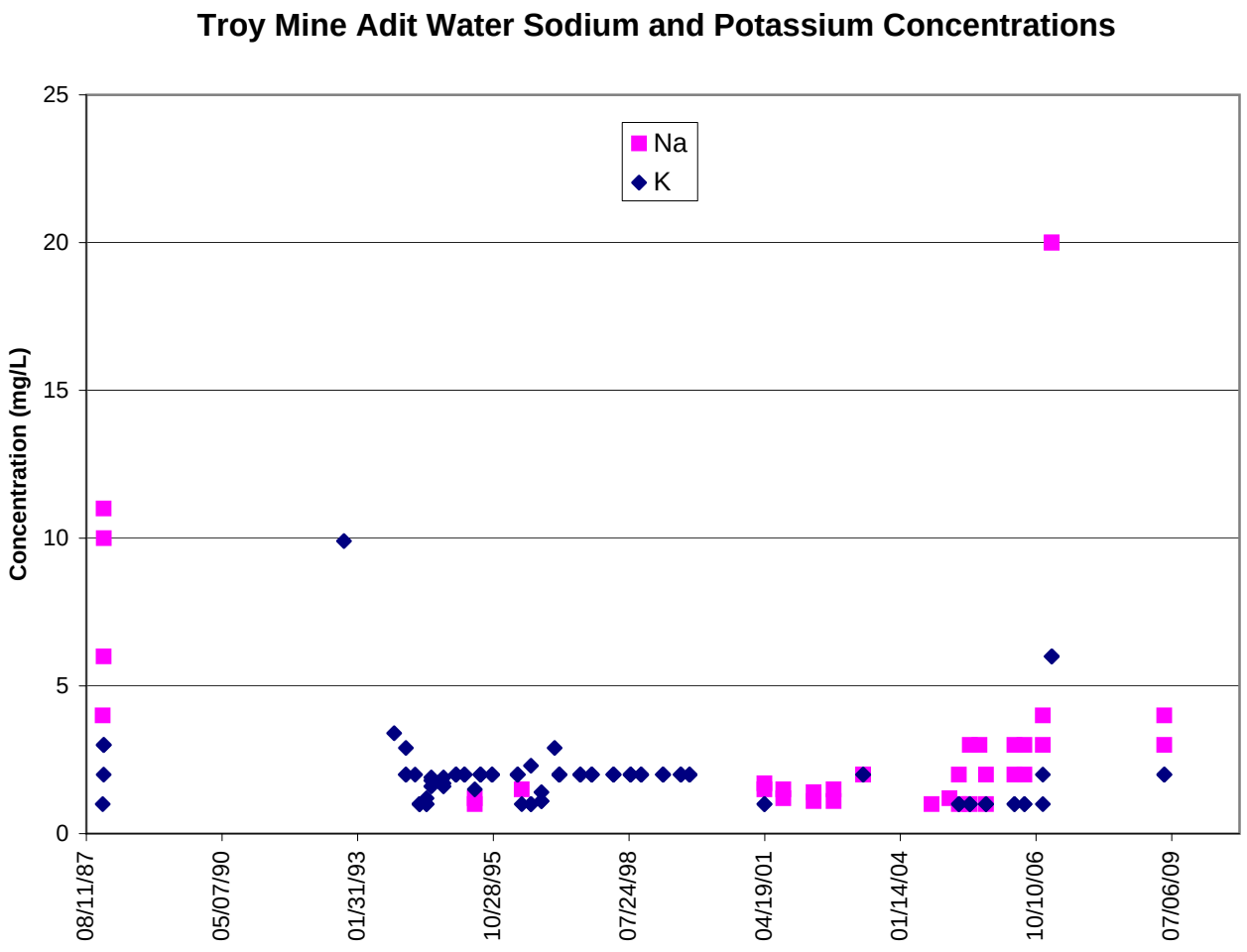
CONCENTRATION TIME SERIES GRAPHS

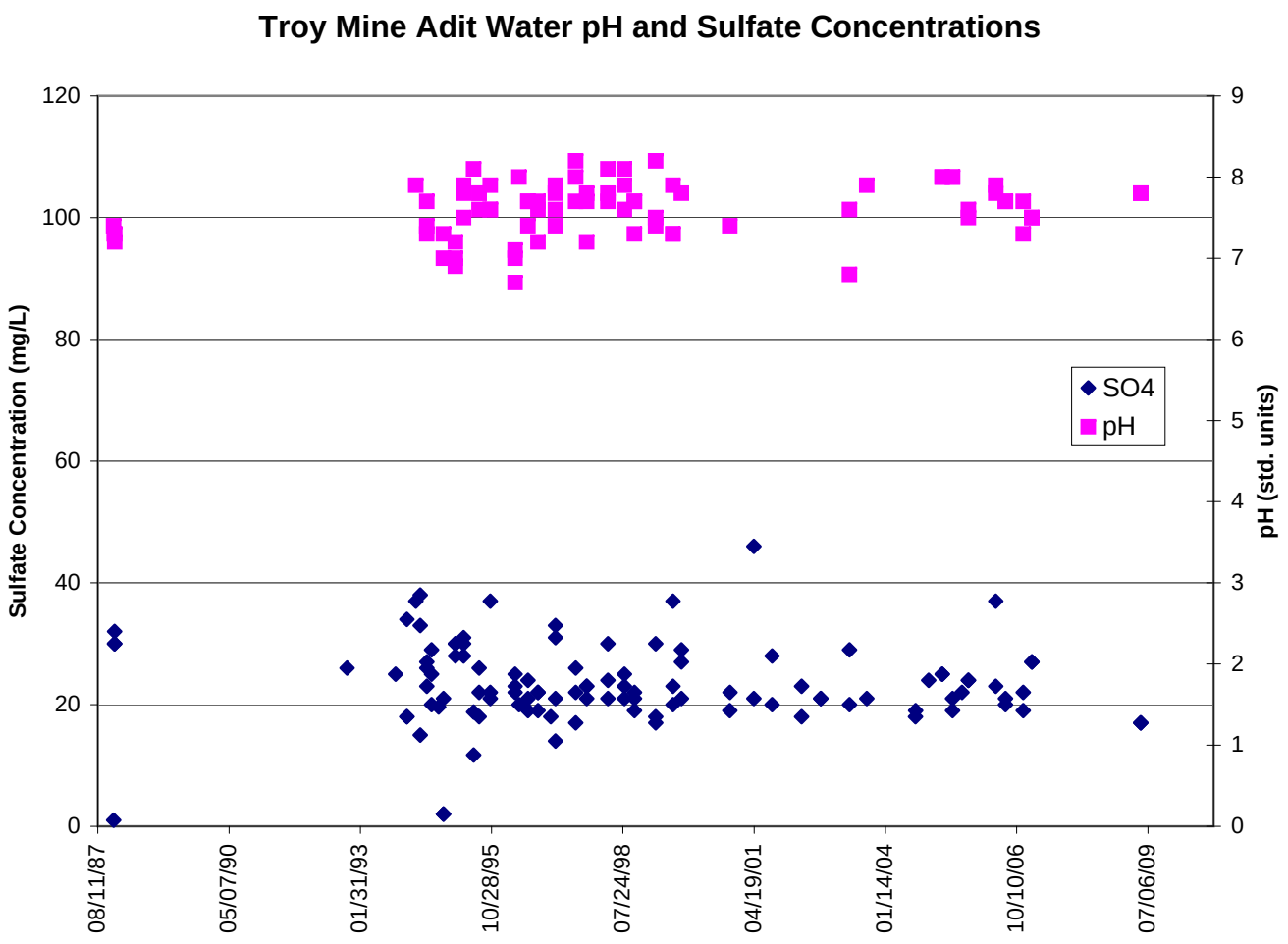

Troy Mine Adit Water Calcium and Bicarbonate Concentrations
HCO3
Ca
Concentration (mg/L)
120
100
80
60
40
20
0
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
07/06/09


Troy Mine Adit Water Copper Concentrations
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Cu DISS
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
02/22/08
07/06/09
11/18/10

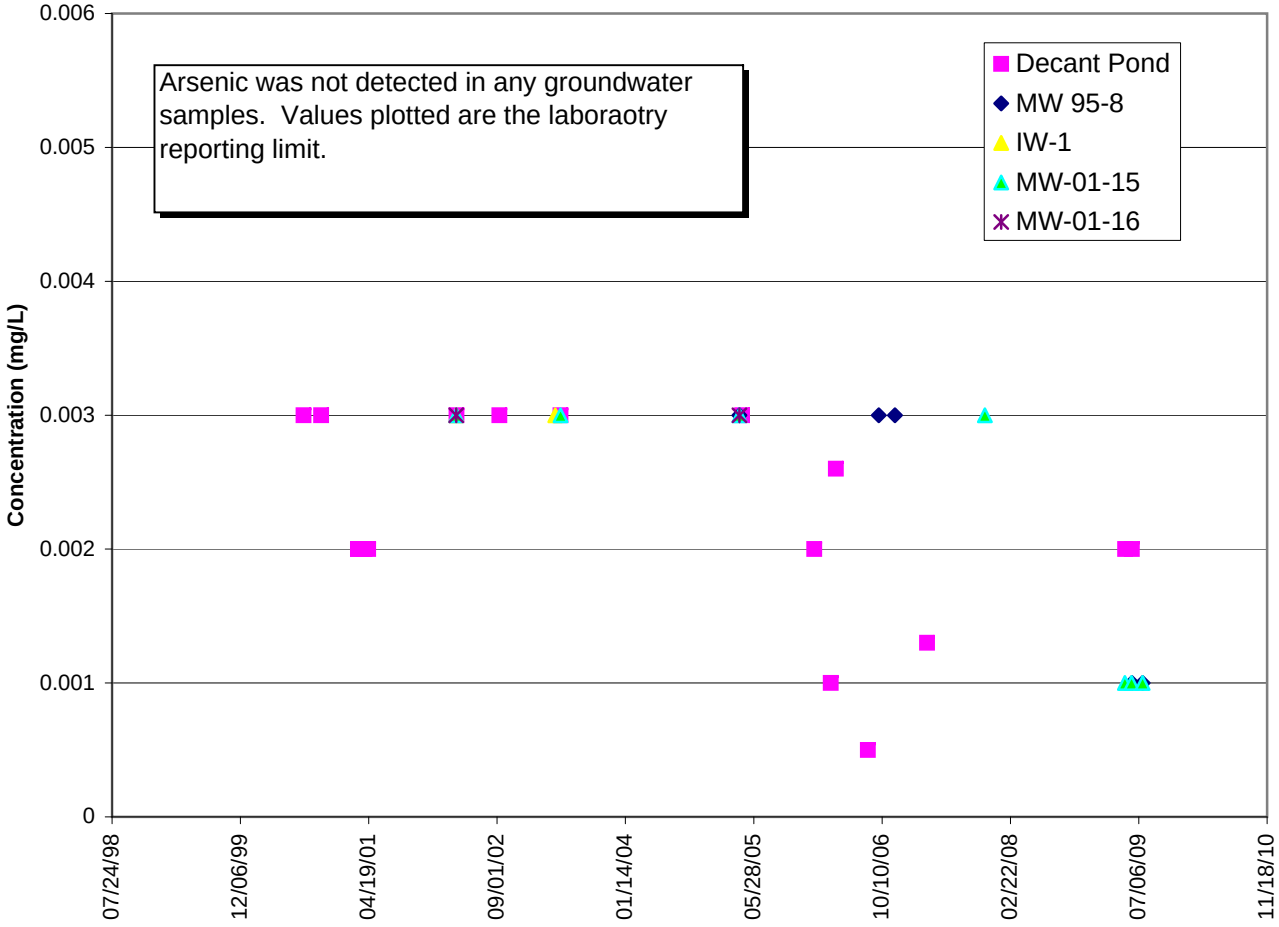

Troy Mine Adit Water Metal Concentrations
Concentration (mg/L)
1
0.1
0.01
0.001
0.0001
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
02/22/08
07/06/09
11/18/10
As DISS
Cd DISS
Pb DISS
Sb DISS
U, DISS

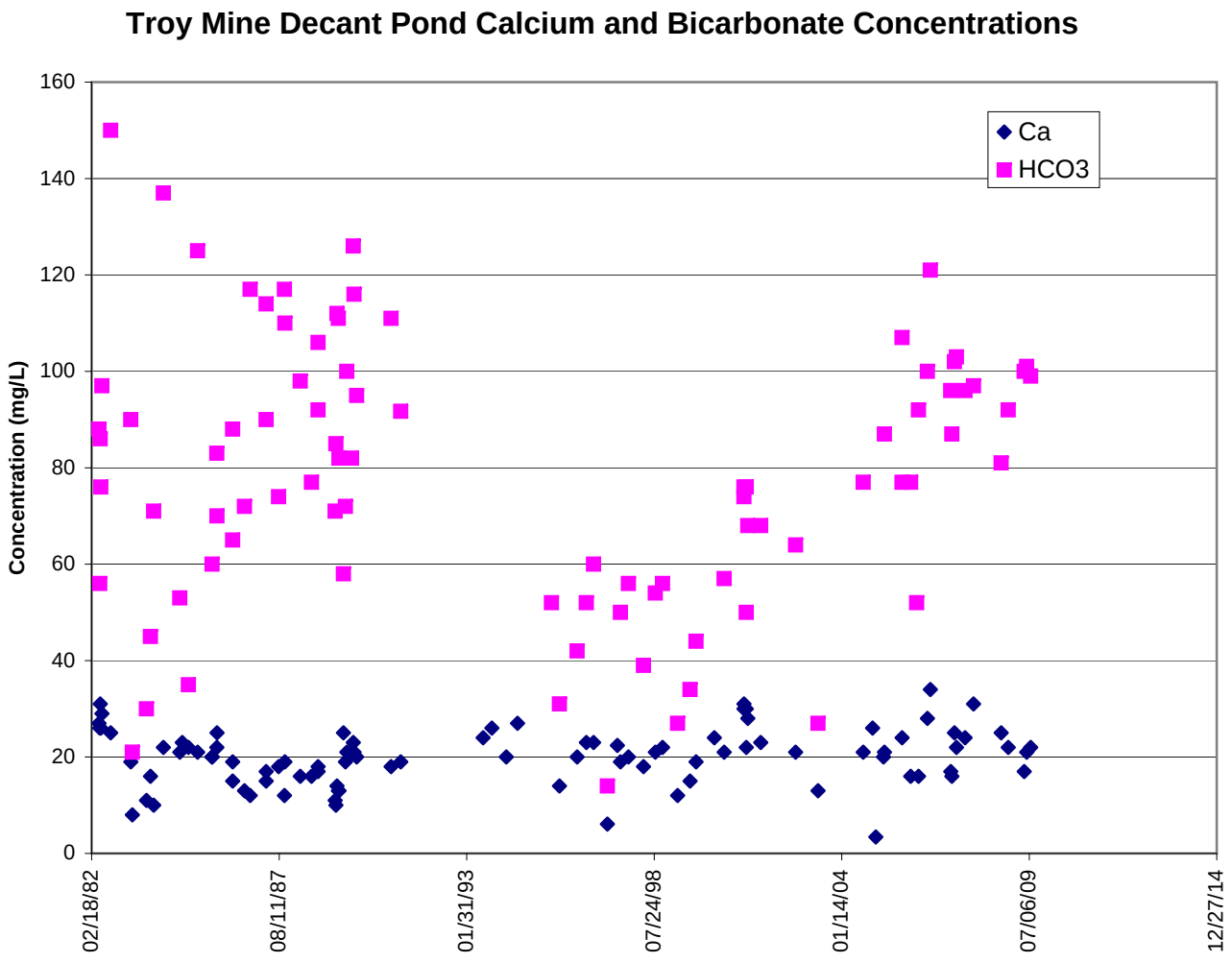

Troy Mine Adit Water Nitrogen Concentrations
Concentration (mg/L)
60
50
40
30
20
10
0
NH3
NO3+NO2-N
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
07/06/09


Troy Mine Adit Water Sodium and Potassium Concentrations
Na
K
Concentration (mg/L)
25
20
15
10
5
0
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
07/06/09

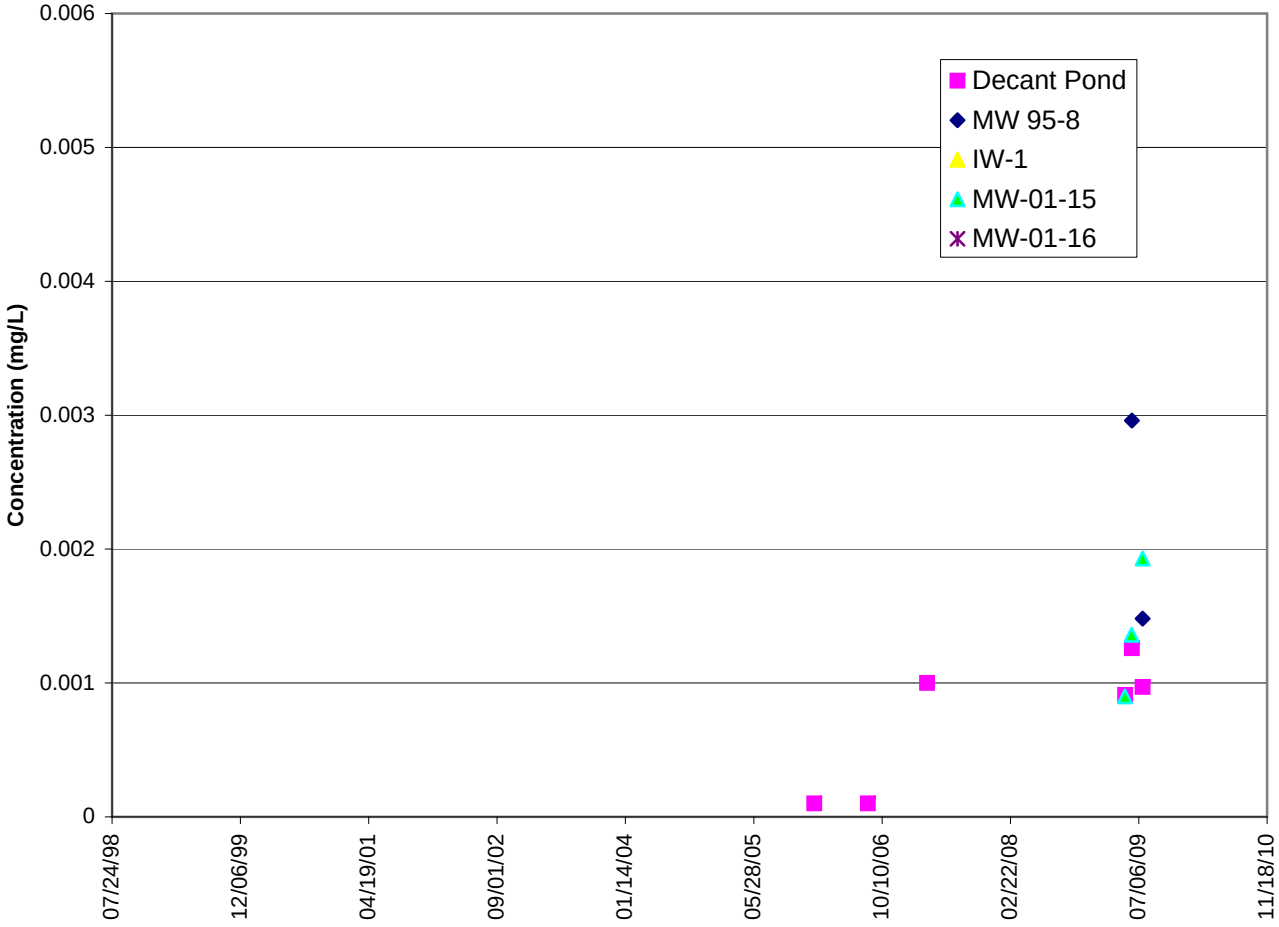

Troy Mine Adit Water pH and Sulfate Concentrations
Sulfate Concentration (mg/L)
pH (std. units)
120
100
80
60
40
20
0
9
8
7
6
5
4
3
2
1
0
SO4
pH
08/11/87
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
07/06/09

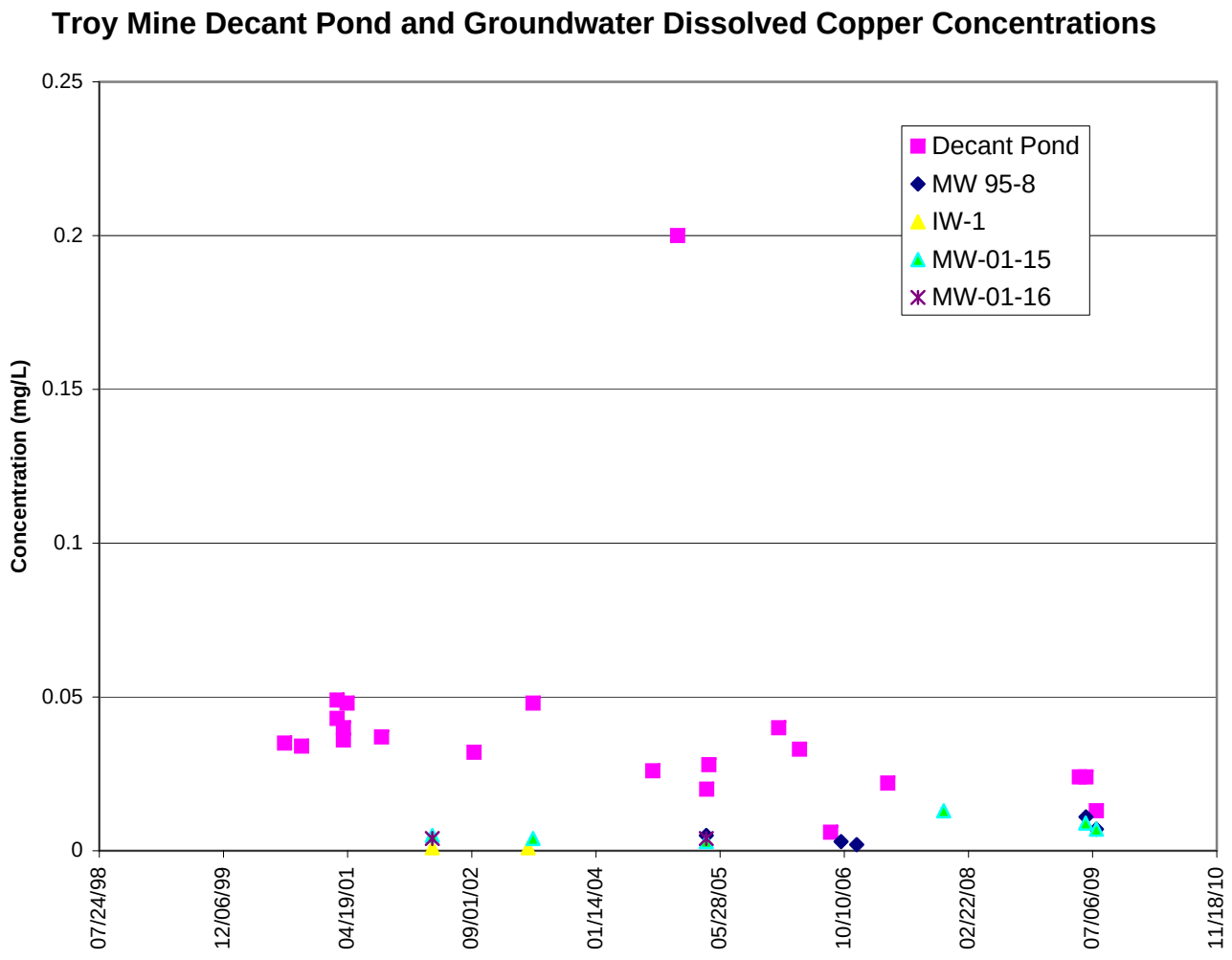
Troy Mine Decant Pond and Groundwater Dissolved Arsenic Concentrations

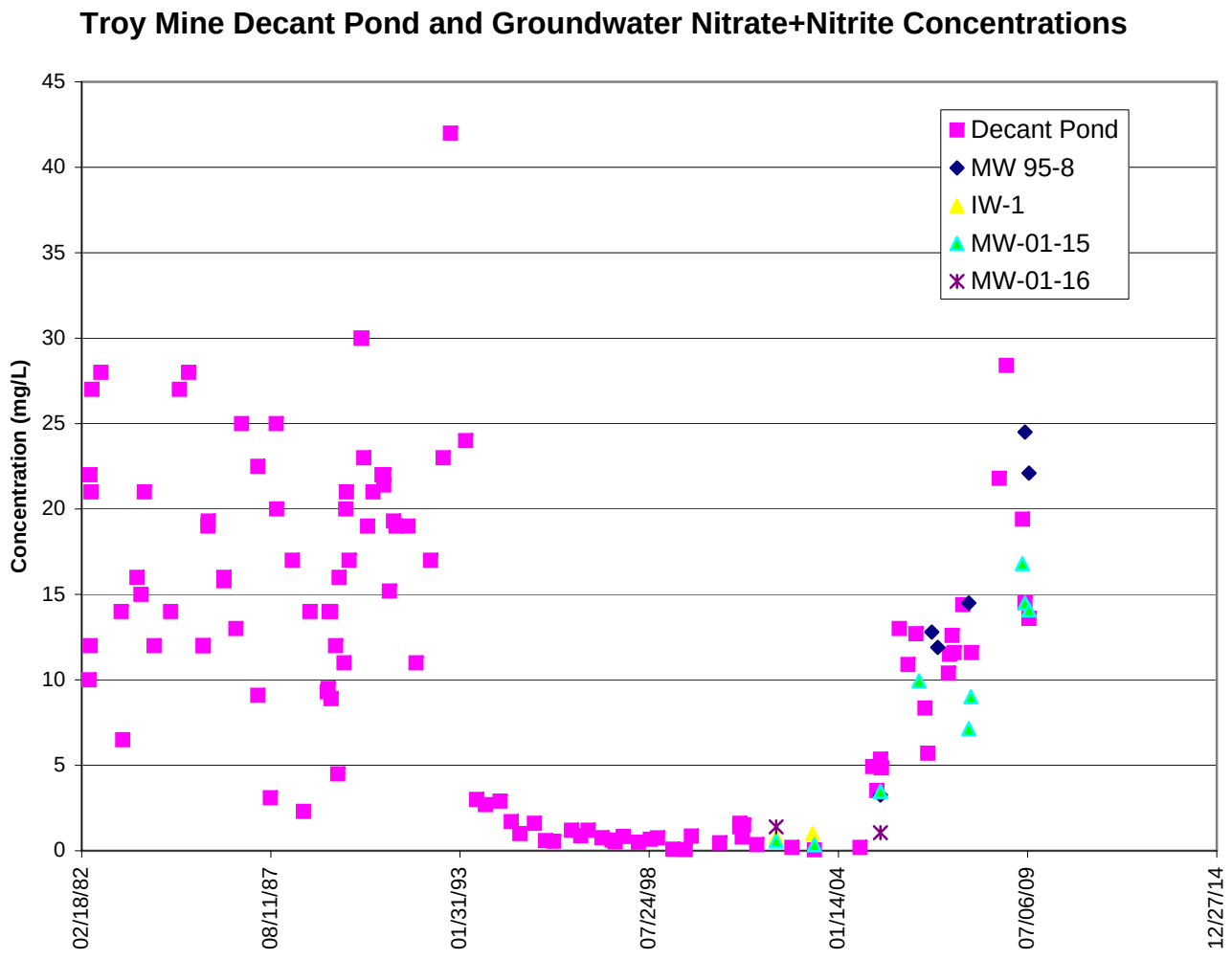


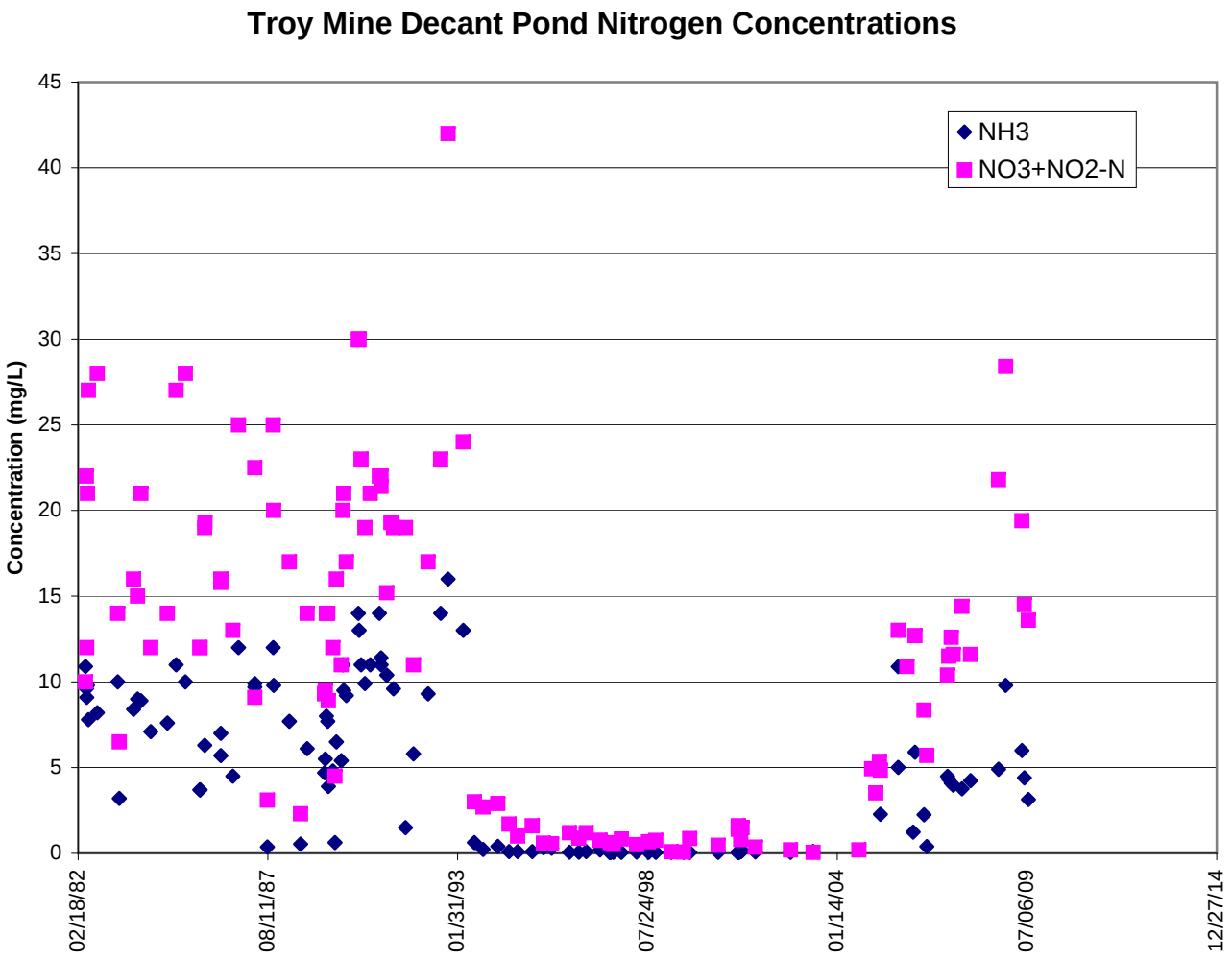

Troy Mine Decant Pond Calcium and Bicarbonate Concentrations
Concentration (mg/L)
160
140
120
100
80
60
40
20
0
02/18/82
08/11/87
01/31/93
07/24/98
01/14/04
07/06/09
12/27/14
Ca
HCO3

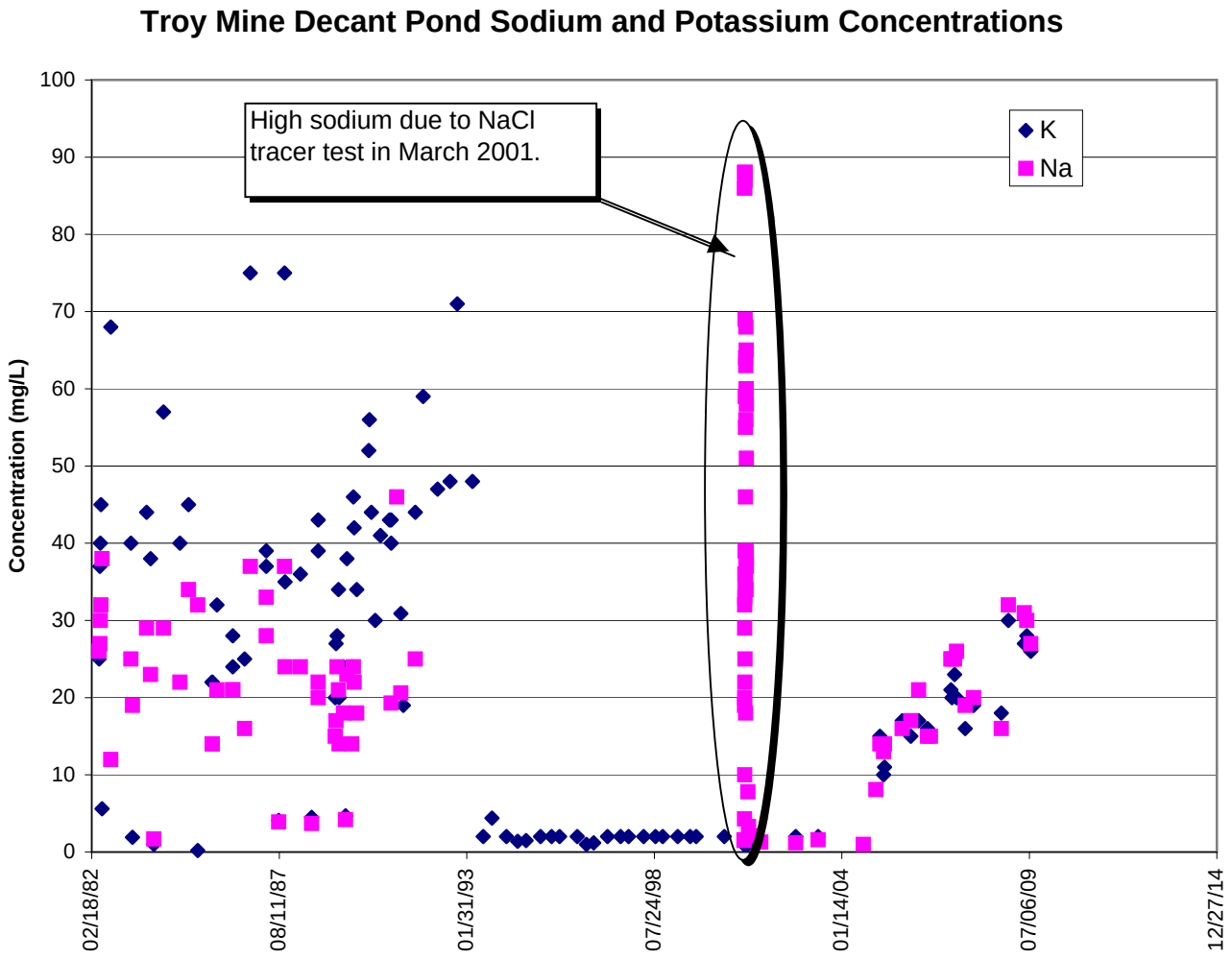
Troy Mine Decant Pond and Groundwater Dissolved Cadmium Concentrations



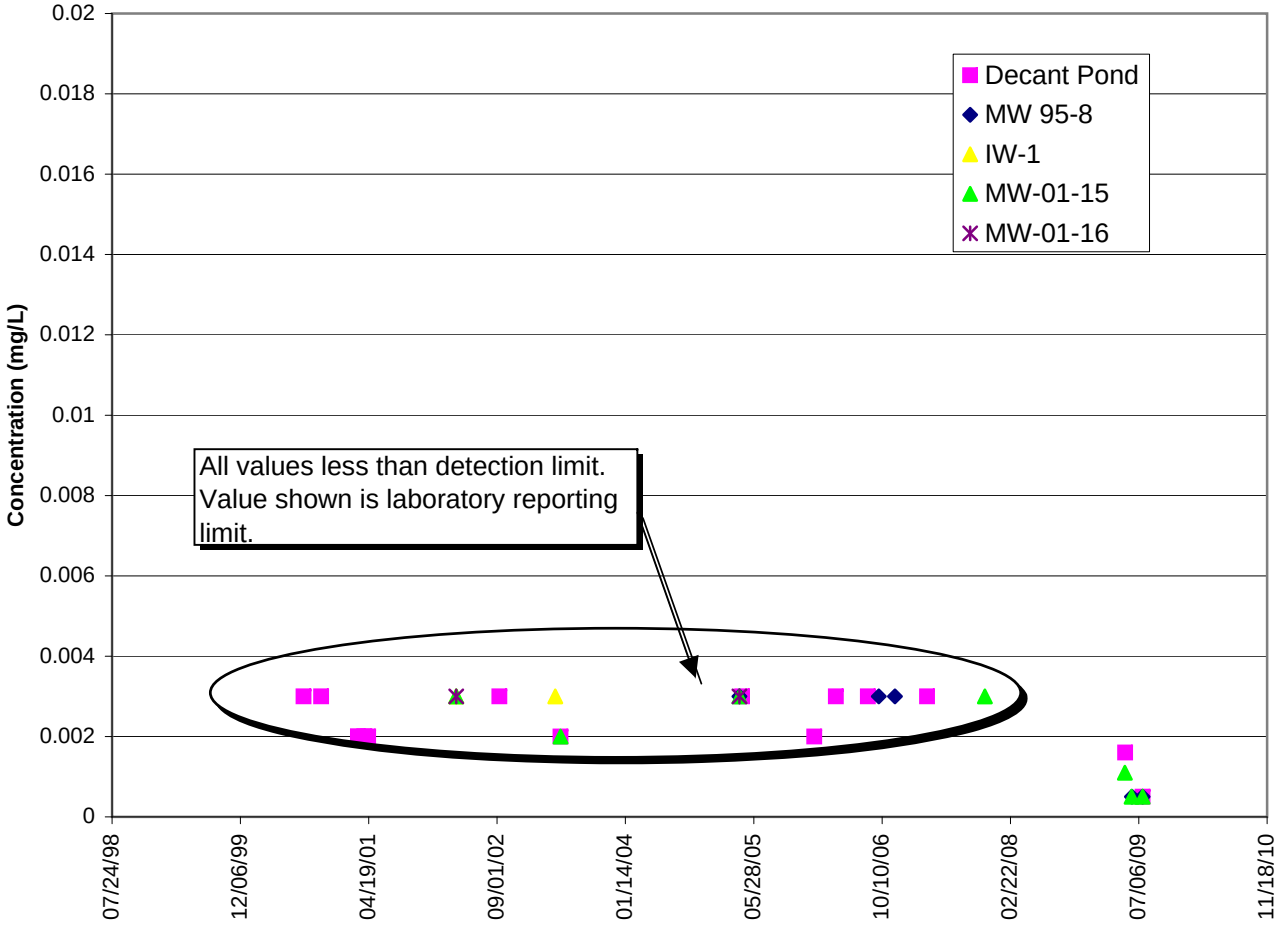

Troy Mine Decant Pond and Groundwater Dissolved Copper Concentrations
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
02/22/08
07/06/09
11/18/10
Decant Pond
MW 95-8
IW-1
MW-01-15
MW-01-16

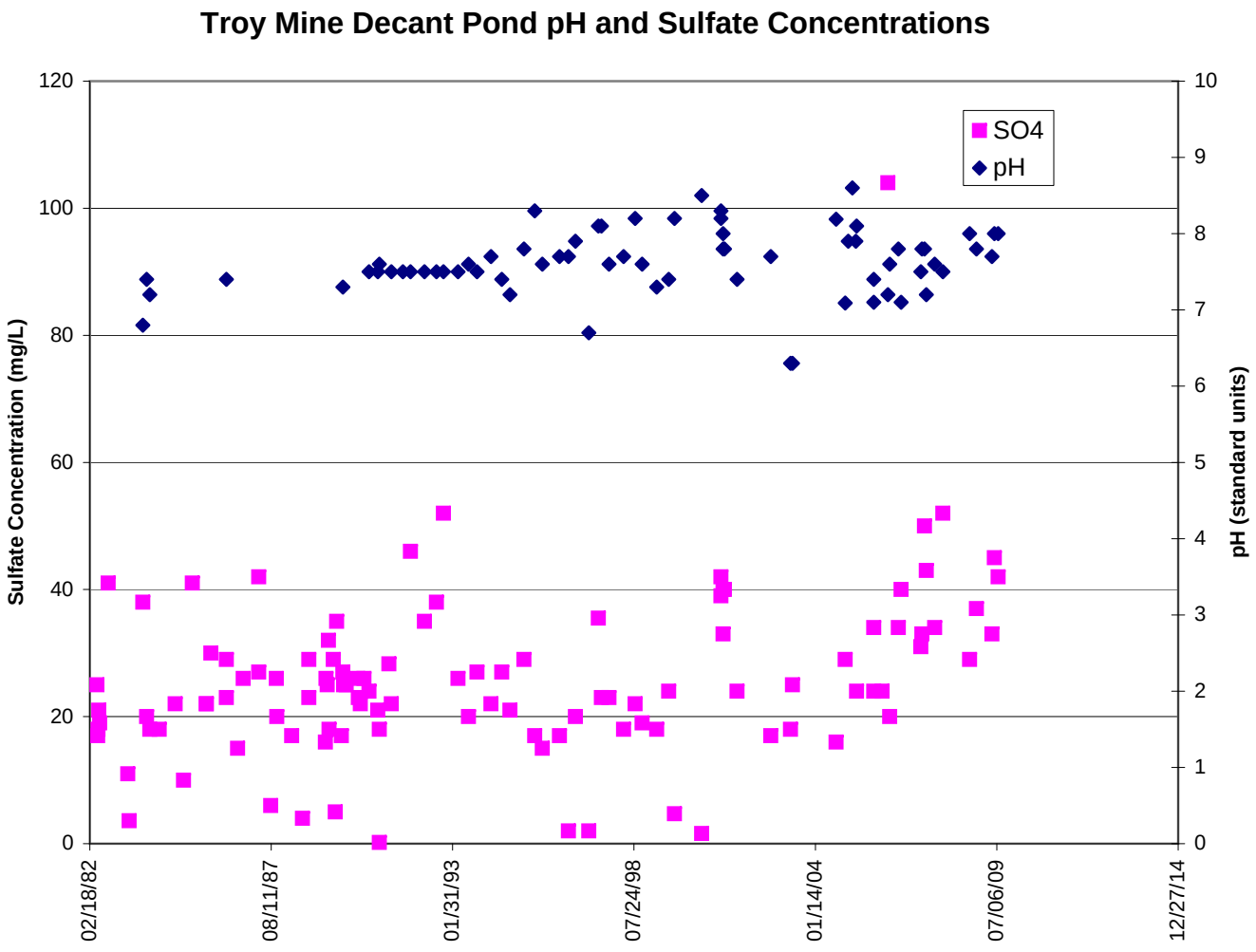

Troy Mine Decant Pond and Groundwater Nitrate+Nitrite Concentrations
Concentration (mg/L)
45
40
35
30
25
20
15
10
5
0
02/18/82
08/11/87
01/31/93
07/24/98
01/14/04
07/06/09
12/27/14
Decant Pond
MW 95-8
IW-1
MW-01-15
MW-01-16

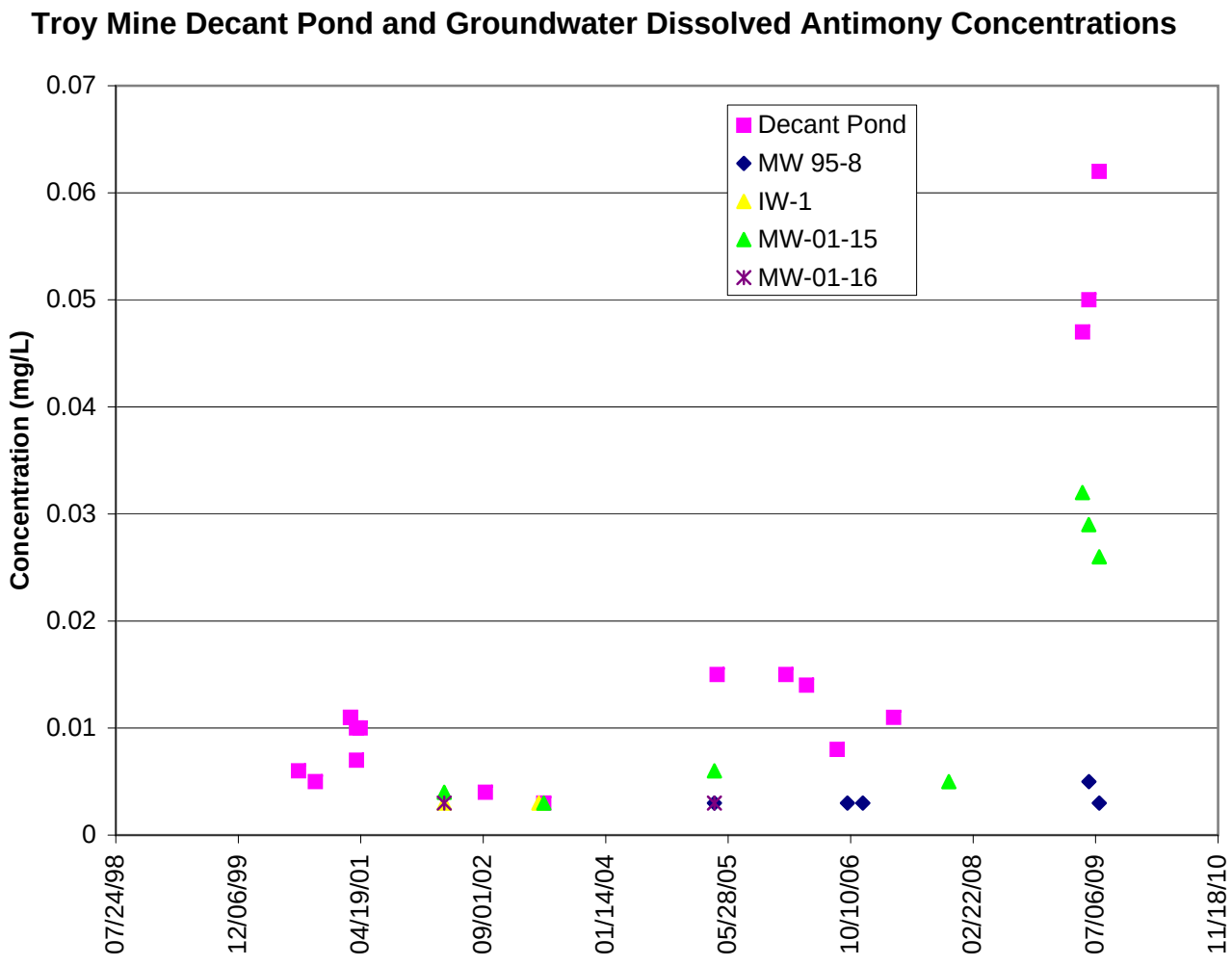

Troy Mine Decant Pond Nitrogen Concentrations
Concentration (mg/L)
45
40
35
30
25
20
15
10
5
0
NH3
NO3+NO2-N
02/18/82
08/11/87
01/31/93
07/24/98
01/14/04
07/06/09
12/27/14

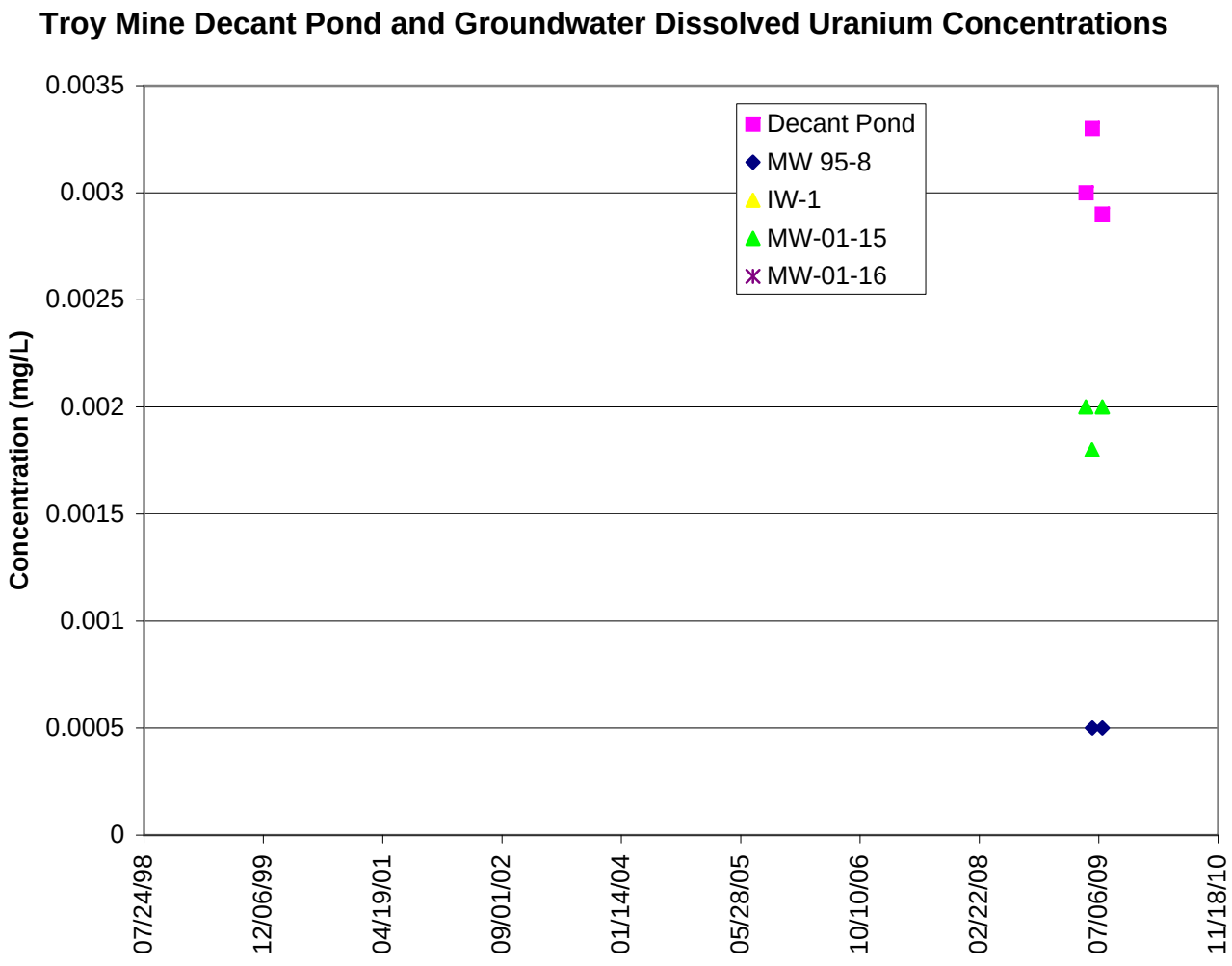

Troy Mine Decant Pond Sodium and Potassium Concentrations
High sodium due to NaCl tracer test in March 2001.
K
Na
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
02/18/82
08/11/87
01/31/93
07/24/98
01/14/04
07/06/09
12/27/14

Troy Mine Decant Pond and Groundwater Dissolved Lead Concentrations




Troy Mine Decant Pond pH and Sulfate Concentrations
Sulfate Concentration (mg/L)
pH (standard units)
SO4
pH
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
02/18/82
08/11/87
01/31/93
07/24/98
01/14/04
07/06/09
12/27/14


Troy Mine Decant Pond and Groundwater Dissolved Antimony Concentrations
Concentration (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
02/22/08
07/06/09
11/18/10
Decant Pond
MW 95-8
IW-1
MW-01-15
MW-01-16


Troy Mine Decant Pond and Groundwater Dissolved Uranium Concentrations
Concentration (mg/L)
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
02/22/08
07/06/09
11/18/10
Decant Pond
MW 95-8
IW-1
MW-01-15
MW-01-16

APPENDIX C

GEOCHEMICAL MODEL RESULTS

```
Temperature =  20.9 C    Pressure =  1.013 bars
pH =  8.000              log fO2 =  -22.996
Eh =   0.4280 volts      pe =   7.3361
Ionic strength      =    0.004457
Charge imbalance    =   -0.000212 eq/kg (-6.354% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000303 kg
Solution density    =    1.016    g/cm3
Chlorinity          =    0.000111 molal
Dissolved solids    =         303 mg/kg sol'n
Elect. conductivity =      345.82 uS/cm (or umho/cm)
Hardness            =       74.36 mg/kg sol'n as CaCO3
  carbonate         =       74.36 mg/kg sol'n as CaCO3
  non-carbonate     =        0.00 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       78.60 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.4280	7.3361
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5686	9.7454

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001538	93.82	0.9312	-2.8439
Na+	0.001154	26.52	0.9312	-2.9687
NO3-	0.0009562	59.27	0.9299	-3.0510
K+	0.0006533	25.54	0.9299	-3.2164
Ca++	0.0005140	20.60	0.7595	-3.4085
SO4--	0.0004036	38.76	0.7511	-3.5184
SiO2(aq)	0.0002188	13.14	1.0000	-3.6600
Mg++	0.0001890	4.592	0.7674	-3.8385
N2(aq)	0.0001169	3.274	1.0000	-3.9321
Cl-	0.0001111	3.936	0.9299	-3.9860
CO2(aq)	3.444e-005	1.515	1.0000	-4.4629
CaSO4(aq)	1.504e-005	2.047	1.0000	-4.8228
F-	1.031e-005	0.1959	0.9306	-5.0179
MgSO4(aq)	1.025e-005	1.233	1.0000	-4.9894
CO3--	8.015e-006	0.4808	0.7533	-5.2191
CaHCO3+	6.817e-006	0.6890	0.9312	-5.1973
CaCO3(aq)	4.634e-006	0.4637	1.0000	-5.3340
Mn++	3.567e-006	0.1959	0.7595	-5.5672
MgHCO3+	2.475e-006	0.2111	0.9312	-5.6374
NaHCO3(aq)	2.386e-006	0.2004	1.0000	-5.6223
HSiO3-	2.376e-006	0.1831	0.9312	-5.6552
KSO4-	1.506e-006	0.2035	0.9312	-5.8531
MgCO3(aq)	8.065e-007	0.06798	1.0000	-6.0934
Ba++	7.945e-007	0.1091	0.7554	-6.2218
OH-	7.732e-007	0.01315	0.9306	-6.1430
Sb(OH)3(aq)	5.014e-007	0.08661	1.0000	-6.2998
Cu++	2.015e-007	0.01280	0.7595	-6.8153
MnSO4(aq)	1.787e-007	0.02697	1.0000	-6.7480
HPO4--	1.681e-007	0.01612	0.7511	-6.8988
NaHSiO3(aq)	1.165e-007	0.01166	1.0000	-6.9336
HAsO4--	6.269e-008	0.008770	0.7511	-7.3271
MgF+	3.420e-008	0.001480	0.9312	-7.4970
NaCO3-	2.564e-008	0.002128	0.9312	-7.6220
H2PO4-	2.269e-008	0.002200	0.9312	-7.6751

CaF+	1.915e-008	0.001131	0.9312	-7.7488
NaCl(aq)	1.819e-008	0.001063	1.0000	-7.7401
MgCl+	1.219e-008	0.0007281	0.9312	-7.9450
H+	1.067e-008	1.075e-005	0.9374	-8.0000
CaCl+	8.781e-009	0.0006630	0.9312	-8.0874
Cd++	8.495e-009	0.0009547	0.7554	-8.1926
UO2(CO3)2--	6.367e-009	0.002483	0.7511	-8.3204
UO2(CO3)3----	5.581e-009	0.002511	0.3179	-8.7510
H2AsO4-	3.004e-009	0.0004233	0.9312	-8.5532
KCl(aq)	1.852e-009	0.0001380	1.0000	-8.7324
BaCO3(aq)	1.474e-009	0.0002907	1.0000	-8.8316
NaF(aq)	1.007e-009	4.228e-005	1.0000	-8.9968
MnCl+	5.536e-010	5.003e-005	0.9312	-9.2877
HSO4-	2.831e-010	2.748e-005	0.9312	-9.5789
HF(aq)	1.321e-010	2.641e-006	1.0000	-9.8792
NaOH(aq)	1.270e-010	5.079e-006	1.0000	-9.8961
UO2CO3(aq)	4.893e-011	1.615e-005	1.0000	-10.3104
Sb(OH)4-	4.654e-011	8.829e-006	0.9312	-10.3631
BaCl+	2.011e-011	3.474e-006	0.9312	-10.7275
AsO4---	1.953e-011	2.713e-006	0.5250	-10.9891
PO4---	1.034e-011	9.819e-007	0.5250	-11.2653
BaF+	3.915e-012	6.119e-007	0.9312	-11.4382
Cu+	3.531e-012	2.243e-007	0.9312	-11.4830
CdSO4(aq)	1.965e-012	4.094e-007	1.0000	-11.7067
CaCl2(aq)	1.010e-012	1.121e-007	1.0000	-11.9955
UO2OH+	8.973e-013	2.575e-007	0.9312	-12.0780
Sb(OH)2F(aq)	5.990e-013	1.047e-007	1.0000	-12.2226
HNO3(aq)	4.065e-013	2.561e-008	1.0000	-12.3909
HCl(aq)	2.128e-013	7.756e-009	1.0000	-12.6721
Sb(OH)2+	1.950e-013	3.036e-008	0.9312	-12.7410
CdCl2(aq)	1.452e-013	2.662e-008	1.0000	-12.8379
H3PO4(aq)	3.007e-014	2.946e-009	1.0000	-13.5219
KHSO4(aq)	1.049e-014	1.428e-009	1.0000	-13.9792
MgP2O7--	7.430e-015	1.473e-009	0.7511	-14.2533
H3AsO4(aq)	4.727e-015	6.708e-010	1.0000	-14.3254
UO2++	2.313e-015	6.245e-010	0.7533	-14.7588
UO2F+	2.005e-015	5.793e-010	0.9312	-14.7288
UO2SO4(aq)	5.624e-016	2.058e-010	1.0000	-15.2499
HF2-	3.137e-016	1.223e-011	0.9312	-15.5345
HP2O7---	7.509e-017	1.313e-011	0.5250	-16.4043
UO2F2(aq)	5.572e-017	1.716e-011	1.0000	-16.2540
P2O7----	7.591e-018	1.320e-012	0.3179	-17.6174
CdCl3-	3.558e-018	7.781e-013	0.9312	-17.4797
H2P2O7--	2.309e-018	4.061e-013	0.7511	-17.7609
UO2(SO4)2--	1.699e-018	7.851e-013	0.7511	-17.8940
KP2O7---	5.703e-019	1.215e-013	0.5250	-18.5238
UO2Cl+	2.658e-019	8.116e-014	0.9312	-18.6064
UO2F3-	9.968e-020	3.259e-014	0.9312	-19.0323
(UO2)2(OH)2++	7.451e-020	4.276e-014	0.7533	-19.2508
(UO2)3(OH)5+	8.158e-021	7.300e-015	0.9312	-20.1193
(UO2)3(CO3)6(6-)	4.328e-021	5.063e-015	0.0759	-21.4837
UO2+	2.410e-021	6.505e-016	0.9312	-20.6490
UO2F4--	6.889e-024	2.383e-018	0.7511	-23.2862
H3P2O7-	4.158e-024	7.356e-019	0.9312	-23.4120
Mn+++	2.126e-024	1.167e-019	0.5317	-23.9469
UO2Cl2(aq)	1.289e-024	4.394e-019	1.0000	-23.8897
NO2-	1.449e-025	6.664e-021	0.9299	-24.8705
U(OH)4(aq)	1.336e-025	4.087e-020	1.0000	-24.8742
HAsO2(aq)	5.108e-026	5.511e-021	1.0000	-25.2918
As(OH)3(aq)	4.414e-026	5.558e-021	1.0000	-25.3551
O2(aq)	1.391e-026	4.449e-022	1.0000	-25.8567
AsO2-	2.552e-027	2.728e-022	0.9312	-26.6240
H2AsO3-	2.522e-027	3.150e-022	0.9312	-26.6292

HNO2(aq)	2.615e-030	1.229e-025	1.0000	-29.5824
AsO2OH--	2.529e-030	3.133e-025	0.7511	-29.7214
H4P2O7(aq)	1.154e-030	2.053e-025	1.0000	-29.9378
MnO4--	7.769e-033	9.238e-028	0.7511	-32.2339
ClO-	6.945e-033	3.572e-028	0.9312	-32.1893
Formate	4.587e-034	2.064e-029	0.9306	-33.3697
HO2-	2.881e-034	9.507e-030	0.9312	-33.5714
H2(aq)	1.373e-034	2.766e-031	1.0000	-33.8625
MnO4-	3.368e-035	4.005e-030	0.9306	-34.5039
Ca(For)+	5.014e-036	4.266e-031	0.9312	-35.3307
Mg(For)+	1.971e-036	1.366e-031	0.9312	-35.7363
Na(For)(aq)	5.277e-037	3.588e-032	1.0000	-36.2776
K(For)(aq)	2.767e-037	2.327e-032	1.0000	-36.5580
Mn(For)+	6.631e-038	6.626e-033	0.9312	-37.2094
Formic_acid(aq)	2.451e-038	1.128e-033	1.0000	-37.6107
SO3--	1.733e-038	1.387e-033	0.7533	-37.8843
Cu(For)+	7.300e-039	7.923e-034	0.9312	-38.1676
Ba(For)+	6.564e-039	1.197e-033	0.9312	-38.2138
HSO3-	2.191e-039	1.776e-034	0.9312	-38.6902
SiF6--	7.276e-040	1.033e-034	0.7511	-39.2624
Cd(For)+	2.178e-040	3.427e-035	0.9312	-39.6930
NH4+	5.474e-041	9.872e-037	0.9292	-40.2936
CO(aq)	5.096e-041	1.427e-036	1.0000	-40.2927
Oxalate	1.725e-041	1.518e-036	0.7511	-40.8875
NH3(aq)	2.163e-042	3.682e-038	1.0000	-41.6650
HSO5-	9.080e-043	1.026e-037	0.9312	-42.0729
U(CO3)5(6-)	8.077e-044	4.345e-038	0.0759	-44.2128
UOH+++	3.124e-045	7.965e-040	0.5317	-44.7796
H-Oxalate	2.464e-045	2.193e-040	0.9312	-44.6393
SO2(aq)	1.368e-045	8.763e-041	1.0000	-44.8638
UF3+	2.245e-046	6.623e-041	0.9312	-45.6796
UF2++	1.377e-046	3.801e-041	0.7533	-45.9840
UF4(aq)	1.867e-047	5.860e-042	1.0000	-46.7289
UF+++	2.516e-048	6.466e-043	0.5317	-47.8736
U(SO4)2(aq)	1.329e-049	5.715e-044	1.0000	-48.8765
USO4++	9.484e-050	3.168e-044	0.7533	-49.1460
Oxalic_acid(aq)	4.240e-052	3.816e-047	1.0000	-51.3726
U++++	2.345e-052	5.580e-047	0.3288	-52.1130
ClO2-	6.132e-054	4.135e-049	0.9312	-53.2433
UCl+++	8.519e-055	2.329e-049	0.5317	-54.3440
S2O8--	1.538e-059	2.954e-054	0.7511	-58.9373
ClO3-	6.091e-061	5.082e-056	0.9306	-60.2465
S2O6--	5.262e-063	8.424e-058	0.7511	-62.4031
Ca(For)2(aq)	1.569e-068	2.041e-063	1.0000	-67.8042
Mg(For)2(aq)	6.558e-069	7.496e-064	1.0000	-68.1832
U+++	1.465e-069	3.487e-064	0.5317	-69.1084
Mn(For)2(aq)	3.523e-070	5.105e-065	1.0000	-69.4531
Na(For)2-	1.403e-070	1.585e-065	0.9312	-69.8839
K(For)2-	6.758e-071	8.725e-066	0.9312	-70.2011
Cu(For)2(aq)	6.743e-071	1.035e-065	1.0000	-70.1712
N3-	5.954e-071	2.501e-066	0.9312	-70.2561
Ba(For)2(aq)	1.775e-071	4.035e-066	1.0000	-70.7508
Cd(For)2(aq)	9.697e-072	1.963e-066	1.0000	-71.0133
ClO4-	2.827e-072	2.811e-067	0.9306	-71.5799
Formaldehyde(aq)	1.294e-073	3.884e-069	1.0000	-72.8881
HN3(aq)	3.171e-074	1.364e-069	1.0000	-73.4988
UO2ClO3+	3.376e-075	1.193e-069	0.9312	-74.5025
S2O5--	8.522e-083	1.228e-077	0.7511	-82.1937
Cu(NH3)2++	3.527e-083	3.441e-078	0.7533	-82.5757
Cd(NH3)2++	3.559e-087	5.212e-082	0.7533	-86.5717
HCN(aq)	7.301e-088	1.973e-083	1.0000	-87.1366
Urea(aq)	3.579e-088	2.149e-083	1.0000	-87.4462
CN-	3.452e-089	8.978e-085	0.9299	-88.4936

Methanol(aq)	1.840e-092	5.894e-088	1.0000	-91.7352
Glycolate	1.466e-098	1.100e-093	0.9312	-97.8647
Ca(Glyc)+	2.701e-100	3.109e-095	0.9312	-99.5993
HS-	5.647e-101	1.867e-096	0.9306	-100.2794
Mg(Glyc)+	4.776e-101	4.743e-096	0.9312	-100.3519
Na(Glyc)(aq)	1.701e-101	1.667e-096	1.0000	-100.7693
K(Glyc)(aq)	8.918e-102	1.018e-096	1.0000	-101.0497
H2S(aq)	5.951e-102	2.028e-097	1.0000	-101.2254
Cu(Glyc)+	1.973e-102	2.733e-097	0.9312	-101.7359
Mn(Glyc)+	1.623e-102	2.108e-097	0.9312	-101.8207
Glycolic_acid(aq	9.419e-103	7.161e-098	1.0000	-102.0260
Ba(Glyc)+	9.023e-104	1.916e-098	0.9312	-103.0756
Cd(Glyc)+	7.530e-105	1.411e-099	0.9312	-104.1541
S2O4--	3.383e-105	4.333e-100	0.7554	-104.5925
S--	6.050e-106	1.939e-101	0.7554	-105.3401
Methane(aq)	3.863e-106	6.196e-102	1.0000	-105.4131
S2O3--	1.387e-107	1.555e-102	0.7511	-106.9821
Acetate	1.393e-111	8.221e-107	0.9319	-110.8868
CaCH3COO+	4.766e-114	4.722e-109	0.9312	-113.3528
MgCH3COO+	4.194e-114	3.495e-109	0.9312	-113.4083
NaCH3COO(aq)	1.130e-114	9.268e-110	1.0000	-113.9469
Acetic_acid(aq)	7.443e-115	4.468e-110	1.0000	-114.1283
KCH3COO(aq)	4.264e-115	4.183e-110	1.0000	-114.3702
MnCH3COO+	6.573e-116	7.490e-111	0.9312	-115.2132
CuCH3COO+	4.028e-116	4.937e-111	0.9312	-115.4258
BaCH3COO+	8.068e-117	1.584e-111	0.9312	-116.1242
CdCH3COO+	8.189e-118	1.404e-112	0.9312	-117.1177
Malonate	2.581e-120	2.633e-115	0.7511	-119.7125
Cu(NH3)3++	5.739e-122	6.577e-117	0.7533	-121.3642
H-Malonate	1.013e-122	1.044e-117	0.9312	-122.0253
CuCH3COO(aq)	9.601e-123	1.177e-117	1.0000	-122.0177
AsH3(aq)	4.362e-123	3.399e-118	1.0000	-122.3603
Malonic_acid(aq)	6.757e-128	7.029e-123	1.0000	-127.1703
Methanamine(aq)	1.057e-131	3.283e-127	1.0000	-130.9757
Glycine(aq)	4.580e-135	3.437e-130	1.0000	-134.3391
Cu(Gly)+	4.286e-135	5.896e-130	0.9312	-134.3988
Mg(Gly)+	2.785e-137	2.739e-132	0.9312	-136.5861
Mn(Gly)+	8.271e-139	1.067e-133	0.9312	-138.1134
Ca(Gly)+	5.249e-139	5.989e-134	0.9312	-138.3109
S3O6--	6.336e-140	1.217e-134	0.7511	-139.3225
Cd(Gly)+	2.144e-140	3.996e-135	0.9312	-139.6998
Ba(Gly)+	1.070e-141	2.261e-136	0.9312	-141.0016
Acetaldehyde(aq)	5.669e-149	2.497e-144	1.0000	-148.2465
SCN-	1.708e-150	9.920e-146	0.9306	-149.7987
NH4CH3COO(aq)	1.090e-151	8.398e-147	1.0000	-150.9626
Acetamide(aq)	1.017e-151	6.007e-147	1.0000	-150.9926
UO2SCN+	7.487e-164	2.456e-158	0.9312	-163.1566
Cd(NH3)4++	4.911e-168	8.863e-163	0.7533	-167.4319
Ethyne(aq)	2.511e-170	6.536e-166	1.0000	-169.6002
Ethanol(aq)	2.532e-172	1.166e-167	1.0000	-171.5965
Ethylene(aq)	7.077e-177	1.985e-172	1.0000	-176.1502
Lactate	2.276e-178	2.027e-173	0.9312	-177.6737
Ca(Lac)+	2.481e-180	3.203e-175	0.9312	-179.6363
Mg(Lac)+	7.986e-181	9.052e-176	0.9312	-180.1286
Na(Lac)(aq)	2.670e-181	2.991e-176	1.0000	-180.5735
K(Lac)(aq)	1.400e-181	1.794e-176	1.0000	-180.8538
Mn(Lac)+	1.787e-182	2.573e-177	0.9312	-181.7787
Lactic_acid(aq)	1.558e-182	1.403e-177	1.0000	-181.8074
Cu(Lac)+	1.431e-182	2.183e-177	0.9312	-181.8753
Ba(Lac)+	6.055e-184	1.370e-178	0.9312	-183.2488
Cd(Lac)+	7.946e-185	1.601e-179	0.9312	-184.1308
Ethane(aq)	3.432e-190	1.032e-185	1.0000	-189.4644
Propanoate	1.643e-193	1.200e-188	0.9312	-192.8152

Ca(Prop)+	3.133e-196	3.544e-191	0.9312	-195.5350
Na(Prop)(aq)	1.900e-196	1.825e-191	1.0000	-195.7213
Mg(Prop)+	1.351e-196	1.315e-191	0.9312	-195.9003
Propanoic_acid(a	1.187e-196	8.793e-192	1.0000	-195.9254
K(Prop)(aq)	9.962e-197	1.117e-191	1.0000	-196.0016
Ca(Glyc)2(aq)	6.460e-197	1.228e-191	1.0000	-196.1898
Mn(Prop)+	8.953e-198	1.146e-192	0.9312	-197.0790
Mg(Glyc)2(aq)	6.364e-198	1.109e-192	1.0000	-197.1963
Cu(Prop)+	4.609e-198	6.295e-193	0.9312	-197.3673
Cu(Glyc)2(aq)	1.675e-198	3.577e-193	1.0000	-197.7760
USCN+++	2.559e-199	7.575e-194	0.5317	-198.8663
Na(Glyc)2-	2.254e-199	3.900e-194	0.9312	-198.6779
Mn(Glyc)2(aq)	1.577e-199	3.232e-194	1.0000	-198.8022
Ba(Prop)+	1.336e-199	2.811e-194	0.9312	-198.9050
K(Glyc)2-	1.094e-199	2.069e-194	0.9312	-198.9920
Cd(Prop)+	8.809e-200	1.633e-194	0.9312	-199.0860
Succinate	1.119e-200	1.299e-195	0.7511	-200.0753
S4O6--	8.713e-201	1.953e-195	0.7511	-200.1841
Ba(Glyc)2(aq)	5.866e-201	1.686e-195	1.0000	-200.2316
Cd(Glyc)2(aq)	2.781e-201	7.298e-196	1.0000	-200.5558
Serine(aq)	2.014e-202	2.115e-197	1.0000	-201.6960
H-Succinate	3.882e-203	4.543e-198	0.9312	-202.4419
Succinic_acid(aq	5.978e-207	7.057e-202	1.0000	-206.2235
Ethanamine(aq)	1.887e-213	8.506e-209	1.0000	-212.7242
Alanine(aq)	9.728e-216	8.665e-211	1.0000	-215.0120
Cu(Ala)+	2.068e-216	3.135e-211	0.9312	-215.7154
Mg(Ala)+	4.701e-220	5.282e-215	0.9312	-219.3588
Ca(Ala)+	2.225e-220	2.851e-215	0.9312	-219.6835
Mn(Ala)+	1.673e-220	2.392e-215	0.9312	-219.8074
Cd(Ala)+	2.591e-221	5.194e-216	0.9312	-220.6174
Ba(Ala)+	1.739e-223	3.920e-218	0.9312	-222.7905
Ca(CH3COO)2(aq)	1.002e-223	1.584e-218	1.0000	-222.9993
Mg(CH3COO)2(aq)	3.348e-224	4.766e-219	1.0000	-223.4752
Cu(CH3COO)2(aq)	1.389e-225	2.522e-220	1.0000	-224.8574
Na(CH3COO)2-	7.289e-226	1.028e-220	0.9312	-225.1683
Mn(CH3COO)2(aq)	6.072e-226	1.050e-220	1.0000	-225.2167
Acetone(aq)	4.530e-226	2.630e-221	1.0000	-225.3439
K(CH3COO)2-	1.959e-226	3.079e-221	0.9312	-225.7388
Aspartic_acid(aq	1.336e-226	1.777e-221	1.0000	-225.8743
Ba(CH3COO)2(aq)	3.227e-227	8.239e-222	1.0000	-226.4913
Cd(CH3COO)2(aq)	1.842e-227	4.245e-222	1.0000	-226.7347
Propanal(aq)	2.405e-230	1.396e-225	1.0000	-229.6189
Cu(CH3COO)2-	1.430e-233	2.596e-228	0.9312	-232.8757
1-Propyne(aq)	3.629e-248	1.453e-243	1.0000	-247.4402
1-Propanol(aq)	3.379e-254	2.030e-249	1.0000	-253.4712
S3--	1.084e-254	1.042e-249	0.7511	-254.0894
1-Propene(aq)	1.476e-256	6.211e-252	1.0000	-255.8308
2-Hydroxybutanoa	1.153e-260	1.188e-255	0.9312	-259.9692
NH4(CH3COO)2-	1.226e-262	1.669e-257	0.9312	-261.9423
Asparagine(aq)	2.301e-263	3.039e-258	1.0000	-262.6381
Cu(Gly)2(aq)	5.266e-264	1.114e-258	1.0000	-263.2785
2-Hydroxybutanoi	7.017e-265	7.303e-260	1.0000	-264.1538
Mg(Gly)2(aq)	1.725e-270	2.973e-265	1.0000	-269.7633
Diglycine(aq)	5.237e-272	6.916e-267	1.0000	-271.2810
Mn(Gly)2(aq)	4.483e-272	9.101e-267	1.0000	-271.3484
Propane(aq)	1.927e-272	8.497e-268	1.0000	-271.7150
Cd(Gly)2(aq)	6.626e-273	1.726e-267	1.0000	-272.1787
Diketopiperazine	3.291e-274	3.754e-269	1.0000	-273.4826
Ca(Gly)2(aq)	1.598e-274	3.007e-269	1.0000	-273.7963
Butanoate	6.496e-276	5.656e-271	0.9312	-275.2183
Ba(Gly)2(aq)	4.091e-277	1.167e-271	1.0000	-276.3881
Ca(But)+	8.547e-279	1.087e-273	0.9312	-278.0991
Na(But)(aq)	7.187e-279	7.910e-274	1.0000	-278.1434

Butanoic_acid(aq	3.867e-279	3.406e-274	1.0000	-278.4126
K(But)(aq)	3.769e-279	4.755e-274	1.0000	-278.4238
Mg(But)+	3.519e-279	3.919e-274	0.9312	-278.4845
Mn(But)+	3.015e-280	4.281e-275	0.9312	-279.5517
Cu(But)+	1.444e-280	2.175e-275	0.9312	-279.8713
Ba(But)+	3.558e-282	7.983e-277	0.9312	-281.4797
Glutarate	3.533e-282	4.596e-277	0.7511	-281.5761
Cd(But)+	1.508e-282	3.009e-277	0.9312	-281.8524
Threonine(aq)	8.315e-285	9.902e-280	1.0000	-284.0801
H-Glutarate	7.403e-285	9.703e-280	0.9312	-284.1615
Ethylacetate(aq)	5.529e-288	4.870e-283	1.0000	-287.2574
Glutaric_acid(aq	1.518e-288	2.006e-283	1.0000	-287.8186
S5O6--	8.593e-291	2.202e-285	0.7511	-290.1902
1-Propanamine(aq	8.385e-295	4.955e-290	1.0000	-294.0765
a-Aminobutyric_a	8.241e-298	8.495e-293	1.0000	-297.0840
Glutamic_acid(aq	5.243e-307	7.712e-302	1.0000	-300.0000
UO2(SCN)2(aq)	7.148e-314	2.760e-308	1.0000	-300.0000
Butanal(aq)	3.779e-314	2.724e-309	1.0000	-300.0000
Cd(CH3COO)3-	0.0000	0.0000	0.9312	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9312	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9312	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9312	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9312	-300.0000
p-Toluate	0.0000	0.0000	0.9312	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9312	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9312	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butyne(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9312	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9312	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9312	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9312	-300.0000
H-Sebacate	0.0000	0.0000	0.9312	-300.0000
H-Pimelate	0.0000	0.0000	0.9312	-300.0000

Adipate	0.0000	0.0000	0.7511	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
U(SCN)2++	0.0000	0.0000	0.7533	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9312	-300.0000
H-Adipate	0.0000	0.0000	0.9312	-300.0000
Suberate	0.0000	0.0000	0.7511	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7511	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Sb2S4--	0.0000	0.0000	0.7511	-300.0000
Glutamine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7511	-300.0000
S4--	0.0000	0.0000	0.7511	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butene(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7511	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Pentanoate	0.0000	0.0000	0.9312	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9312	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9312	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9312	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9312	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9338	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9312	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9312	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxypentano	0.0000	0.0000	0.9312	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9312	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9312	-300.0000
Na(But)2-	0.0000	0.0000	0.9312	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9312	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000

1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butanol(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9312	-300.0000
Cu(CH3COO)3-	0.0000	0.0000	0.9312	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9312	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9312	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(CH3COO)3-	0.0000	0.0000	0.9312	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9312	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9312	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9312	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9312	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9312	-300.0000
K(Prop)2-	0.0000	0.0000	0.9312	-300.0000
K(Pent)2-	0.0000	0.0000	0.9312	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9312	-300.0000
Azelate	0.0000	0.0000	0.7511	-300.0000
o-Phthalate	0.0000	0.0000	0.7511	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Fluorapatite	6.0547s/sat	UO2SO4:3H2O	-16.9565
Witherite	1.9760s/sat	CdF2	-17.1899
Malachite	1.3998s/sat	UO2F2:3H2O	-17.4547

Brochantite	1.3884s/sat	Larnite	-17.4812
Tenorite	1.3681s/sat	MnCl2:2H2O	-17.6270
Bixbyite	0.5891s/sat	UO2F2	-17.6467
Talc	0.4616s/sat	Autunite-H	-18.0475
Quartz	0.4527s/sat	CuCl2	-18.6326
Dolomite	0.4114s/sat	Na2UO4(alpha)	-19.1563
Dolomite-ord	0.4114s/sat	MnCl2:H2O	-19.2114
Barite	0.3110s/sat	MgCl2:4H2O	-19.2714
Tridymite	0.2556s/sat	UO2SO4	-20.4433
Chalcedony	0.1776s/sat	Lime	-20.4701
Cristobalite(alp	-0.1073	UO2.3333(beta)	-21.2558
Ice	-0.1228	Rankinite	-22.1481
Calcite	-0.1612	Scacchite	-22.4912
Rhodochrosite	-0.2670	UO2(NO3)2:6H2O	-23.1265
Hausmannite	-0.2981	Tobermorite-14A	-23.2499
Aragonite	-0.3057	Hydrophilite	-23.3662
Coesite	-0.3682	K2UO4	-23.4915
Cristobalite(bet	-0.5628	Ningyoite	-23.6153
Dioptase	-0.6041	UOFOH:.5H2O	-23.9159
SiO2(am)	-0.8683	UO2Cl	-24.1663
Monohydrocalcite	-0.9842	UOFOH	-24.3863
Pyrolusite	-1.0428	UO2(NO3)2:3H2O	-24.5959
Magnesite	-1.0819	MgCl2:2H2O	-24.8075
Dolomite-dis	-1.1638	Tobermorite-11A	-25.1512
Atacamite	-1.8371	Antigorite	-25.2114
Gypsum	-2.4365	UO2(NO3)2:2H2O	-25.8634
CaUO4	-2.4404	Merwinite	-26.9112
Chrysotile	-2.4423	Foshagite	-27.3448
Anhydrite	-2.6524	UOF2:H2O	-27.5295
Enstatite	-3.0003	UOF2	-28.1118
Rhodonite	-3.0880	MgCl2:H2O	-28.2176
Hydroxylapatite	-3.1069	UO2(PO3)2	-28.4008
Bassanite	-3.2986	(UO2)3(PO4)2	-28.4084
Fluorite	-3.3649	UO2Cl2:3H2O	-28.4579
CaSO4:0.5H2O(bet	-3.4720	Tobermorite-9A	-28.7244
CdSiO3	-3.4787	(UO2)2P2O7	-28.8730
Sb2O3	-3.4801	Ba2SiO4	-29.2578
Azurite	-3.5906	UO2(NO3)2:H2O	-29.5024
Schoepite	-3.7199	Afwillite	-30.3236
UO3:2H2O	-3.7226	UO2Cl2:H2O	-31.2100
Diopside	-3.8032	U(HPO4)2:4H2O	-32.9886
UO2(OH)2(beta)	-3.8496	UP2O7	-32.9933
UO3:.9H2O(alpha)	-3.9137	UO2(NO3)2	-33.0179
Schoepite-dehy(.	-3.9178	KMgCl3:2H2O	-33.1710
Sepiolite	-3.9650	Chloromagnesite	-34.0577
Schoepite-dehy(.	-3.9954	UO2Cl2	-35.1379
Schoepite-dehy(1	-4.0043	As2O5	-35.3509
Whitlockite	-4.0640	UO2SO3	-36.6375
Nesquehonite	-4.0952	Cd	-36.7582
Brucite	-4.4148	(UO2)2As2O7	-38.6912
Sellaite	-4.5085	BaO	-38.7016
Wollastonite	-4.9897	UF4:2.5H2O	-38.7406
Cuprite	-4.9946	UO2(AsO3)2	-39.0729
Huntite	-5.0083	(UO2)3(AsO4)2	-39.1677
Okenite	-5.1017	Xonotlite	-39.3890
Mn(OH)2(am)	-5.1163	BaSiF6	-39.5524
Schoepite-dehy(.	-5.1268	Hatrurite	-40.3493
Pseudowollastoni	-5.2362	KMgCl3	-40.5932
Tremolite	-5.2897	Ba2U2O7	-42.7918
UO2CO3	-5.5224	UF4	-43.0148
Rutherfordine	-5.5432	U(SO4)2:8H2O	-46.6820
Schoepite-dehy(.	-5.6540	U(SO4)2:4H2O	-47.7949
Nahcolite	-5.6583	U(SO4)2	-47.8773

Niter	-5.9668	Arsenolite	-49.2152
Cd(OH)2	-6.1448	Claudetite	-49.2792
Tephroite	-6.2428	U(CO3)2	-49.7485
Artinite	-6.4989	UOCl2	-49.8935
UO3(gamma)	-6.6713	C	-50.1332
Sanbornite	-7.0316	UClF3	-53.8119
UO3(beta)	-7.2827	Na3UO4	-54.5471
BaUO4	-7.5191	Na4SiO4	-54.9700
Monteponite	-7.5433	UOF4	-55.7630
UO3(alpha)	-7.6191	U5O12Cl	-56.4523
Forsterite	-7.6808	Na	-56.8340
Chalcanthite	-7.6936	Na2O	-58.2460
Manganosite	-7.7941	As	-58.6301
Cd(OH)Cl	-7.7945	(UO2)2Cl3	-60.4397
Sylvite	-7.9988	K	-60.7147
Arcanite	-8.0764	Mn	-60.8400
Mirabilite	-8.1227	UOCl3	-61.4804
Halite	-8.5256	UF5(beta)	-64.6562
UO2HPO4:4H2O	-8.5947	UF3	-64.7234
Nantokite	-8.6021	UF5(alpha)	-65.0101
Gyrolite	-8.8246	Ba3UO6	-65.1802
Monticellite	-8.9497	UCl2F2	-66.9242
Thenardite	-9.1377	UOCl	-67.7537
UO2FOH:2H2O	-9.1696	U2O3F6	-73.5592
Periclase	-9.5485	S	-75.4469
UO2FOH:H2O	-9.5695	K2O	-75.5429
Nitrobarite	-9.7579	Covellite	-76.0017
Mg1.25SO4(OH)0.5	-9.8048	UCl3F	-79.8588
Cu	-9.9309	Na6Si2O7	-79.8729
CdSO4:2.667H2O	-9.9510	Chalcocite	-79.9940
UO2FOH	-10.0350	CdS	-84.3946
MgUO4	-10.0995	CdCl2(NH3)2	-90.5493
CdSO4:H2O	-10.1305	UCl4	-90.6249
BaU2O7	-10.1786	U(SO3)2	-91.0717
Natron	-10.2680	UCl3	-94.3816
Portlandite	-10.2868	UF6	-94.9222
Na2U2O7	-10.4832	Alabandite	-97.5044
Na2CO3:7H2O	-10.6626	As4O6(mono)	-98.0748
Mg1.5SO4(OH)	-10.8309	U3O5F8	-98.2947
UO2.25	-11.6565	As4O6(cubi)	-98.3116
UO2.25(beta)	-11.7195	Mg	-99.3120
CdSO4	-11.7269	U2F9	-104.4943
Thermonatrite	-11.8093	UCl5	-110.4951
MnSO4	-11.8901	U2O2Cl5	-112.5860
Anthophyllite	-11.8998	UN1.73(alpha)	-113.6605
Saleeite	-11.9581	BaS	-114.9882
Na2CO3	-12.0582	UN1.59(alpha)	-116.3777
UO2SO4:H2O	-12.3420	Ca	-116.3870
MgSO4	-12.4471	Ba	-120.5856
UO2ClOH:2H2O	-13.1328	P	-124.7877
Chalcocyanite	-13.4296	Si	-128.8429
Ca3(AsO4)2	-13.5119	UCl6	-129.1989
UO2.6667	-13.7527	UN	-129.2412
Uranocircite	-13.8988	CdCl2(NH3)4	-175.8183
Torbernite	-14.0373	U	-175.9735
Hydromagnesite	-14.1553	U4F17	-189.6476
BaCl2:2H2O	-14.3883	UAs	-192.3358
CdCl2:H2O	-14.5041	US	-194.3875
Ba(OH)2:8H2O	-14.8546	UC	-208.5342
Ba2Si3O8	-14.8950	UH3(beta)	-209.0686
BaCl2:H2O	-15.0365	US1.9	-228.7876
(UO2)3(PO4)2:4H2	-15.1445	US2	-234.5942
Natrosilite	-15.4595	UAs2	-248.3141

Uraninite	-15.4773	UP	-253.4965
CdCl2	-15.5579	UC1.94(alpha)	-257.7055
Hillebrandite	-15.7749	CdCl2(NH3)6	-261.1641
Coffinite	-15.8395	Stibnite	-283.4737
UPO5	-15.8768	US3	-306.8374
Akermanite	-15.9534	Orpiment	-313.6382
Na2SiO3	-16.0157	UP2	-373.1818
MgOHCl	-16.0301	U2S3	-421.9494
NaUO3	-16.0940	o-Phthalic_acid	-433.8985
Dicalcium_silica	-16.1636	U2C3	-468.7190
MnCl2:4H2O	-16.3198	U3As4	-633.5510
BaCl2	-16.4863	U3S5	-651.9311
UO2SO4:3.5H2O	-16.8613	U3P4	-880.1697
UO2SO4:2.5H2O	-16.8715		

Gases	fugacity	log fug.
N2(g)	0.1662	-0.779
H2O(g)	0.02011	-1.697
CO2(g)	0.0008846	-3.053
NO2(g)	7.243e-014	-13.140
HF(g)	5.240e-015	-14.281
HCl(g)	3.365e-019	-18.473
O2(g)	1.009e-023	-22.996
NO(g)	5.500e-028	-27.260
H2(g)	1.689e-031	-30.772
CO(g)	4.755e-038	-37.323
Cl2(g)	9.527e-041	-40.021
SiF4(g)	2.527e-041	-40.597
NH3(g)	2.813e-044	-43.551
SO2(g)	7.821e-046	-45.107
Cd(g)	2.779e-051	-50.556
UO2F2(g)	5.011e-061	-60.300
Cu(g)	1.229e-063	-62.910
Na(g)	2.693e-071	-70.570
UO3(g)	1.052e-071	-70.978
K(g)	3.030e-072	-71.519
UO2Cl2(g)	2.269e-072	-71.644
UOF4(g)	1.316e-076	-75.881
UF5(g)	2.274e-085	-84.643
UF4(g)	2.519e-088	-87.599
F2(g)	2.346e-096	-95.630
UF6(g)	1.348e-096	-95.870
H2S(g)	5.150e-101	-100.288
CH4(g)	2.483e-103	-102.605
UO2(g)	3.223e-114	-113.492
UCl4(g)	2.814e-116	-115.551
Mg(g)	4.379e-120	-119.359
UCl5(g)	7.856e-129	-128.105
UF3(g)	3.223e-133	-132.492
UCl6(g)	5.153e-136	-135.288
UCl3(g)	1.483e-141	-140.829
Ca(g)	9.505e-143	-142.022
U2F10(g)	1.852e-144	-143.732
S2(g)	7.788e-166	-165.109
C(g)	3.193e-170	-169.496
C2H4(g)	1.329e-174	-173.876
UF2(g)	6.948e-175	-174.158
UCl2(g)	2.472e-184	-183.607
UO(g)	1.330e-188	-187.876
Si(g)	1.026e-201	-200.989
UF(g)	4.812e-210	-209.318
U2Cl8(g)	3.761e-221	-220.425

UCl(g)	1.030e-224	-223.987
U2Cl10(g)	3.978e-230	-229.400
U(g)	1.333e-263	-262.875

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ba++	7.96e-007	7.96e-007	0.109			
Ca++	0.000541	0.000541	21.7			
Cd++	8.50e-009	8.50e-009	0.000955			
Cl-	0.000111	0.000111	3.94			
Cu++	2.01e-007	2.01e-007	0.0128			
F-	1.04e-005	1.04e-005	0.197			
H+	1.76e-005	1.76e-005	0.0177			
H2AsO4-	6.57e-008	6.57e-008	0.00926			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00160	0.00160	97.5			
HPO4--	1.91e-007	1.91e-007	0.0183			
K+	0.000655	0.000655	25.6			
Mg++	0.000203	0.000203	4.92			
Mn++	3.75e-006	3.75e-006	0.206			
NH3(aq)	0.000234	0.000234	3.98			
NO3-	0.000956	0.000956	59.3			
Na+	0.00116	0.00116	26.6			
O2(aq)	0.000175	0.000175	5.61			
SO4--	0.000431	0.000431	41.3			
Sb(OH)3(aq)	5.01e-007	5.01e-007	0.0866			
SiO2(aq)	0.000221	0.000221	13.3			
UO2++	1.20e-008	1.20e-008	0.00324			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Antimony	5.015e-007	5.015e-007	0.06104		
Arsenic	6.572e-008	6.572e-008	0.004922		
Barium	7.960e-007	7.960e-007	0.1093		
Cadmium	8.497e-009	8.497e-009	0.0009549		
Calcium	0.0005406	0.0005406	21.66		
Carbon	0.001598	0.001598	19.18		
Chlorine	0.0001111	0.0001111	3.938		
Copper	2.015e-007	2.015e-007	0.01280		
Fluorine	1.037e-005	1.037e-005	0.1969		
Hydrogen	111.0	111.0	1.119e+005		
Magnesium	0.0002026	0.0002026	4.922		
Manganese	3.746e-006	3.746e-006	0.2057		
Nitrogen	0.001190	0.001190	16.66		
Oxygen	55.52	55.52	8.880e+005		
Phosphorus	1.908e-007	1.908e-007	0.005907		
Potassium	0.0006548	0.0006548	25.60		
Silicon	0.0002213	0.0002213	6.212		
Sodium	0.001157	0.001157	26.58		
Sulfur	0.0004305	0.0004305	13.80		
Uranium	1.200e-008	1.200e-008	0.002855		

```
Temperature =  15.1 C    Pressure =  1.013 bars
pH =  8.000              log fO2 =  -30.606
Eh =   0.3360 volts      pe =   5.8750
Ionic strength      =    0.004609
Charge imbalance    =   -0.000231 eq/kg (-6.639% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000317 kg
Solution density    =    1.020    g/cm3
Chlorinity          =    0.000111 molal
Dissolved solids    =         316 mg/kg sol'n
Hardness            =       71.62 mg/kg sol'n as CaCO3
  carbonate         =       71.62 mg/kg sol'n as CaCO3
  non-carbonate     =        0.00 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       79.64 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3360	5.8750
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5400	9.4422

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001562	95.26	0.9308	-2.8376
Na+	0.001277	29.35	0.9308	-2.9250
NO3-	0.001015	62.94	0.9294	-3.0252
K+	0.0007008	27.39	0.9294	-3.1862
Ca++	0.0004890	19.59	0.7581	-3.4309
SO4--	0.0004331	41.60	0.7495	-3.4886
SiO2(aq)	0.0002135	12.82	1.0000	-3.6706
Mg++	0.0001891	4.595	0.7661	-3.8390
N2(aq)	0.0001632	4.570	1.0000	-3.7873
Cl-	0.0001106	3.921	0.9294	-3.9879
CO2(aq)	3.861e-005	1.699	1.0000	-4.4133
CaSO4(aq)	1.482e-005	2.017	1.0000	-4.8291
F-	1.027e-005	0.1951	0.9301	-5.0198
MgSO4(aq)	9.432e-006	1.135	1.0000	-5.0254
Mn++	7.785e-006	0.4275	0.7581	-5.2290
CO3--	7.115e-006	0.4269	0.7517	-5.2717
CaHCO3+	6.612e-006	0.6682	0.9308	-5.2109
AlO2-	6.258e-006	0.3690	0.9308	-5.2347
CaCO3(aq)	3.470e-006	0.3472	1.0000	-5.4597
NaHCO3(aq)	2.996e-006	0.2516	1.0000	-5.5235
MgHCO3+	2.514e-006	0.2144	0.9308	-5.6308
HPO4--	2.303e-006	0.2210	0.7495	-5.7629
HSiO3-	1.888e-006	0.1455	0.9308	-5.7553
KSO4-	1.712e-006	0.2313	0.9308	-5.7977
Fe++	8.754e-007	0.04887	0.7581	-6.1781
Ba++	8.345e-007	0.1146	0.7539	-6.2013
MgCO3(aq)	6.715e-007	0.05660	1.0000	-6.1730
OH-	4.830e-007	0.008213	0.9301	-6.3475
Sb(OH)3(aq)	4.028e-007	0.06957	1.0000	-6.3949
MnSO4(aq)	3.918e-007	0.05914	1.0000	-6.4070
Cu++	3.703e-007	0.02352	0.7581	-6.5517
H2PO4-	3.255e-007	0.03156	0.9308	-6.5186
HAlO2(aq)	2.808e-007	0.01684	1.0000	-6.5516
NaHSiO3(aq)	1.160e-007	0.01161	1.0000	-6.9354
MgF+	3.398e-008	0.001471	0.9308	-7.4999

NaCO3-	2.955e-008	0.002452	0.9308	-7.5605
HAsO4--	2.494e-008	0.003488	0.7495	-7.7283
NaCl(aq)	1.937e-008	0.001132	1.0000	-7.7129
Pb++	1.795e-008	0.003718	0.7517	-7.8699
CaF+	1.758e-008	0.001038	0.9308	-7.7863
MgCl+	1.242e-008	0.0007418	0.9308	-7.9371
Cd++	1.099e-008	0.001235	0.7539	-8.0816
H+	1.067e-008	1.075e-005	0.9370	-8.0000
CaCl+	8.286e-009	0.0006256	0.9308	-8.1128
UO2(CO3)3----	7.593e-009	0.003416	0.3152	-8.6210
UO2(CO3)2--	5.949e-009	0.002320	0.7495	-8.3508
Al(OH)2+	3.951e-009	0.0002409	0.9308	-8.4344
FeCO3+	2.748e-009	0.0003183	0.9308	-8.5921
KCl(aq)	1.766e-009	0.0001316	1.0000	-8.7530
H2AsO4-	1.240e-009	0.0001747	0.9308	-8.9377
BaCO3(aq)	1.208e-009	0.0002383	1.0000	-8.9180
NaAlO2(aq)	1.129e-009	9.248e-005	1.0000	-8.9475
NaF(aq)	1.054e-009	4.425e-005	1.0000	-8.9771
MnCl+	1.051e-009	9.494e-005	0.9308	-9.0097
HSO4-	2.609e-010	2.531e-005	0.9308	-9.6148
Cu+	1.529e-010	9.710e-006	0.9308	-9.8469
PO4---	1.247e-010	1.184e-005	0.5225	-10.1861
HF(aq)	1.185e-010	2.371e-006	1.0000	-9.9261
NaOH(aq)	9.068e-011	3.626e-006	1.0000	-10.0425
UO2CO3(aq)	5.659e-011	1.867e-005	1.0000	-10.2473
FeCl+	5.028e-011	4.589e-006	0.9308	-10.3298
AlOH++	4.175e-011	1.836e-006	0.7517	-10.5033
PbCl+	3.935e-011	9.545e-006	0.9308	-10.4362
Sb(OH)4-	2.427e-011	4.605e-006	0.9308	-10.6460
BaCl+	1.940e-011	3.351e-006	0.9308	-10.7434
AsO4---	6.682e-012	9.280e-007	0.5225	-11.4570
BaF+	3.847e-012	6.011e-007	0.9308	-11.4461
CdSO4(aq)	2.716e-012	5.661e-007	1.0000	-11.5660
MgP2O7--	1.033e-012	2.047e-007	0.7495	-12.1111
CaCl2(aq)	1.023e-012	1.135e-007	1.0000	-11.9900
UO2OH+	8.362e-013	2.400e-007	0.9308	-12.1088
Sb(OH)2F(aq)	6.436e-013	1.124e-007	1.0000	-12.1914
H3PO4(aq)	4.068e-013	3.985e-008	1.0000	-12.3907
HNO3(aq)	3.793e-013	2.390e-008	1.0000	-12.4210
HCl(aq)	2.150e-013	7.837e-009	1.0000	-12.6676
Sb(OH)2+	1.958e-013	3.048e-008	0.9308	-12.7394
CdCl2(aq)	1.794e-013	3.287e-008	1.0000	-12.7463
Al+++	1.009e-013	2.722e-009	0.5549	-13.2519
Fe+++	6.235e-014	3.481e-009	0.5549	-13.4610
PbCl2(aq)	1.335e-014	3.712e-009	1.0000	-13.8745
HP2O7---	1.211e-014	2.118e-009	0.5225	-14.1988
KHSO4(aq)	9.668e-015	1.316e-009	1.0000	-14.0147
FeF++	5.158e-015	3.859e-010	0.7517	-14.4115
UO2++	3.086e-015	8.330e-010	0.7517	-14.6345
UO2F+	2.646e-015	7.646e-010	0.9308	-14.6086
H3AsO4(aq)	1.842e-015	2.614e-010	1.0000	-14.7346
P2O7----	1.174e-015	2.042e-010	0.3152	-15.4315
FeSO4+	7.451e-016	1.131e-010	0.9308	-15.1590
UO2SO4(aq)	6.905e-016	2.527e-010	1.0000	-15.1609
FeF2+	5.762e-016	5.406e-011	0.9308	-15.2706
H2P2O7--	3.759e-016	6.613e-011	0.7495	-15.5501
HF2-	2.637e-016	1.028e-011	0.9308	-15.6100
KP2O7---	8.970e-017	1.910e-011	0.5225	-16.3291
UO2F2(aq)	7.348e-017	2.263e-011	1.0000	-16.1339
FeCl2(aq)	2.388e-017	3.026e-012	1.0000	-16.6219
CdCl3-	4.041e-018	8.838e-013	0.9308	-17.4247
UO2(SO4)2--	2.003e-018	9.253e-013	0.7495	-17.8236
PbCl3-	7.228e-019	2.266e-013	0.9308	-18.1721

FeCl++	4.587e-019	4.187e-014	0.7517	-18.4624
UO2Cl+	3.332e-019	1.018e-013	0.9308	-18.5085
UO2F3-	1.304e-019	4.261e-014	0.9308	-18.9160
(UO2)2(OH)2++	9.619e-020	5.520e-014	0.7517	-19.1408
UO2+	8.349e-020	2.254e-014	0.9308	-19.1095
(UO2)3(CO3)6(6-)	9.620e-021	1.125e-014	0.0744	-21.1451
(UO2)3(OH)5+	8.489e-021	7.597e-015	0.9308	-20.1023
H3P2O7-	6.759e-022	1.196e-016	0.9308	-21.2013
U(OH)4(aq)	1.899e-022	5.811e-017	1.0000	-21.7214
PbCl4--	7.486e-023	2.612e-017	0.7495	-22.2509
HAsO2(aq)	3.408e-023	3.677e-018	1.0000	-22.4674
As(OH)3(aq)	2.977e-023	3.748e-018	1.0000	-22.5262
UO2F4--	9.237e-024	3.195e-018	0.7495	-23.1597
UO2Cl2(aq)	1.510e-024	5.147e-019	1.0000	-23.8210
AsO2-	1.350e-024	1.443e-019	0.9308	-23.9007
H2AsO3-	1.345e-024	1.680e-019	0.9308	-23.9025
FeCl4--	1.030e-024	2.036e-019	0.7495	-24.1122
Mn+++	1.026e-025	5.633e-021	0.5293	-25.2653
AsO2OH--	1.083e-027	1.342e-022	0.7495	-27.0904
H4P2O7(aq)	1.748e-028	3.111e-023	1.0000	-27.7573
Formate	3.386e-031	1.524e-026	0.9301	-30.5019
NO2-	2.318e-031	1.066e-026	0.9294	-30.6668
H2(aq)	8.716e-032	1.756e-028	1.0000	-31.0597
Ca(For)+	3.631e-033	3.089e-028	0.9308	-32.4711
Mg(For)+	1.616e-033	1.120e-028	0.9308	-32.8228
Na(For)(aq)	4.370e-034	2.971e-029	1.0000	-33.3595
O2(aq)	3.821e-034	1.222e-029	1.0000	-33.4178
K(For)(aq)	2.144e-034	1.803e-029	1.0000	-33.6688
Mn(For)+	1.134e-034	1.133e-029	0.9308	-33.9766
Formic_acid(aq)	1.828e-035	8.409e-031	1.0000	-34.7381
Fe(For)+	1.821e-035	1.836e-030	0.9308	-34.7708
SO3--	1.248e-035	9.993e-031	0.7517	-35.0276
Cu(For)+	1.086e-035	1.179e-030	0.9308	-34.9952
Ba(For)+	4.930e-036	8.986e-031	0.9308	-35.3384
HNO2(aq)	4.705e-036	2.211e-031	1.0000	-35.3275
NH4+	2.772e-036	5.000e-032	0.9286	-35.5893
HSO3-	1.488e-036	1.206e-031	0.9308	-35.8585
ClO-	6.622e-037	3.406e-032	0.9308	-36.2102
Pb(For)+	3.523e-037	8.884e-032	0.9308	-36.4842
Cd(For)+	2.221e-037	3.495e-032	0.9308	-36.6847
NH3(aq)	7.163e-038	1.220e-033	1.0000	-37.1449
CO(aq)	3.323e-038	9.306e-034	1.0000	-37.4784
HO2-	1.593e-038	5.257e-034	0.9308	-37.8289
Oxalate	1.237e-038	1.089e-033	0.7495	-38.0328
SiF6--	1.314e-039	1.867e-034	0.7495	-39.0065
U(CO3)5(6-)	1.543e-040	8.301e-035	0.0744	-40.9398
MnO4--	1.310e-040	1.558e-035	0.7495	-40.0078
UOH+++	5.651e-042	1.441e-036	0.5293	-41.5242
H-Oxalate	1.691e-042	1.505e-037	0.9308	-41.8030
SO2(aq)	8.219e-043	5.264e-038	1.0000	-42.0852
UF3+	6.022e-043	1.776e-037	0.9308	-42.2514
UF2++	3.806e-043	1.050e-037	0.7517	-42.5435
UF4(aq)	5.288e-044	1.660e-038	1.0000	-43.2767
MnO4-	9.258e-045	1.101e-039	0.9301	-44.0650
UF+++	7.063e-045	1.815e-039	0.5293	-44.4273
U(SO4)2(aq)	3.189e-046	1.371e-040	1.0000	-45.4964
USO4++	2.581e-046	8.621e-041	0.7517	-45.7121
HSO5-	5.194e-047	5.871e-042	0.9308	-46.3157
U++++	6.283e-049	1.495e-043	0.3262	-48.6883
Oxalic_acid(aq)	2.873e-049	2.585e-044	1.0000	-48.5417
UCl+++	2.676e-051	7.316e-046	0.5293	-50.8488
S2O6--	2.015e-060	3.226e-055	0.7495	-59.8209
ClO2-	6.566e-062	4.428e-057	0.9308	-61.2139

Ca(For)2(aq)	8.903e-063	1.158e-057	1.0000	-62.0504
Mg(For)2(aq)	4.586e-063	5.241e-058	1.0000	-62.3386
S2O8--	6.074e-064	1.167e-058	0.7495	-63.3418
Mn(For)2(aq)	4.861e-064	7.045e-059	1.0000	-63.3133
Fe(For)2(aq)	1.044e-064	1.523e-059	1.0000	-63.9812
Na(For)2-	9.626e-065	1.088e-059	0.9308	-64.0477
Cu(For)2(aq)	8.379e-065	1.286e-059	1.0000	-64.0768
U+++	4.174e-065	9.933e-060	0.5293	-64.6557
K(For)2-	4.131e-065	5.333e-060	0.9308	-64.4151
Ba(For)2(aq)	9.714e-066	2.208e-060	1.0000	-65.0126
Cd(For)2(aq)	8.323e-066	1.685e-060	1.0000	-65.0797
Pb(For)2(aq)	1.865e-066	5.541e-061	1.0000	-65.7294
Formaldehyde(aq)	6.149e-068	1.846e-063	1.0000	-67.2112
N3-	2.171e-070	9.118e-066	0.9308	-69.6946
ClO3-	1.396e-072	1.164e-067	0.9301	-71.8867
HN3(aq)	1.301e-073	5.597e-069	1.0000	-72.8857
Cu(NH3)2++	1.016e-073	9.910e-069	0.7517	-73.1172
S2O5--	4.029e-077	5.806e-072	0.7495	-76.5200
Cd(NH3)2++	6.249e-078	9.150e-073	0.7517	-77.3281
Urea(aq)	5.440e-079	3.266e-074	1.0000	-78.2644
HCN(aq)	1.283e-080	3.465e-076	1.0000	-79.8919
CN-	4.166e-082	1.084e-077	0.9294	-81.4121
Methanol(aq)	1.225e-083	3.923e-079	1.0000	-82.9120
UO2ClO3+	1.068e-086	3.774e-081	0.9308	-86.0026
ClO4-	1.251e-087	1.244e-082	0.9301	-86.9342
HS-	6.639e-089	2.195e-084	0.9301	-88.2094
Glycolate	9.678e-090	7.260e-085	0.9308	-89.0454
H2S(aq)	8.568e-090	2.919e-085	1.0000	-89.0671
Ca(Glyc)+	1.778e-091	2.046e-086	0.9308	-90.7812
Mg(Glyc)+	3.260e-092	3.238e-087	0.9308	-91.5179
Na(Glyc)(aq)	1.267e-092	1.242e-087	1.0000	-91.8971
K(Glyc)(aq)	6.217e-093	7.094e-088	1.0000	-92.2064
Cu(Glyc)+	2.756e-093	3.819e-088	0.9308	-92.5908
Mn(Glyc)+	2.482e-093	3.226e-088	0.9308	-92.6363
Fe(Glyc)+	1.215e-093	1.590e-088	0.9308	-92.9467
Glycolic_acid(aq	6.317e-094	4.803e-089	1.0000	-93.1995
S--	4.783e-094	1.533e-089	0.7539	-93.4430
Methane(aq)	4.517e-094	7.244e-090	1.0000	-93.3452
Ba(Glyc)+	6.307e-095	1.339e-089	0.9308	-94.2314
Pb(Glyc)+	2.716e-095	7.664e-090	0.9308	-94.5972
S2O3--	1.960e-095	2.198e-090	0.7495	-94.8328
Cd(Glyc)+	6.918e-096	1.296e-090	0.9308	-95.1912
S2O4--	1.716e-096	2.198e-091	0.7539	-95.8882
Acetate	1.562e-099	9.221e-095	0.9314	-98.8371
MgCH3COO+	5.135e-102	4.279e-097	0.9308	-101.3206
CaCH3COO+	5.122e-102	5.076e-097	0.9308	-101.3217
NaCH3COO(aq)	1.421e-102	1.165e-097	1.0000	-101.8474
Acetic_acid(aq)	8.388e-103	5.035e-098	1.0000	-102.0764
KCH3COO(aq)	4.980e-103	4.886e-098	1.0000	-102.3027
MnCH3COO+	1.680e-103	1.914e-098	0.9308	-102.8058
CuCH3COO+	9.271e-104	1.136e-098	0.9308	-103.0640
FeCH3COO+	2.245e-104	2.579e-099	0.9308	-103.6799
BaCH3COO+	9.090e-105	1.784e-099	0.9308	-104.0726
PbCH3COO+	5.527e-105	1.471e-099	0.9308	-104.2887
CdCH3COO+	1.282e-105	2.197e-100	0.9308	-104.9234
Cu(NH3)3++	6.515e-108	7.466e-103	0.7517	-107.3100
Malonate	2.561e-108	2.613e-103	0.7495	-107.7167
CuCH3COO(aq)	4.888e-109	5.990e-104	1.0000	-108.3109
AlCH3COO++	1.755e-110	1.510e-105	0.7517	-109.8796
H-Malonate	9.791e-111	1.009e-105	0.9308	-110.0403
AsH3(aq)	1.147e-111	8.934e-107	1.0000	-110.9406
Malonic_acid(aq)	6.601e-116	6.867e-111	1.0000	-115.1804
Methanamine(aq)	2.905e-118	9.021e-114	1.0000	-117.5368

Cu(Gly)+	2.658e-121	3.656e-116	0.9308	-120.6067
Glycine(aq)	1.796e-121	1.348e-116	1.0000	-120.7457
Mg(Gly)+	8.118e-124	7.983e-119	0.9308	-123.1217
Mn(Gly)+	5.129e-125	6.614e-120	0.9308	-124.3212
Fe(Gly)+	2.627e-125	3.411e-120	0.9308	-124.6117
Ca(Gly)+	1.225e-125	1.398e-120	0.9308	-124.9430
Pb(Gly)+	7.272e-126	2.045e-120	0.9308	-125.1695
Cd(Gly)+	8.119e-127	1.514e-121	0.9308	-126.1216
S3O6--	4.043e-128	7.768e-123	0.7495	-127.5185
Ba(Gly)+	2.613e-128	5.522e-123	0.9308	-127.6140
SCN-	6.456e-134	3.749e-129	0.9301	-133.2215
Acetaldehyde(aq)	4.268e-134	1.879e-129	1.0000	-133.3698
NH4CH3COO(aq)	6.128e-135	4.722e-130	1.0000	-134.2127
Acetamide(aq)	5.361e-135	3.166e-130	1.0000	-134.2707
UO2SCN+	3.699e-147	1.213e-141	0.9308	-146.4631
Cd(NH3)4++	1.110e-149	2.004e-144	0.7517	-149.0786
Ethanol(aq)	2.189e-154	1.008e-149	1.0000	-153.6598
Ethyne(aq)	6.190e-156	1.611e-151	1.0000	-155.2083
Ethylene(aq)	4.523e-159	1.268e-154	1.0000	-158.3446
Lactate	1.915e-160	1.705e-155	0.9308	-159.7491
Ca(Lac)+	2.072e-162	2.675e-157	0.9308	-161.7148
Mg(Lac)+	6.690e-163	7.582e-158	0.9308	-162.2057
Na(Lac)(aq)	2.546e-163	2.852e-158	1.0000	-162.5941
K(Lac)(aq)	1.249e-163	1.601e-158	1.0000	-162.9034
Mn(Lac)+	3.475e-164	5.003e-159	0.9308	-163.4902
Cu(Lac)+	2.519e-164	3.844e-159	0.9308	-163.6299
Fe(Lac)+	2.119e-164	3.070e-159	0.9308	-163.7050
Lactic_acid(aq)	1.320e-164	1.189e-159	1.0000	-163.8793
Ba(Lac)+	5.255e-166	1.189e-160	0.9308	-165.3106
Pb(Lac)+	5.197e-166	1.539e-160	0.9308	-165.3154
Cd(Lac)+	9.269e-167	1.867e-161	0.9308	-166.0641
Ethane(aq)	4.202e-169	1.263e-164	1.0000	-168.3766
Propanoate	2.128e-172	1.555e-167	0.9308	-171.7031
Ca(Prop)+	3.885e-175	4.394e-170	0.9308	-174.4418
Na(Prop)(aq)	2.790e-175	2.679e-170	1.0000	-174.5544
Mg(Prop)+	1.900e-175	1.849e-170	0.9308	-174.7525
Propanoic_acid(a	1.540e-175	1.141e-170	1.0000	-174.8123
K(Prop)(aq)	1.369e-175	1.535e-170	1.0000	-174.8636
Mn(Prop)+	2.662e-176	3.406e-171	0.9308	-175.6060
Cu(Prop)+	1.230e-176	1.680e-171	0.9308	-175.9412
Fe(Prop)+	6.887e-177	8.876e-172	0.9308	-176.1931
Pb(Prop)+	6.573e-178	1.842e-172	0.9308	-177.2134
Ba(Prop)+	1.680e-178	3.534e-173	0.9308	-177.8058
Cd(Prop)+	1.597e-178	2.961e-173	0.9308	-177.8279
USCN+++	3.252e-179	9.628e-174	0.5293	-178.7641
Ca(Glyc)2(aq)	3.020e-179	5.742e-174	1.0000	-178.5199
S4O6--	1.510e-179	3.386e-174	0.7495	-178.9461
Succinate	1.365e-179	1.583e-174	0.7495	-178.9902
Mg(Glyc)2(aq)	3.245e-180	5.657e-175	1.0000	-179.4888
Cu(Glyc)2(aq)	1.779e-180	3.798e-175	1.0000	-179.7499
Fe(Glyc)2(aq)	6.281e-181	1.293e-175	1.0000	-180.2020
Mn(Glyc)2(aq)	1.715e-181	3.516e-176	1.0000	-180.7656
Na(Glyc)2-	1.242e-181	2.149e-176	0.9308	-180.9371
K(Glyc)2-	5.422e-182	1.025e-176	0.9308	-181.2970
H-Succinate	4.796e-182	5.613e-177	0.9308	-181.3503
Pb(Glyc)2(aq)	1.454e-182	5.193e-177	1.0000	-181.8375
Serine(aq)	5.921e-183	6.221e-178	1.0000	-182.2276
Ba(Glyc)2(aq)	2.689e-183	7.727e-178	1.0000	-182.5704
Cd(Glyc)2(aq)	1.865e-183	4.895e-178	1.0000	-182.7293
Succinic_acid(aq	7.628e-186	9.005e-181	1.0000	-185.1176
Ethanamine(aq)	6.202e-191	2.795e-186	1.0000	-190.2075
Alanine(aq)	4.846e-193	4.316e-188	1.0000	-192.3147
Cu(Ala)+	1.624e-193	2.461e-188	0.9308	-192.8207

Fe(Ala)+	8.192e-197	1.179e-191	0.9308	-196.1178
Mg(Ala)+	1.594e-197	1.790e-192	0.9308	-196.8288
Mn(Ala)+	1.240e-197	1.774e-192	0.9308	-196.9376
Ca(Ala)+	6.444e-198	8.256e-193	0.9308	-197.2220
Pb(Ala)+	1.623e-198	4.790e-193	0.9308	-197.8209
Cd(Ala)+	1.238e-198	2.481e-193	0.9308	-197.9385
Ca(CH3COO)2(aq)	1.318e-199	2.084e-194	1.0000	-198.8800
Mg(CH3COO)2(aq)	5.337e-200	7.597e-195	1.0000	-199.2727
Ba(Ala)+	5.170e-201	1.165e-195	0.9308	-200.3177
Cu(CH3COO)2(aq)	4.131e-201	7.502e-196	1.0000	-200.3839
Mn(CH3COO)2(aq)	1.908e-201	3.301e-196	1.0000	-200.7193
Na(CH3COO)2-	1.152e-201	1.624e-196	0.9308	-200.9698
Fe(CH3COO)2(aq)	6.387e-202	1.111e-196	1.0000	-201.1947
Acetone(aq)	4.653e-202	2.701e-197	1.0000	-201.3323
K(CH3COO)2-	2.754e-202	4.328e-197	0.9308	-201.5912
Pb(CH3COO)2(aq)	6.905e-203	2.245e-197	1.0000	-202.1608
Ba(CH3COO)2(aq)	4.026e-203	1.028e-197	1.0000	-202.3951
Cd(CH3COO)2(aq)	3.607e-203	8.311e-198	1.0000	-202.4429
Aspartic_acid(aq	6.263e-204	8.334e-199	1.0000	-203.2032
Propanal(aq)	2.125e-206	1.234e-201	1.0000	-205.6726
Al(CH3COO)2+	2.333e-207	3.384e-202	0.9308	-206.6632
Cu(CH3COO)2-	9.465e-208	1.719e-202	0.9308	-207.0550
S3--	2.591e-224	2.492e-219	0.7495	-223.7117
1-Propyne(aq)	1.236e-224	4.952e-220	1.0000	-223.9078
1-Propanol(aq)	3.392e-227	2.038e-222	1.0000	-226.4696
1-Propene(aq)	1.182e-229	4.974e-225	1.0000	-228.9272
2-Hydroxybutanoa	1.091e-233	1.124e-228	0.9308	-232.9934
NH4(CH3COO)2-	8.429e-234	1.147e-228	0.9308	-233.1054
Asparagine(aq)	4.889e-236	6.457e-231	1.0000	-235.3108
Cu(Gly)2(aq)	1.153e-236	2.440e-231	1.0000	-235.9381
2-Hydroxybutanoi	6.674e-238	6.945e-233	1.0000	-237.1756
Propane(aq)	2.665e-242	1.175e-237	1.0000	-241.5744
Mg(Gly)2(aq)	1.520e-243	2.620e-238	1.0000	-242.8182
Mn(Gly)2(aq)	7.911e-245	1.606e-239	1.0000	-244.1018
Diglycine(aq)	7.553e-245	9.976e-240	1.0000	-244.1219
Fe(Gly)2(aq)	7.508e-245	1.531e-239	1.0000	-244.1245
Pb(Gly)2(aq)	2.541e-245	9.025e-240	1.0000	-244.5950
Butanoate	9.532e-246	8.300e-241	0.9308	-245.0520
Cd(Gly)2(aq)	7.515e-246	1.957e-240	1.0000	-245.1241
Diketopiperazine	3.646e-247	4.159e-242	1.0000	-246.4382
Ca(Gly)2(aq)	9.321e-248	1.754e-242	1.0000	-247.0305
Na(But)(aq)	1.198e-248	1.319e-243	1.0000	-247.9214
Ca(But)+	1.195e-248	1.520e-243	0.9308	-247.9537
K(But)(aq)	5.880e-249	7.418e-244	1.0000	-248.2306
Butanoic_acid(aq	5.593e-249	4.926e-244	1.0000	-248.2524
Mg(But)+	5.576e-249	6.210e-244	0.9308	-248.2848
Mn(But)+	1.015e-249	1.442e-244	0.9308	-249.0245
Cu(But)+	4.360e-250	6.566e-245	0.9308	-249.3916
Fe(But)+	3.178e-250	4.541e-245	0.9308	-249.5290
Ba(Gly)2(aq)	2.340e-250	6.676e-245	1.0000	-249.6309
Pb(But)+	8.388e-252	2.468e-246	0.9308	-251.1075
Ba(But)+	5.044e-252	1.132e-246	0.9308	-251.3284
Glutarate	5.016e-252	6.524e-247	0.7495	-251.4249
Cd(But)+	3.056e-252	6.094e-247	0.9308	-251.5461
H-Glutarate	1.044e-254	1.368e-249	0.9308	-254.0126
Threonine(aq)	2.741e-256	3.263e-251	1.0000	-255.5622
Ethylacetate(aq)	5.479e-258	4.825e-253	1.0000	-257.2613
Glutaric_acid(aq	2.153e-258	2.844e-253	1.0000	-257.6669
S5O6--	1.729e-260	4.430e-255	0.7495	-259.8875
1-Propanamine(aq	3.222e-263	1.904e-258	1.0000	-262.4918
a-Aminobutyric_a	4.664e-266	4.808e-261	1.0000	-265.3312
Glutamic_acid(aq	2.751e-275	4.046e-270	1.0000	-274.5606
UO2(SCN)2(aq)	1.268e-280	4.897e-275	1.0000	-279.8968

Butanal(aq)	3.504e-281	2.526e-276	1.0000	-280.4555
S4--	1.056e-289	1.354e-284	0.7495	-289.1016
1-Butyne(aq)	5.259e-298	2.844e-293	1.0000	-297.2791
Cu(CH3COO)3-	1.863e-298	4.481e-293	0.9308	-297.7611
Pb(CH3COO)3-	1.096e-299	4.212e-294	0.9308	-298.9912
Mn(CH3COO)3-	9.148e-300	2.122e-294	0.9308	-299.0699
1-Butanol(aq)	2.944e-301	2.181e-296	1.0000	-300.0000
Cd(CH3COO)3-	1.454e-301	4.208e-296	0.9308	-300.0000
1-Butene(aq)	3.250e-303	1.823e-298	1.0000	-300.0000
2-Hydroxypentano	9.287e-307	1.087e-301	0.9308	-300.0000
Glutamine(aq)	2.460e-309	3.595e-304	1.0000	-300.0000
2-Hydroxypentano	3.373e-311	3.983e-306	1.0000	-300.0000
U(SCN)2++	2.434e-311	8.617e-306	0.7517	-300.0000
n-Butane(aq)	1.479e-315	8.592e-311	1.0000	-300.0000
Alanylglycine(aq	9.867e-317	1.442e-311	1.0000	-300.0000
Pentanoate	5.093e-319	5.148e-314	0.9308	-300.0000
Ca(Lac)2(aq)	4.511e-321	9.840e-316	1.0000	-300.0000
Mg(Lac)2(aq)	1.443e-321	2.920e-316	1.0000	-300.0000
Na(Pent)(aq)	6.719e-322	8.337e-317	1.0000	-300.0000
Ca(Pent)+	3.755e-322	5.300e-317	0.9308	-300.0000
K(Pent)(aq)	3.310e-322	4.640e-317	1.0000	-300.0000
Pentanoic_acid(a	3.261e-322	3.329e-317	1.0000	-300.0000
Cu(Lac)2(aq)	2.075e-322	5.014e-317	1.0000	-300.0000
Fe(Lac)2(aq)	1.976e-322	4.623e-317	1.0000	-300.0000
Mg(Pent)+	1.680e-322	2.106e-317	0.9308	-300.0000
Mn(Lac)2(aq)	7.905e-323	1.842e-317	1.0000	-300.0000
Na(Lac)2-	5.435e-323	1.093e-317	0.9308	-300.0000
Mn(Pent)+	4.447e-323	6.937e-318	0.9308	-300.0000
Cu(Pent)+	1.976e-323	3.253e-318	0.9308	-300.0000
K(Lac)2-	1.976e-323	4.292e-318	0.9308	-300.0000
Fe(Pent)+	1.482e-323	2.326e-318	0.9308	-300.0000
Pb(Lac)2(aq)	4.941e-324	1.903e-318	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9308	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9308	-300.0000
H-Suberate	0.0000	0.0000	0.9308	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9308	-300.0000
H-Sebacate	0.0000	0.0000	0.9308	-300.0000
H-Pimelate	0.0000	0.0000	0.9308	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9308	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
H-Adipate	0.0000	0.0000	0.9308	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7495	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7495	-300.0000
Sb2S4--	0.0000	0.0000	0.7495	-300.0000
S5--	0.0000	0.0000	0.7495	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7495	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000

Fe(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)+	0.0000	0.0000	0.9308	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.7495	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9308	-300.0000
Fe(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9308	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9308	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9308	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9308	-300.0000
Benzoate	0.0000	0.0000	0.9334	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9308	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9308	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9308	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9308	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9308	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000

Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9308	-300.0000
K(Prop)2-	0.0000	0.0000	0.9308	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9308	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9308	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9308	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9308	-300.0000
Azelate	0.0000	0.0000	0.7495	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9308	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9308	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9308	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9308	-300.0000
p-Toluate	0.0000	0.0000	0.9308	-300.0000
o-Toluate	0.0000	0.0000	0.9308	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7495	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Nontronite-Ca	24.7416s/sat	BaU2O7	-10.6158
Nontronite-Mg	24.6938s/sat	MgUO4	-10.6863
Nontronite-K	24.6091s/sat	Na2U2O7	-10.7635
Nontronite-Na	24.3261s/sat	Portlandite	-10.7687
Nontronite-H	23.6719s/sat	Cotunnite	-10.8330
Hematite	20.1990s/sat	Mg1.5SO4(OH)	-11.2407
Cronstedtite-7A	19.3646s/sat	AlF3	-11.2740

Magnetite	19.1299s/sat	Torbernite	-11.5875
Ferrite-Cu	18.9411s/sat	Uranocircite	-11.6012
Delafossite	15.0009s/sat	MnSO4	-11.7434
Clinoptilolite-h	12.9113s/sat	CdSO4	-11.7635
Clinoptilolite-C	12.8547s/sat	UO2.6667	-11.7754
Andradite	12.7477s/sat	Thermonatrite	-11.8127
Clinoptilolite-K	12.5588s/sat	Na2CO3	-12.1046
Clinoptilolite-h	12.3360s/sat	UO2SO4:H2O	-12.3187
Muscovite	11.1226s/sat	Uraninite	-12.3322
Epidote-ord	11.0277s/sat	Coffinite	-12.5923
Epidote	11.0269s/sat	(UO2)3(PO4)2:4H2	-12.6577
Stilbite	10.6439s/sat	PbF2	-12.7171
Ferrite-Ca	10.5340s/sat	MgSO4	-12.7307
Ferrite-Mg	10.5025s/sat	FeSO4	-12.7412
Goethite	9.6357s/sat	Przhevalskite	-13.0273
Clinoptilolite-N	9.2525s/sat	UPO5	-13.0752
Clinoptilolite-h	9.2520s/sat	UO2ClOH:2H2O	-13.1324
Fluorapatite	9.0603s/sat	Mordenite-dehy	-13.2449
Illite	7.8871s/sat	Chalcocyanite	-13.3867
Mesolite	7.4478s/sat	Ferrite-Dicalciu	-13.4867
Paragonite	7.2510s/sat	Anthophyllite	-13.6354
Beidellite-Ca	7.2285s/sat	Bassetite	-13.9167
Beidellite-Mg	7.1806s/sat	FeF2	-14.1285
Beidellite-K	7.0961s/sat	BaCl2:2H2O	-14.3046
Beidellite-Na	6.8130s/sat	CdCl2:H2O	-14.4177
Kaolinite	6.5126s/sat	NaUO3	-14.7132
Montmor-Mg	6.4461s/sat	Ca3(AsO4)2	-14.8798
Montmor-Ca	6.4207s/sat	BaCl2:H2O	-15.0006
Montmor-K	6.3616s/sat	Ba(OH)2:8H2O	-15.0512
Beidellite-H	6.1592s/sat	Hydromagnesite	-15.1926
Montmor-Na	6.0742s/sat	Ba2Si3O8	-15.1954
Scolecite	6.0607s/sat	CdCl2	-15.5091
Pyrophyllite	5.9264s/sat	CaAl2O4	-15.5278
Jarosite	5.7104s/sat	Natrosilite	-15.5604
Smectite-low-Fe-	5.3660s/sat	Autunite-H	-15.6276
Celadonite	5.2963s/sat	MnCl2:4H2O	-16.0241
Smectite-high-Fe	4.8945s/sat	Na2SiO3	-16.2258
Maximum_Microcli	4.8082s/sat	Gehlenite	-16.2564
K-Feldspar	4.8067s/sat	MgOHCl	-16.4524
Laumontite	4.7655s/sat	BaCl2	-16.5067
Fe(OH)3	4.3770s/sat	Hillebrandite	-16.5459
Daphnite-14A	4.3055s/sat	UO2SO4:3.5H2O	-16.8052
Amesite-14A	4.1026s/sat	UO2SO4:2.5H2O	-16.8446
Margarite	4.0879s/sat	UO2SO4:3H2O	-16.9250
Sanidine_high	3.5417s/sat	Dicalcium_silica	-16.9853
Lawsonite	3.1157s/sat	Akermanite	-17.0287
Annite	3.1014s/sat	UO2.3333(beta)	-17.0952
Diaspore	2.9228s/sat	CdF2	-17.2396
Mordenite	2.5047s/sat	CaAl4O7	-17.3748
Boehmite	2.5019s/sat	UO2F2:3H2O	-17.3800
Chamosite-7A	2.4688s/sat	MnCl2:2H2O	-17.4120
Gibbsite	2.3751s/sat	UO2F2	-17.6469
Ripidolite-14A	2.3065s/sat	Pargasite	-17.9934
Witherite	2.0641s/sat	Ningyoite	-18.0591
Brochantite	1.8878s/sat	Larnite	-18.3364
Albite_low	1.8588s/sat	Alum-K	-18.4202
Albite	1.8587s/sat	CuCl2	-18.5388
Phlogopite	1.8402s/sat	MnCl2:H2O	-19.0529
Malachite	1.6640s/sat	MgCl2:4H2O	-19.4288
Corundum	1.6421s/sat	Na2UO4(alpha)	-19.5652
Tenorite	1.4015s/sat	UO2SO4	-20.5765
Saponite-Ca	1.2335s/sat	UOFOH:.5H2O	-20.7264
Analcime	1.1884s/sat	Lime	-21.1831

Saponite-Mg	1.1868s/sat	UOFOH	-21.2189
Natrolite	1.1066s/sat	Scacchite	-22.4099
Saponite-K	1.1011s/sat	UO2Cl	-22.7001
Prehnite	0.9323s/sat	UO2(NO3)2:6H2O	-22.8769
Daphnite-7A	0.8413s/sat	Rankinite	-23.2943
Saponite-Na	0.8181s/sat	Hydrophilite	-23.6738
Kyanite	0.8020s/sat	Lawrencite	-23.7427
Cerussite	0.5971s/sat	K2UO4	-23.9348
Quartz	0.5692s/sat	Pb	-24.0319
Andalusite	0.5055s/sat	Tobermorite-14A	-24.2047
Clinozoisite	0.4746s/sat	UOF2:H2O	-24.2177
Albite_high	0.4732s/sat	Clinoptilolite-d	-24.3156
Clinochlore-14A	0.4689s/sat	UO2(NO3)2:3H2O	-24.4495
Barite	0.4649s/sat	Clinoptilolite-d	-24.6367
Zoisite	0.4275s/sat	UOF2	-24.8393
Hercynite	0.3836s/sat	MgCl2:2H2O	-25.1328
Kalsilite	0.3812s/sat	UO2(NO3)2:2H2O	-25.7726
Tridymite	0.3694s/sat	UO2(PO3)2	-26.1925
Minnesotaite	0.3298s/sat	(UO2)3(PO4)2	-26.2777
Chalcedony	0.2886s/sat	Tobermorite-11A	-26.2974
Dolomite-ord	0.1955s/sat	Ettringite	-26.4377
Dolomite	0.1955s/sat	(UO2)2P2O7	-26.7018
Dawsonite	0.1816s/sat	U(HPO4)2:4H2O	-27.2183
Saponite-H	0.1641s/sat	UP2O7	-27.4111
Sillimanite	0.1223s/sat	KAl(SO4)2	-27.5736
Wairakite	0.0357s/sat	Clinoptilolite-d	-27.9270
Rhodochrosite	0.0052s/sat	UO2Cl2:3H2O	-28.5012
Cristobalite(alp	-0.0041	Merwinite	-28.5130
Talc	-0.0747	MgCl2:H2O	-28.6391
Strengite	-0.0793	Foshagite	-28.7218
Ice	-0.1008	UO2(NO3)2:H2O	-29.5197
Calcite	-0.2647	Tobermorite-9A	-30.0203
Coesite	-0.2671	Ba2SiO4	-30.0617
Jadeite	-0.3332	UO2Cl2:H2O	-31.3683
Aragonite	-0.4095	Afwillite	-31.5225
Dioptase	-0.4325	UO2(NO3)2	-33.1303
Hydroxylapatite	-0.4644	KMgCl3:2H2O	-33.4141
Cristobalite(bet	-0.4762	UO2SO3	-33.6252
SiO2(am)	-0.7992	Cd	-34.1320
Siderite	-1.0107	Chloromagnesite	-34.6190
Monohydrocalcite	-1.0738	Fe	-34.7530
Ripidolite-7A	-1.1521	UF4:2.5H2O	-35.2230
Magnesite	-1.2308	UO2Cl2	-35.3992
Atacamite	-1.2610	As2O5	-36.2408
Alamosite	-1.2894	Antigorite	-37.2881
Dolomite-dis	-1.4233	BaSiF6	-39.1742
Greenalite	-1.4667	BaO	-39.6432
Anorthite	-1.5999	UF4	-39.6481
Ferrosilite	-1.6040	(UO2)2As2O7	-39.7201
Cuprite	-1.6240	Al2(SO4)3:6H2O	-39.8477
Whitlockite	-2.2541	Molysite	-39.8603
Nepheline	-2.4218	UO2(AsO3)2	-40.0993
Gypsum	-2.4266	(UO2)3(AsO4)2	-40.2199
Anhydrite	-2.7003	Ba2U2O7	-40.5477
Bixbyite	-2.7315	KMgCl3	-41.0321
CaUO4	-2.8073	Xonotlite	-41.2933
Lanarkite	-2.8743	Hatrurite	-41.9669
Alunite	-2.9179	Fe2(SO4)3	-42.0269
Rhodonite	-2.9818	U(SO4)2:8H2O	-43.3206
Clinochlore-7A	-2.9869	Arsenolite	-43.4519
Azurite	-3.2169	Claudetite	-43.5230
Chrysotile	-3.2247	C	-43.9540
Enstatite	-3.2968	U(SO4)2:4H2O	-44.5540

Fluorite	-3.3389	U(SO4)2	-44.7363
Bassanite	-3.3482	U(CO3)2	-46.9183
Anglesite	-3.4089	UOCl2	-46.9713
Sb2O3	-3.4404	U5O12Cl	-48.8040
CaSO4:0.5H2O(bet	-3.5290	UClF3	-50.6442
CdSiO3	-3.5471	As	-51.2115
Hausmannite	-3.5576	Na3UO4	-53.9264
Wustite	-3.6532	Ca4Al2Fe2O10	-54.5139
Schoepite	-3.7786	Na4SiO4	-55.9677
UO3:2H2O	-3.7798	UOF4	-56.1672
UO2(OH)2(beta)	-3.9287	Na	-56.2553
Schoepite-dehy(.	-3.9930	Al2(SO4)3	-58.1497
UO3:.9H2O(alpha)	-3.9935	Mn	-58.5025
Paralaurionite	-4.0042	Ca3Al2O6	-58.8647
Fayalite	-4.0183	(UO2)2Cl3	-59.2710
Schoepite-dehy(.	-4.0773	Na2O	-59.4133
Schoepite-dehy(1	-4.0903	K	-60.1918
Nesquehonite	-4.2892	UF3	-60.2421
Diopside	-4.3049	UOCl3	-60.2921
Cordierite_hydr	-4.3302	Pb2Cl5NH4	-60.4620
FeO	-4.3516	UF5(beta)	-63.2730
Berlinite	-4.3637	Covellite	-63.3007
Pyrolusite	-4.4612	UF5(alpha)	-63.6551
Sepiolite	-4.5390	UOCl	-63.6848
Sellaite	-4.5487	Chalcocite	-63.9112
PbCO3.PbO	-4.5760	UCl2F2	-63.9551
Fe(OH)2	-4.6612	S	-66.2158
Brucite	-4.8129	Ba3UO6	-67.0174
Litharge	-4.9052	CdS	-71.9585
Massicot	-5.0976	Galena	-72.7066
Mn(OH)2(am)	-5.1289	U2O3F6	-73.9621
Okenite	-5.2015	K2O	-77.0032
Hedenbergite	-5.2292	UCl3F	-77.0846
Schoepite-dehy(.	-5.2407	CdCl2(NH3)2	-81.1722
NaFeO2	-5.2567	Na6Si2O7	-81.2996
Wollastonite	-5.2858	U(SO3)2	-81.8409
Analcime-dehy	-5.4210	Troilite	-82.6013
UO2CO3	-5.4603	Pyrrhotite	-82.7037
Rutherfordine	-5.4782	PbSO4(NH3)2	-83.4469
Pseudowollastoni	-5.5429	Alabandite	-85.1749
Nahcolite	-5.5444	As4O6(mono)	-86.5612
Huntite	-5.6008	As4O6(cubi)	-86.7821
Niter	-5.7803	UCl4	-88.0498
Schoepite-dehy(.	-5.7810	UCl3	-90.3736
Pb2SiO4	-5.9288	UF6	-95.7164
Tephroite	-6.1398	Mg	-98.1874
Pb3SO6	-6.1561	U3O5F8	-98.8347
Grossular	-6.2186	U2F9	-99.6782
Cd(OH)2	-6.3482	BaS	-103.2237
Spinel	-6.3755	UN1.73(alpha)	-105.2680
Cu	-6.6478	UN1.59(alpha)	-108.0614
Tremolite	-6.7941	U2O2Cl5	-108.5178
Nantokite	-6.8159	UCl5	-109.8337
UO3(gamma)	-6.8358	Ca	-115.5592
Cordierite_anhyd	-6.9147	P	-117.2064
Artinite	-6.9572	Ba	-119.6947
Sanbornite	-7.1232	Al	-119.9205
Melanterite	-7.2325	UN	-121.3085
UO2HPO4:4H2O	-7.2806	Si	-124.3627
Chalcanthite	-7.3783	UCl6	-130.4253
UO3(beta)	-7.4600	Pb(N3)2(orth)	-137.9602
PbFCl	-7.6808	Pyrite	-138.0734
Ca-Al_Pyroxene	-7.7231	Pb(N3)2(mono)	-138.4109

Mirabilite	-7.7355	Chalcopyrite	-139.7899
Cd(OH)Cl	-7.7917	CdCl2(NH3)4	-157.3412
Monteponite	-7.8031	PbSO4(NH3)4	-161.2503
UO3(alpha)	-7.8064	U	-169.0862
BaUO4	-7.8532	US	-177.1208
Manganosite	-7.8881	UAs	-177.1946
Arcanite	-7.8913	U4F17	-178.0789
Sylvite	-7.9034	UC	-195.1184
Forsterite	-8.4157	UH3(beta)	-197.5607
Halite	-8.4666	US1.9	-202.5438
Phosgenite	-8.6016	US2	-207.3899
Thenardite	-9.0205	Mayenite	-217.3524
UO2FOH:2H2O	-9.1288	UAs2	-225.6913
Gyrolite	-9.1708	CdCl2(NH3)6	-233.5967
UO2.25	-9.3082	UP	-238.0663
FeF3	-9.3382	UC1.94(alpha)	-238.5260
UO2.25(beta)	-9.3743	Stibnite	-246.3138
Pb4SO7	-9.5074	Bornite	-267.2668
Nitrobarite	-9.5315	US3	-270.3336
UO2FOH:H2O	-9.5611	Orpiment	-270.5038
Monticellite	-9.6710	Pb(SCN)2	-274.1957
Saleeite	-9.8198	UP2	-350.0482
CdSO4:2.667H2O	-9.8730	U2S3	-377.3484
Natron	-10.0008	o-Phthalic_acid	-388.5448
UO2FOH	-10.0610	U2C3	-435.7527
Periclase	-10.0842	U3S5	-580.0168
CdSO4:H2O	-10.0960	U3As4	-580.6483
Mg1.25SO4(OH)0.5	-10.1124	U3P4	-826.1780
Na2CO3:7H2O	-10.4842		

Gases	fugacity	log fug.
N2(g)	0.2106	-0.676
H2O(g)	0.01398	-1.854
CO2(g)	0.0008301	-3.081
NO2(g)	3.255e-012	-11.487
HF(g)	3.155e-015	-14.501
HCl(g)	1.825e-019	-18.739
H2(g)	1.030e-028	-27.987
O2(g)	2.479e-031	-30.606
NO(g)	4.923e-032	-31.308
CO(g)	2.791e-035	-34.554
NH3(g)	6.947e-040	-39.158
SiF4(g)	1.989e-041	-40.701
SO2(g)	3.741e-043	-42.427
Cl2(g)	1.009e-044	-43.996
Cd(g)	4.657e-049	-48.332
Pb(g)	2.341e-054	-53.631
Cu(g)	1.465e-061	-60.834
UO2F2(g)	4.231e-062	-61.374
Na(g)	4.183e-071	-70.378
K(g)	4.825e-072	-71.317
UO3(g)	2.205e-073	-72.657
UO2Cl2(g)	1.332e-073	-72.875
UOF4(g)	1.375e-077	-76.862
UF5(g)	1.325e-084	-83.878
UF4(g)	4.487e-086	-85.348
H2S(g)	6.330e-089	-88.199
CH4(g)	2.573e-091	-90.590
UF6(g)	1.444e-097	-96.840
F2(g)	1.556e-101	-100.808
UO2(g)	3.084e-113	-112.511
UCl4(g)	2.036e-114	-113.691

Mg(g)	1.712e-119	-118.766
UCl5(g)	9.956e-129	-128.002
UF3(g)	2.484e-130	-129.605
UCl6(g)	1.597e-137	-136.797
UCl3(g)	1.035e-138	-137.985
U2F10(g)	3.274e-142	-141.485
Ca(g)	1.454e-142	-141.838
S2(g)	7.877e-148	-147.104
C2H4(g)	7.328e-157	-156.135
C(g)	1.322e-166	-165.879
UF2(g)	2.794e-171	-170.554
Al(g)	2.611e-173	-172.583
UCl2(g)	7.751e-181	-180.111
UO(g)	1.253e-185	-184.902
Si(g)	7.594e-199	-198.120
UF(g)	1.476e-205	-204.831
U2Cl8(g)	4.995e-217	-216.301
UCl(g)	1.751e-220	-219.757
U2Cl10(g)	3.375e-229	-228.472
U(g)	1.295e-258	-257.888

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Al+++	6.54e-006	6.54e-006	0.177			
Ba++	8.36e-007	8.36e-007	0.115			
Ca++	0.000514	0.000514	20.6			
Cd++	1.10e-008	1.10e-008	0.00124			
Cl-	0.000111	0.000111	3.92			
Cu++	3.70e-007	3.70e-007	0.0235			
F-	1.03e-005	1.03e-005	0.196			
Fe++	8.78e-007	8.78e-007	0.0490			
H+	-2.10e-006	-2.10e-006	-0.00212			
H2AsO4-	2.62e-008	2.62e-008	0.00369			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00162	0.00162	99.0			
HPO4--	2.63e-006	2.63e-006	0.252			
K+	0.000702	0.000702	27.5			
Mg++	0.000202	0.000202	4.90			
Mn++	8.18e-006	8.18e-006	0.449			
NH3(aq)	0.000326	0.000326	5.56			
NO3-	0.00102	0.00102	62.9			
Na+	0.00128	0.00128	29.4			
O2(aq)	0.000244	0.000244	7.82			
Pb++	1.80e-008	1.80e-008	0.00373			
SO4--	0.000459	0.000459	44.1			
Sb(OH)3(aq)	4.03e-007	4.03e-007	0.0696			
SiO2(aq)	0.000215	0.000215	12.9			
UO2++	1.36e-008	1.36e-008	0.00367			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Aluminum	6.544e-006	6.544e-006	0.1765		
Antimony	4.028e-007	4.028e-007	0.04903		
Arsenic	2.619e-008	2.619e-008	0.001961		
Barium	8.357e-007	8.357e-007	0.1147		
Cadmium	1.099e-008	1.099e-008	0.001236		
Calcium	0.0005140	0.0005140	20.59		
Carbon	0.001624	0.001624	19.50		
Chlorine	0.0001107	0.0001107	3.922		
Copper	3.705e-007	3.705e-007	0.02353		
Fluorine	1.033e-005	1.033e-005	0.1961		

Hydrogen	111.0	111.0	1.119e+005
Iron	8.782e-007	8.782e-007	0.04903
Lead	1.799e-008	1.799e-008	0.003726
Magnesium	0.0002018	0.0002018	4.903
Manganese	8.178e-006	8.178e-006	0.4491
Nitrogen	0.001342	0.001342	18.79
Oxygen	55.52	55.52	8.880e+005
Phosphorus	2.629e-006	2.629e-006	0.08139
Potassium	0.0007025	0.0007025	27.46
Silicon	0.0002155	0.0002155	6.050
Sodium	0.001280	0.001280	29.42
Sulfur	0.0004595	0.0004595	14.73
Uranium	1.360e-008	1.360e-008	0.003236

```
Temperature =   9.5 C    Pressure =  1.013 bars
pH =  7.600              log fO2 =  -29.159
Eh =   0.3970 volts      pe =   7.0792
Ionic strength      =    0.004191
Charge imbalance    =   -0.000351 eq/kg (-10.64% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000306 kg
Solution density    =    1.024    g/cm3
Chlorinity          =    0.000110 molal
Dissolved solids    =         306 mg/kg sol'n
Hardness            =       57.57 mg/kg sol'n as CaCO3
  carbonate         =       57.57 mg/kg sol'n as CaCO3
  non-carbonate     =        0.00 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       74.27 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3970	7.0792
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5859	10.4477
14*e- + 16*H+ + 2*SO4-- = 8*H2O + S2--	-0.2531	-4.5127

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001469	89.62	0.9340	-2.8626
Na+	0.001314	30.21	0.9340	-2.9109
NO3-	0.001228	76.12	0.9328	-2.9410
K+	0.0006736	26.33	0.9328	-3.2018
Ca++	0.0003995	16.00	0.7681	-3.5131
SO4--	0.0003201	30.74	0.7602	-3.6137
N2(aq)	0.0002217	6.209	1.0000	-3.6542
Mg++	0.0001536	3.732	0.7755	-3.9240
SiO2(aq)	0.0001378	8.279	1.0000	-3.8607
Cl-	0.0001102	3.907	0.9328	-3.9880
CO2(aq)	0.0001026	4.514	1.0000	-3.9889
F-	1.024e-005	0.1946	0.9334	-5.0195
Mn++	9.510e-006	0.5223	0.7681	-5.1364
CaSO4(aq)	8.979e-006	1.222	1.0000	-5.0468
CaHCO3+	5.239e-006	0.5295	0.9340	-5.3104
MgSO4(aq)	5.040e-006	0.6065	1.0000	-5.2975
AlO2-	3.423e-006	0.2018	0.9340	-5.4952
NaHCO3(aq)	3.265e-006	0.2742	1.0000	-5.4861
HPO4--	3.065e-006	0.2941	0.7602	-5.6326
CO3--	2.280e-006	0.1368	0.7623	-5.7600
MgHCO3+	1.971e-006	0.1681	0.9340	-5.7350
KSO4-	1.230e-006	0.1663	0.9340	-5.9396
H2PO4-	1.163e-006	0.1128	0.9340	-5.9641
Fe++	1.025e-006	0.05722	0.7681	-6.1039
CaCO3(aq)	8.372e-007	0.08377	1.0000	-6.0772
Ba++	6.900e-007	0.09472	0.7642	-6.2779
S2--	6.095e-007	0.03908	0.7602	-6.3340
HAlO2(aq)	5.322e-007	0.03191	1.0000	-6.2740
Cu++	4.306e-007	0.02735	0.7681	-6.4805
HSiO3-	3.935e-007	0.03033	0.9340	-6.4347
Sb(OH)3(aq)	3.692e-007	0.06377	1.0000	-6.4327
MnSO4(aq)	3.442e-007	0.05197	1.0000	-6.4631
MgCO3(aq)	1.701e-007	0.01434	1.0000	-6.7693
OH-	1.186e-007	0.002017	0.9334	-6.9558

NaHSiO3(aq)	2.857e-008	0.002858	1.0000	-7.5441
MgF+	2.813e-008	0.001218	0.9340	-7.5804
Al(OH)2+	2.740e-008	0.001671	0.9340	-7.5918
H+	2.673e-008	2.693e-005	0.9397	-7.6000
FeCO3+	2.497e-008	0.002892	0.9340	-7.6322
HAsO4--	2.304e-008	0.003223	0.7602	-7.7566
NaCl(aq)	1.944e-008	0.001136	1.0000	-7.7113
CaF+	1.422e-008	0.0008398	0.9340	-7.8768
Pb++	1.224e-008	0.002535	0.7623	-8.0302
NaCO3-	1.151e-008	0.0009550	0.9340	-7.9686
MgCl+	1.055e-008	0.0006300	0.9340	-8.0066
Cd++	7.736e-009	0.0008693	0.7642	-8.2283
UO2(CO3)2--	7.049e-009	0.002749	0.7602	-8.2709
CaCl+	6.883e-009	0.0005197	0.9340	-8.1919
UO2(CO3)3----	4.627e-009	0.002082	0.3337	-8.8114
H2AsO4-	3.049e-009	0.0004296	0.9340	-8.5455
KCl(aq)	1.526e-009	0.0001138	1.0000	-8.8163
MnCl+	1.145e-009	0.0001035	0.9340	-8.9708
AlOH++	1.072e-009	4.713e-005	0.7623	-9.0878
NaF(aq)	1.040e-009	4.367e-005	1.0000	-8.9828
NaAlO2(aq)	6.029e-010	4.940e-005	1.0000	-9.2198
HSO4-	4.254e-010	4.128e-005	0.9340	-9.4009
BaCO3(aq)	2.927e-010	5.775e-005	1.0000	-9.5336
HF(aq)	2.704e-010	5.408e-006	1.0000	-9.5680
UO2CO3(aq)	2.272e-010	7.495e-005	1.0000	-9.6436
FeCl+	5.938e-011	5.419e-006	0.9340	-10.2560
PO4---	5.645e-011	5.359e-006	0.5394	-10.5164
PbCl+	2.662e-011	6.459e-006	0.9340	-10.6044
NaOH(aq)	2.409e-011	9.633e-007	1.0000	-10.6181
BaCl+	1.509e-011	2.606e-006	0.9340	-10.8510
Al+++	9.562e-012	2.579e-007	0.5698	-11.2637
Cu+	9.174e-012	5.828e-007	0.9340	-11.0671
Sb(OH)4-	5.658e-012	1.073e-006	0.9340	-11.2770
H3PO4(aq)	3.474e-012	3.404e-007	1.0000	-11.4591
BaF+	3.049e-012	4.765e-007	0.9340	-11.5455
UO2OH+	2.878e-012	8.259e-007	0.9340	-11.5705
AsO4---	2.054e-012	2.853e-007	0.5394	-11.9554
Sb(OH)2F(aq)	1.994e-012	3.484e-007	1.0000	-11.7002
CdSO4(aq)	1.454e-012	3.030e-007	1.0000	-11.8375
MgP2O7--	1.141e-012	2.261e-007	0.7602	-12.0619
HNO3(aq)	1.023e-012	6.444e-008	1.0000	-11.9902
Fe+++	9.416e-013	5.257e-008	0.5698	-12.2704
CaCl2(aq)	9.269e-013	1.028e-007	1.0000	-12.0330
Sb(OH)2+	5.613e-013	8.741e-008	0.9340	-12.2804
HCl(aq)	5.505e-013	2.007e-008	1.0000	-12.2592
CdCl2(aq)	1.241e-013	2.274e-008	1.0000	-12.9063
FeF++	7.213e-014	5.397e-009	0.7623	-13.2598
HP2O7---	4.747e-014	8.302e-009	0.5394	-13.5917
UO2++	3.780e-014	1.020e-008	0.7623	-13.5404
UO2F+	3.283e-014	9.486e-009	0.9340	-13.5134
KHSO4(aq)	1.432e-014	1.950e-009	1.0000	-13.8440
H3AsO4(aq)	1.080e-014	1.533e-009	1.0000	-13.9664
PbCl2(aq)	8.907e-015	2.476e-009	1.0000	-14.0503
FeF2+	7.644e-015	7.171e-010	0.9340	-14.1463
FeSO4+	7.251e-015	1.101e-009	0.9340	-14.1693
UO2SO4(aq)	5.587e-015	2.045e-009	1.0000	-14.2529
H2P2O7--	3.772e-015	6.636e-010	0.7602	-14.5424
P2O7----	1.684e-015	2.928e-010	0.3337	-15.2504
UO2F2(aq)	9.245e-016	2.847e-010	1.0000	-15.0341
HF2-	5.622e-016	2.192e-011	0.9340	-15.2797
KP2O7---	1.219e-016	2.596e-011	0.5394	-16.1821
FeCl2(aq)	2.800e-017	3.548e-012	1.0000	-16.5528
UO2(SO4)2--	1.084e-017	5.006e-012	0.7602	-17.0842

FeCl++	5.333e-018	4.868e-013	0.7623	-17.3909
UO2Cl+	3.927e-018	1.199e-012	0.9340	-17.4356
CdCl3-	2.584e-018	5.651e-013	0.9340	-17.6173
(UO2)2(OH)2++	1.672e-018	9.598e-013	0.7623	-17.8946
UO2F3-	1.621e-018	5.300e-013	0.9340	-17.8198
PbCl3-	4.842e-019	1.518e-013	0.9340	-18.3446
(UO2)3(OH)5+	7.027e-020	6.288e-014	0.9340	-19.1829
UO2+	5.830e-020	1.574e-014	0.9340	-19.2639
(UO2)3(CO3)6(6-)	4.023e-020	4.706e-014	0.0846	-20.4682
H3P2O7-	1.735e-020	3.070e-015	0.9340	-19.7902
UO2F4--	1.180e-022	4.080e-017	0.7602	-22.0473
PbCl4--	5.730e-023	1.999e-017	0.7602	-22.3609
UO2Cl2(aq)	1.670e-023	5.691e-018	1.0000	-22.7774
U(OH)4(aq)	1.203e-023	3.682e-018	1.0000	-22.9196
HAsO2(aq)	1.013e-023	1.093e-018	1.0000	-22.9942
As(OH)3(aq)	9.004e-024	1.134e-018	1.0000	-23.0455
Mn+++	1.257e-024	6.904e-020	0.5458	-24.1636
FeCl4--	1.174e-024	2.320e-019	0.7602	-24.0494
H2AsO3-	1.265e-025	1.580e-020	0.9340	-24.9275
AsO2-	1.249e-025	1.335e-020	0.9340	-24.9330
H4P2O7(aq)	1.054e-026	1.876e-021	1.0000	-25.9770
AsO2OH--	3.194e-029	3.957e-024	0.7602	-28.6147
NO2-	8.877e-031	4.083e-026	0.9328	-30.0820
O2(aq)	1.203e-032	3.849e-028	1.0000	-31.9197
Formate	6.846e-033	3.081e-028	0.9334	-32.1945
H2(aq)	1.644e-033	3.314e-030	1.0000	-32.7840
Ca(For)+	6.336e-035	5.390e-030	0.9340	-34.2278
HNO2(aq)	5.093e-035	2.394e-030	1.0000	-34.2930
Mg(For)+	3.014e-035	2.089e-030	0.9340	-34.5504
Na(For)(aq)	9.346e-036	6.354e-031	1.0000	-35.0294
K(For)(aq)	4.128e-036	3.472e-031	1.0000	-35.3842
Mn(For)+	3.047e-036	3.045e-031	0.9340	-35.5457
ClO-	2.121e-036	1.091e-031	0.9340	-35.7031
Formic_acid(aq)	9.486e-037	4.365e-032	1.0000	-36.0229
Fe(For)+	4.867e-037	4.908e-032	0.9340	-36.3424
Cu(For)+	2.869e-037	3.114e-032	0.9340	-36.5719
SO3--	1.831e-037	1.465e-032	0.7623	-36.8553
Ba(For)+	8.176e-038	1.490e-032	0.9340	-37.1171
SiF6--	6.561e-038	9.319e-033	0.7602	-37.3021
NH4+	5.552e-038	1.001e-033	0.9321	-37.2861
HSO3-	5.291e-038	4.288e-033	0.9340	-37.3061
HO2-	1.166e-038	3.848e-034	0.9340	-37.9628
Pb(For)+	4.900e-039	1.235e-033	0.9340	-38.3394
Cd(For)+	3.461e-039	5.447e-034	0.9340	-38.4904
CO(aq)	1.522e-039	4.262e-035	1.0000	-38.8175
NH3(aq)	3.751e-040	6.386e-036	1.0000	-39.4259
Oxalate	2.223e-040	1.956e-035	0.7602	-39.7720
MnO4--	3.464e-041	4.119e-036	0.7602	-40.5795
UOH+++	6.840e-042	1.744e-036	0.5458	-41.4279
U(CO3)5(6-)	3.145e-042	1.692e-036	0.0846	-42.5752
UF3+	2.906e-042	8.571e-037	0.9340	-41.5664
UF2++	1.849e-042	5.101e-037	0.7623	-41.8511
UF4(aq)	2.768e-043	8.688e-038	1.0000	-42.5579
H-Oxalate	7.468e-044	6.646e-039	0.9340	-43.1565
SO2(aq)	6.591e-044	4.222e-039	1.0000	-43.1810
UF+++	3.380e-044	8.685e-039	0.5458	-43.7340
MnO4-	1.883e-044	2.239e-039	0.9334	-43.7551
USO4++	8.582e-046	2.866e-040	0.7623	-45.1843
U(SO4)2(aq)	6.714e-046	2.887e-040	1.0000	-45.1730
HSO5-	1.777e-046	2.008e-041	0.9340	-45.7800
U++++	2.767e-048	6.583e-043	0.3442	-48.0212
Oxalic_acid(aq)	3.179e-050	2.862e-045	1.0000	-49.4977
UCl+++	1.436e-050	3.927e-045	0.5458	-50.1056

ClO2-	7.979e-061	5.380e-056	0.9340	-60.1277
S2O6--	7.055e-062	1.129e-056	0.7602	-61.2706
S2O8--	2.501e-063	4.804e-058	0.7602	-62.7209
U+++	4.334e-066	1.031e-060	0.5458	-65.6260
Ca(For)2(aq)	3.388e-066	4.407e-061	1.0000	-65.4700
Mg(For)2(aq)	2.033e-066	2.324e-061	1.0000	-65.6918
Mn(For)2(aq)	2.939e-067	4.259e-062	1.0000	-66.5319
Fe(For)2(aq)	6.507e-068	9.489e-063	1.0000	-67.1866
Cu(For)2(aq)	5.148e-068	7.904e-063	1.0000	-67.2884
Na(For)2-	4.702e-068	5.313e-063	0.9340	-67.3573
K(For)2-	1.726e-068	2.228e-063	0.9340	-67.7927
Ba(For)2(aq)	3.263e-069	7.418e-064	1.0000	-68.4863
Cd(For)2(aq)	3.045e-069	6.162e-064	1.0000	-68.5165
Pb(For)2(aq)	5.311e-070	1.578e-064	1.0000	-69.2748
ClO3-	1.227e-070	1.023e-065	0.9334	-69.9412
Formaldehyde(aq)	6.015e-071	1.805e-066	1.0000	-70.2208
N3-	1.603e-072	6.734e-068	0.9340	-71.8247
HN3(aq)	2.715e-075	1.168e-070	1.0000	-74.5662
Cu(NH3)2++	4.576e-078	4.465e-073	0.7623	-77.4574
S2O5--	5.156e-080	7.429e-075	0.7602	-79.4067
Cd(NH3)2++	1.476e-082	2.162e-077	0.7623	-81.9488
Urea(aq)	4.857e-083	2.916e-078	1.0000	-82.3137
UO2ClO3+	1.213e-083	4.285e-078	0.9340	-82.9459
HCN(aq)	2.492e-084	6.732e-080	1.0000	-83.6035
ClO4-	7.169e-085	7.127e-080	0.9334	-84.1745
CN-	2.177e-086	5.663e-082	0.9328	-85.6923
Methanol(aq)	4.973e-088	1.593e-083	1.0000	-87.3034
Glycolate	3.608e-094	2.707e-089	0.9340	-93.4724
HS-	1.059e-094	3.502e-090	0.9334	-94.0050
H2S(aq)	4.268e-095	1.454e-090	1.0000	-94.3697
Ca(Glyc)+	5.839e-096	6.720e-091	0.9340	-95.2633
Mg(Glyc)+	1.049e-096	1.041e-091	0.9340	-96.0090
Na(Glyc)(aq)	5.048e-097	4.947e-092	1.0000	-96.2969
K(Glyc)(aq)	2.230e-097	2.544e-092	1.0000	-96.6518
Cu(Glyc)+	1.415e-097	1.960e-092	0.9340	-96.8789
Mn(Glyc)+	1.236e-097	1.606e-092	0.9340	-96.9378
Fe(Glyc)+	6.146e-098	8.042e-093	0.9340	-97.2410
Glycolic_acid(aq	6.077e-098	4.620e-093	1.0000	-97.2163
Ba(Glyc)+	2.015e-099	4.279e-094	0.9340	-98.7253
Methane(aq)	9.588e-100	1.538e-095	1.0000	-99.0183
Pb(Glyc)+	7.172e-100	2.024e-094	0.9340	-99.1740
S--	2.025e-100	6.493e-096	0.7642	-99.8103
Cd(Glyc)+	2.011e-100	3.769e-095	0.9340	-99.7262
S2O4--	6.981e-101	8.942e-096	0.7642	-100.2729
S2O3--	6.579e-101	7.375e-096	0.7602	-100.3009
Acetate	2.933e-105	1.731e-100	0.9346	-104.5620
MgCH3COO+	8.779e-108	7.315e-103	0.9340	-107.0862
CaCH3COO+	8.139e-108	8.065e-103	0.9340	-107.1191
Acetic_acid(aq)	4.015e-108	2.410e-103	1.0000	-107.3963
NaCH3COO(aq)	2.831e-108	2.321e-103	1.0000	-107.5481
KCH3COO(aq)	8.869e-109	8.701e-104	1.0000	-108.0521
MnCH3COO+	4.140e-109	4.718e-104	0.9340	-108.4126
CuCH3COO+	2.323e-109	2.847e-104	0.9340	-108.6635
FeCH3COO+	5.316e-110	6.105e-105	0.9340	-109.3041
BaCH3COO+	1.388e-110	2.724e-105	0.9340	-109.8874
PbCH3COO+	7.385e-111	1.966e-105	0.9340	-110.1613
CdCH3COO+	1.881e-111	3.224e-106	0.9340	-110.7552
Malonate	3.879e-114	3.957e-109	0.7602	-113.5304
AlCH3COO++	3.863e-114	3.322e-109	0.7623	-113.5310
Cu(NH3)3++	1.821e-114	2.087e-109	0.7623	-113.8576
CuCH3COO(aq)	5.881e-116	7.207e-111	1.0000	-115.2306
H-Malonate	3.710e-116	3.823e-111	0.9340	-115.4602
AsH3(aq)	3.432e-117	2.675e-112	1.0000	-116.4644

Malonic_acid(aq)	6.428e-121	6.687e-116	1.0000	-120.1920
Methanamine(aq)	7.700e-125	2.391e-120	1.0000	-124.1135
Glycine(aq)	1.588e-127	1.192e-122	1.0000	-126.7992
Cu(Gly)+	9.535e-128	1.312e-122	0.9340	-127.0503
Mg(Gly)+	1.756e-130	1.727e-125	0.9340	-129.7851
Mn(Gly)+	1.630e-131	2.102e-126	0.9340	-130.8175
Fe(Gly)+	8.010e-132	1.040e-126	0.9340	-131.1260
Ca(Gly)+	2.246e-132	2.562e-127	0.9340	-131.6783
Pb(Gly)+	1.262e-132	3.548e-127	0.9340	-131.9287
S3O6--	2.745e-133	5.275e-128	0.7602	-132.6804
Cd(Gly)+	1.533e-133	2.857e-128	0.9340	-132.8441
Ba(Gly)+	4.595e-135	9.711e-130	0.9340	-134.3673
Acetaldehyde(aq)	4.036e-141	1.778e-136	1.0000	-140.3940
SCN-	1.231e-141	7.146e-137	0.9334	-140.9398
NH4CH3COO(aq)	2.324e-142	1.790e-137	1.0000	-141.6339
Acetamide(aq)	1.897e-142	1.120e-137	1.0000	-141.7219
UO2SCN+	8.646e-154	2.836e-148	0.9340	-153.0928
Cd(NH3)4++	8.357e-159	1.508e-153	0.7623	-158.1958
Ethanol(aq)	7.051e-163	3.247e-158	1.0000	-162.1518
Ethyne(aq)	1.925e-163	5.012e-159	1.0000	-162.7155
Ethylene(aq)	1.080e-167	3.028e-163	1.0000	-166.9667
Lactate	5.553e-169	4.945e-164	0.9340	-168.2851
Ca(Lac)+	5.282e-171	6.820e-166	0.9340	-170.3068
Mg(Lac)+	1.615e-171	1.831e-166	0.9340	-170.8213
Na(Lac)(aq)	7.942e-172	8.897e-167	1.0000	-171.1001
K(Lac)(aq)	3.509e-172	4.496e-167	1.0000	-171.4548
Mn(Lac)+	1.345e-172	1.936e-167	0.9340	-171.9009
Cu(Lac)+	9.973e-173	1.522e-167	0.9340	-172.0308
Lactic_acid(aq)	9.798e-173	8.823e-168	1.0000	-172.0089
Fe(Lac)+	8.374e-173	1.213e-167	0.9340	-172.1067
Ba(Lac)+	1.276e-174	2.888e-169	0.9340	-173.9237
Pb(Lac)+	1.074e-174	3.180e-169	0.9340	-173.9987
Cd(Lac)+	2.094e-175	4.217e-170	0.9340	-174.7087
Ethane(aq)	5.700e-179	1.713e-174	1.0000	-178.2441
Propanoate	2.820e-182	2.060e-177	0.9340	-181.5794
Propanoic_acid(a	5.183e-185	3.838e-180	1.0000	-184.2854
Ca(Prop)+	4.362e-185	4.934e-180	0.9340	-184.3900
Na(Prop)(aq)	3.977e-185	3.820e-180	1.0000	-184.4004
Mg(Prop)+	2.285e-185	2.224e-180	0.9340	-184.6708
K(Prop)(aq)	1.757e-185	1.970e-180	1.0000	-184.7553
Mn(Prop)+	4.675e-186	5.983e-181	0.9340	-185.3598
USCN+++	3.557e-186	1.053e-180	0.5458	-185.7118
Cu(Prop)+	2.190e-186	2.991e-181	0.9340	-185.6892
Fe(Prop)+	1.214e-186	1.565e-181	0.9340	-185.9454
Pb(Prop)+	6.223e-188	1.744e-182	0.9340	-187.2356
Ca(Glyc)2(aq)	4.073e-188	7.744e-183	1.0000	-187.3900
S4O6--	3.256e-188	7.300e-183	0.7602	-187.6064
Ba(Prop)+	1.753e-188	3.688e-183	0.9340	-187.7858
Cd(Prop)+	1.663e-188	3.083e-183	0.9340	-187.8088
Mg(Glyc)2(aq)	4.510e-189	7.863e-184	1.0000	-188.3458
Cu(Glyc)2(aq)	4.015e-189	8.574e-184	1.0000	-188.3964
Succinate	1.548e-189	1.796e-184	0.7602	-188.9293
Fe(Glyc)2(aq)	1.403e-189	2.888e-184	1.0000	-188.8531
Mn(Glyc)2(aq)	3.515e-190	7.205e-185	1.0000	-189.4541
Na(Glyc)2-	2.094e-190	3.623e-185	0.9340	-189.7087
K(Glyc)2-	7.899e-191	1.494e-185	0.9340	-190.1320
Pb(Glyc)2(aq)	1.491e-191	5.325e-186	1.0000	-190.8265
H-Succinate	1.417e-191	1.659e-186	0.9340	-190.8782
Serine(aq)	8.086e-192	8.495e-187	1.0000	-191.0923
Ba(Glyc)2(aq)	3.253e-192	9.348e-187	1.0000	-191.4877
Cd(Glyc)2(aq)	2.292e-192	6.014e-187	1.0000	-191.6398
Succinic_acid(aq	5.917e-195	6.985e-190	1.0000	-194.2279
Ethanamine(aq)	1.200e-201	5.408e-197	1.0000	-200.9208

Alanine(aq)	3.325e-203	2.961e-198	1.0000	-202.4782
Cu(Ala)+	4.520e-204	6.852e-199	0.9340	-203.3745
Fe(Ala)+	2.040e-207	2.935e-202	0.9340	-206.7200
Mn(Ala)+	2.888e-208	4.129e-203	0.9340	-207.5691
Mg(Ala)+	2.456e-208	2.759e-203	0.9340	-207.6395
Ca(Ala)+	8.981e-209	1.151e-203	0.9340	-208.0763
Pb(Ala)+	2.105e-209	6.213e-204	0.9340	-208.7065
Cd(Ala)+	1.806e-209	3.619e-204	0.9340	-208.7730
Ca(CH3COO)2(aq)	4.394e-211	6.948e-206	1.0000	-210.3571
Mg(CH3COO)2(aq)	2.037e-211	2.899e-206	1.0000	-210.6911
Ba(Ala)+	6.780e-212	1.528e-206	0.9340	-211.1984
Cu(CH3COO)2(aq)	2.294e-212	4.166e-207	1.0000	-211.6393
Mn(CH3COO)2(aq)	9.922e-213	1.716e-207	1.0000	-212.0034
Na(CH3COO)2-	4.892e-213	6.900e-208	0.9340	-212.3401
Acetone(aq)	3.667e-213	2.129e-208	1.0000	-212.4357
Fe(CH3COO)2(aq)	3.398e-213	5.908e-208	1.0000	-212.4688
K(CH3COO)2-	9.991e-214	1.570e-208	0.9340	-213.0300
Aspartic_acid(aq	9.492e-214	1.263e-208	1.0000	-213.0227
Pb(CH3COO)2(aq)	1.654e-214	5.379e-209	1.0000	-213.7814
Ba(CH3COO)2(aq)	1.165e-214	2.973e-209	1.0000	-213.9339
Cd(CH3COO)2(aq)	1.136e-214	2.618e-209	1.0000	-213.9445
Al(CH3COO)2+	1.280e-216	1.856e-211	0.9340	-215.9224
Propanal(aq)	1.441e-217	8.364e-213	1.0000	-216.8415
Cu(CH3COO)2-	2.516e-220	4.569e-215	0.9340	-219.6289
1-Propyne(aq)	3.246e-236	1.300e-231	1.0000	-235.4887
S3--	4.451e-238	4.281e-233	0.7602	-237.4706
1-Propanol(aq)	7.748e-240	4.655e-235	1.0000	-239.1108
1-Propene(aq)	2.159e-242	9.083e-238	1.0000	-241.6657
2-Hydroxybutanoa	2.173e-246	2.240e-241	0.9340	-245.6926
NH4(CH3COO)2-	6.643e-247	9.040e-242	0.9340	-246.2073
Asparagine(aq)	5.308e-248	7.011e-243	1.0000	-247.2751
Cu(Gly)2(aq)	1.330e-249	2.814e-244	1.0000	-248.8762
2-Hydroxybutanoi	3.392e-250	3.531e-245	1.0000	-249.4695
Propane(aq)	2.492e-256	1.099e-251	1.0000	-255.6034
Mg(Gly)2(aq)	9.046e-257	1.559e-251	1.0000	-256.0436
Diglycine(aq)	5.573e-257	7.361e-252	1.0000	-256.2539
Mn(Gly)2(aq)	6.512e-258	1.322e-252	1.0000	-257.1863
Fe(Gly)2(aq)	6.075e-258	1.239e-252	1.0000	-257.2164
Pb(Gly)2(aq)	1.045e-258	3.712e-253	1.0000	-257.9809
Cd(Gly)2(aq)	3.868e-259	1.008e-253	1.0000	-258.4125
Diketopiperazine	2.065e-259	2.355e-254	1.0000	-258.6852
Butanoate	8.722e-260	7.594e-255	0.9340	-259.0890
Ca(Gly)2(aq)	3.883e-261	7.305e-256	1.0000	-260.4109
Butanoic_acid(aq	1.279e-262	1.127e-257	1.0000	-261.8930
Na(But)(aq)	1.185e-262	1.304e-257	1.0000	-261.9264
Ca(But)+	9.246e-263	1.176e-257	0.9340	-262.0637
K(But)(aq)	5.233e-263	6.602e-258	1.0000	-262.2812
Mg(But)+	4.616e-263	5.141e-258	0.9340	-262.3654
Mn(But)+	1.234e-263	1.752e-258	0.9340	-262.9384
Ba(Gly)2(aq)	8.744e-264	2.495e-258	1.0000	-263.0583
Cu(But)+	5.362e-264	8.075e-259	0.9340	-263.3003
Fe(But)+	3.890e-264	5.559e-259	0.9340	-263.4397
Pb(But)+	5.377e-266	1.582e-260	0.9340	-265.2991
Glutarate	4.038e-266	5.252e-261	0.7602	-265.5129
Ba(But)+	3.625e-266	8.133e-261	0.9340	-265.4703
Cd(But)+	2.172e-266	4.331e-261	0.9340	-265.6928
H-Glutarate	2.145e-268	2.812e-263	0.9340	-267.6982
Threonine(aq)	2.561e-269	3.050e-264	1.0000	-268.5916
Glutaric_acid(aq	1.131e-271	1.494e-266	1.0000	-270.9466
Ethylacetate(aq)	8.605e-272	7.580e-267	1.0000	-271.0652
S5O6--	5.017e-273	1.286e-267	0.7602	-272.4186
1-Propanamine(aq	4.451e-278	2.630e-273	1.0000	-277.3516
a-Aminobutyric_a	2.219e-280	2.288e-275	1.0000	-279.6538

Glutamic_acid(aq	2.843e-289	4.182e-284	1.0000	-288.5462
UO2(SCN)2(aq)	5.421e-295	2.093e-289	1.0000	-294.2659
Butanal(aq)	1.521e-296	1.096e-291	1.0000	-295.8179
S4--	3.691e-307	4.733e-302	0.7602	-300.0000
1-Butyne(aq)	9.427e-314	5.097e-309	1.0000	-300.0000
Cu(CH3COO)3-	2.536e-315	6.101e-310	0.9340	-300.0000
Mn(CH3COO)3-	1.090e-316	2.529e-311	0.9340	-300.0000
Pb(CH3COO)3-	5.705e-317	2.192e-311	0.9340	-300.0000
1-Butanol(aq)	4.502e-318	3.336e-313	1.0000	-300.0000
Cd(CH3COO)3-	1.047e-318	3.031e-313	0.9340	-300.0000
1-Butene(aq)	4.018e-320	2.254e-315	1.0000	-300.0000
2-Hydroxypentano	9.881e-324	1.157e-318	0.9340	-300.0000
m-Toluate	0.0000	0.0000	0.9340	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9340	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9340	-300.0000
H-Suberate	0.0000	0.0000	0.9340	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
H-Sebacate	0.0000	0.0000	0.9340	-300.0000
H-Pimelate	0.0000	0.0000	0.9340	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9340	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
H-Adipate	0.0000	0.0000	0.9340	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7602	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9340	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sb2S4--	0.0000	0.0000	0.7602	-300.0000
Glutamine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7602	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7602	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)+	0.0000	0.0000	0.9340	-300.0000
Pb(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)+	0.0000	0.0000	0.9340	-300.0000
Pb(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.7602	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9340	-300.0000

Fe(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9340	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9340	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9340	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9340	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9340	-300.0000
Benzoate	0.0000	0.0000	0.9364	-300.0000
Pentanoate	0.0000	0.0000	0.9340	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9340	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9340	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9340	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9340	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9340	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9340	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7602	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9340	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9340	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000

U(SCN)2++	0.0000	0.0000	0.7623	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9340	-300.0000
K(Prop)2-	0.0000	0.0000	0.9340	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9340	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9340	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9340	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9340	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9340	-300.0000
Azelate	0.0000	0.0000	0.7602	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9340	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9340	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9340	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9340	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7602	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9340	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9340	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Nontronite-Ca	24.0610s/sat	UO2SO4:H2O	-11.4745
Nontronite-Mg	24.0018s/sat	Periclase	-11.5055
Nontronite-K	23.9782s/sat	Na2U2O7	-11.5658
Nontronite-Na	23.6867s/sat	BaU2O7	-11.6171
Nontronite-H	23.1641s/sat	Gyrolite	-11.7632

Hematite	19.7244s/sat	Przhevalskite	-11.7686
Magnetite	17.6186s/sat	MgUO4	-11.9889
Ferrite-Cu	17.4432s/sat	MnSO4	-11.9908
Cronstedtite-7A	16.8508s/sat	Portlandite	-12.1114
Delafossite	13.3051s/sat	CdSO4	-12.2077
Muscovite	11.6819s/sat	Thermonatrite	-12.3064
Clinoptilolite-K	11.5219s/sat	Monticellite	-12.3126
Clinoptilolite-h	11.3112s/sat	Mg1.5SO4(OH)	-12.3271
Clinoptilolite-C	11.2223s/sat	UO2.6667	-12.4774
Clinoptilolite-h	11.1664s/sat	UO2ClOH:2H2O	-12.5632
Stilbite	9.9090s/sat	UPO5	-12.5666
Goethite	9.4029s/sat	Bassetite	-12.5815
Epidote-ord	8.9314s/sat	Na2CO3	-12.6407
Epidote	8.9302s/sat	PbF2	-12.8823
Ferrite-Ca	8.6944s/sat	FeSO4	-13.0359
Ferrite-Mg	8.6061s/sat	Pb4SO7	-13.1486
Andradite	8.4866s/sat	MgSO4	-13.2479
Clinoptilolite-N	8.0805s/sat	Autunite-H	-13.2709
Clinoptilolite-h	8.0785s/sat	Uraninite	-13.5459
Illite	8.0043s/sat	Chalcocyanite	-13.6864
Paragonite	7.7237s/sat	Coffinite	-13.8779
Beidellite-Ca	7.6983s/sat	Mordenite-dehy	-14.0939
Beidellite-Mg	7.6389s/sat	FeF2	-14.2240
Beidellite-K	7.6155s/sat	BaCl2:2H2O	-14.3087
Fluorapatite	7.5759s/sat	CdCl2:H2O	-14.5815
Beidellite-Na	7.3238s/sat	BaCl2:H2O	-15.0521
Kaolinite	7.1973s/sat	CdCl2	-15.7091
Mesolite	7.0041s/sat	Tremolite	-15.8439
Beidellite-H	6.8019s/sat	NaUO3	-15.8577
Pyrophyllite	6.4386s/sat	UO2SO4:3.5H2O	-15.9348
Montmor-Mg	6.2567s/sat	MnCl2:4H2O	-15.9710
Montmor-Ca	6.2407s/sat	UO2SO4:2.5H2O	-16.0021
Montmor-K	6.2332s/sat	UO2SO4:3H2O	-16.0786
Jarosite	5.9532s/sat	Ba(OH)2:8H2O	-16.1594
Montmor-Na	5.9366s/sat	UO2F2:3H2O	-16.3316
Scolecite	5.4960s/sat	CaAl2O4	-16.3873
Maximum_Microcli	4.5705s/sat	Ca3(AsO4)2	-16.4735
K-Feldspar	4.5684s/sat	BaCl2	-16.6139
Margarite	4.1511s/sat	Alum-K	-16.6297
Laumontite	4.0984s/sat	UO2F2	-16.6676
Fe(OH)3	4.0677s/sat	Natrosilite	-16.8718
Smectite-low-Fe-	4.0091s/sat	Ferrite-Dicalciu	-16.9597
Celadonite	3.8127s/sat	MgOHCl	-17.3554
Diaspore	3.3185s/sat	MnCl2:2H2O	-17.4369
Sanidine_high	3.2644s/sat	Na2SiO3	-17.4718
Smectite-high-Fe	3.0260s/sat	CdF2	-17.5383
Boehmite	2.8876s/sat	CaAl4O7	-17.6780
Gibbsite	2.8007s/sat	Ba2Si3O8	-17.8141
Lawsonite	2.5870s/sat	Ningyoite	-18.1233
Corundum	2.3175s/sat	Gehlenite	-18.3635
Mordenite	2.0194s/sat	CuCl2	-18.6291
Witherite	1.6268s/sat	UO2.3333(beta)	-18.6336
Albite_low	1.5496s/sat	MnCl2:H2O	-19.1330
Albite	1.5495s/sat	Hydromagnesite	-19.1736
Kyanite	1.3831s/sat	Hillebrandite	-19.2131
Chamosite-7A	1.1198s/sat	MgCl2:4H2O	-19.6637
Andalusite	1.0714s/sat	Dicalcium_silica	-19.7022
Analcime	0.9446s/sat	UO2SO4	-19.8883
Strengite	0.7263s/sat	Na2UO4(alpha)	-20.6659
Natrolite	0.7143s/sat	Akermanite	-21.0592
Dawsonite	0.6850s/sat	Larnite	-21.0869
Sillimanite	0.6766s/sat	UOFOH:.5H2O	-21.4934
Amesite-14A	0.5198s/sat	UO2(NO3)2:6H2O	-21.5385

Quartz	0.5111s/sat	UOFOH	-22.0073
Tenorite	0.4417s/sat	Scacchite	-22.5648
Barite	0.3740s/sat	Lime	-22.7566
Malachite	0.3128s/sat	UO2Cl	-22.9236
Tridymite	0.3109s/sat	Anthophyllite	-22.9670
Chalcedony	0.2250s/sat	UO2(NO3)2:3H2O	-23.2130
Kalsilite	0.1931s/sat	Lawrencite	-23.9555
Albite_high	0.1248s/sat	Hydrophilite	-24.0314
Cerussite	0.0690s/sat	(UO2)3(PO4)2	-24.0352
Hercynite	0.0040s/sat	UO2(PO3)2	-24.2117
Cristobalite(alp	-0.0756	UOF2:H2O	-24.4568
Ice	-0.0801	(UO2)2P2O7	-24.5886
Daphnite-14A	-0.1214	UO2(NO3)2:2H2O	-24.5913
Annite	-0.1563	K2UO4	-25.1056
Coesite	-0.3408	UOF2	-25.1163
Rhodochrosite	-0.3971	Pargasite	-25.5128
Alunite	-0.4092	MgCl2:2H2O	-25.5346
Cristobalite(bet	-0.5645	U(HPO4)2:4H2O	-26.2050
Jadeite	-0.5830	KAl(SO4)2	-26.3129
Wairakite	-0.8187	UP2O7	-26.5844
Calcite	-0.8567	Clinoptilolite-d	-26.5887
Prehnite	-0.8921	Pb	-26.7311
SiO2(am)	-0.9059	Clinoptilolite-d	-26.8482
Brochantite	-0.9421	Rankinite	-27.3705
Aragonite	-1.0019	UO2Cl2:3H2O	-27.5716
Dolomite-ord	-1.0227	UO2(NO3)2:H2O	-28.4507
Dolomite	-1.0228	MgCl2:H2O	-29.1366
Clinozoisite	-1.0796	Ettringite	-29.5737
Zoisite	-1.1280	Clinoptilolite-d	-30.0045
Dioptase	-1.4290	Tobermorite-14A	-30.5170
Siderite	-1.4705	UO2Cl2:H2O	-30.5511
Monohydrocalcite	-1.6548	UO2(NO3)2	-32.1551
Magnesite	-1.8935	Tobermorite-11A	-32.7957
Phlogopite	-2.0781	Ba2SiO4	-32.8349
Anorthite	-2.3337	KMgCl3:2H2O	-33.7781
Alamosite	-2.4805	Merwinite	-33.9304
Gypsum	-2.6257	Foshagite	-34.0648
Nepheline	-2.6762	UO2SO3	-34.3220
Dolomite-dis	-2.6852	UF4:2.5H2O	-34.4447
Saponite-Ca	-2.6969	UO2Cl2	-34.6812
Ferrosilite	-2.7113	As2O5	-34.7713
Hydroxylapatite	-2.7175	Chloromagnesite	-35.2559
Saponite-Mg	-2.7544	Afwillite	-35.6535
Saponite-K	-2.7797	Tobermorite-9A	-36.6671
Ripidolite-14A	-2.7966	Al2(SO4)3:6H2O	-36.9451
Minnesotaite	-2.9269	Cd	-37.0931
Anhydrite	-2.9562	BaSiF6	-37.4342
Berlinite	-2.9702	Fe	-37.5511
Saponite-Na	-3.0713	(UO2)2As2O7	-38.0505
Sb2O3	-3.2858	(UO2)3(AsO4)2	-38.4038
Fluorite	-3.3627	UO2(AsO3)2	-38.5966
Whitlockite	-3.4211	UF4	-39.0200
Saponite-H	-3.5935	Molysite	-39.1837
Bassanite	-3.6061	Fe2(SO4)3	-40.8566
Bixbyite	-3.6161	BaO	-41.4826
Anglesite	-3.6356	KMgCl3	-41.5896
Daphnite-7A	-3.6391	U(SO4)2:8H2O	-43.0272
UO3:2H2O	-3.6685	Ba2U2O7	-44.2948
Schoepite	-3.6689	U(SO4)2:4H2O	-44.3756
CaSO4:0.5H2O(bet	-3.7944	Arsenolite	-44.3856
UO2(OH)2(beta)	-3.8386	Claudetite	-44.4636
Atacamite	-3.8555	U(SO4)2	-44.6522
CaUO4	-3.8647	Hatrurite	-46.3403

Schoepite-dehy(.	-3.8987	C	-46.4605
UO3:.9H2O(alpha)	-3.9074	UOCl2	-47.5982
Talc	-3.9662	U(CO3)2	-47.7078
Schoepite-dehy(.	-3.9932	Xonotlite	-49.4047
Schoepite-dehy(1	-4.0106	UClF3	-50.2154
Rhodonite	-4.0964	U5O12Cl	-51.2334
Lanarkite	-4.1830	As	-53.9343
Pyrolusite	-4.3976	UOF4	-54.7846
Paralaurionite	-4.5288	Al2(SO4)3	-55.7908
Greenalite	-4.5881	Na3UO4	-56.6928
Wustite	-4.6295	Na	-58.3728
Enstatite	-4.6534	(UO2)2Cl3	-58.8125
Sellaite	-4.6641	Na4SiO4	-58.8631
Cuprite	-4.7682	UOCl3	-59.9838
CdSiO3	-4.8478	Ca4Al2Fe2O10	-60.5776
UO2CO3	-4.8596	UF3	-61.1693
Rutherfordine	-4.8721	Na2O	-61.4427
Nesquehonite	-5.0212	Mn	-61.7406
Azurite	-5.0803	UF5(beta)	-61.9597
Clinochlore-14A	-5.0954	Pb2Cl5NH4	-62.2028
Schoepite-dehy(.	-5.1883	UF5(alpha)	-62.3700
Hausmannite	-5.4276	K	-62.3809
FeO	-5.4556	Ca3Al2O6	-62.9272
Nahcolite	-5.4894	UCl2F2	-63.7250
Niter	-5.5785	UOCl	-65.8346
Fe(OH)2	-5.7284	Covellite	-69.0549
Schoepite-dehy(.	-5.7414	S	-69.9185
Analcime-dehy	-5.8091	Ba3UO6	-71.3863
Cordierite_hydr	-5.9918	U2O3F6	-71.6004
UO2HPO4:4H2O	-6.0036	Chalcocite	-71.8049
Brucite	-6.0971	UCl3F	-77.0497
Litharge	-6.1024	CdS	-78.0417
Fayalite	-6.1887	Galena	-78.7573
Mn(OH)2(am)	-6.1908	K2O	-79.3570
NaFeO2	-6.2404	U(SO3)2	-84.7232
Massicot	-6.3009	CdCl2(NH3)2	-85.6482
Ripidolite-7A	-6.3055	Na6Si2O7	-85.6599
PbCO3.PbO	-6.3161	PbSO4(NH3)2	-88.1848
Okenite	-6.5149	UCl4	-88.2143
Wollastonite	-6.6168	As4O6(mono)	-88.4418
UO3(gamma)	-6.8306	As4O6(cubi)	-88.6466
Pseudowollastoni	-6.8845	Troilite	-88.7415
Diopside	-6.9016	Pyrrhotite	-88.8459
Chrysotile	-7.0139	Alabandite	-91.3540
Spinel	-7.1008	UCl3	-91.7745
Melanterite	-7.2350	UF6	-93.9116
Chalcanthite	-7.4122	U3O5F8	-95.6270
UO3(beta)	-7.4677	U2F9	-97.6707
Mirabilite	-7.5725	Antigorite	-97.8227
Cd(OH)2	-7.6130	Mg	-102.4786
Hedenbergite	-7.6327	U2O2Cl5	-108.8785
PbFCl	-7.7071	UCl5	-109.2428
UO3(alpha)	-7.8241	BaS	-109.8190
Sylvite	-7.8489	UN1.73(alpha)	-110.3087
Nantokite	-7.8824	UN1.59(alpha)	-113.1774
Arcanite	-7.9461	Ca	-120.1222
FeF3	-8.1732	P	-121.1463
Huntite	-8.2235	Al	-123.6654
Tephroite	-8.3048	Ba	-124.2316
Pb2SiO4	-8.3227	UN	-126.8316
Halite	-8.4329	UCl6	-129.0533
Cd(OH)Cl	-8.4438	Si	-129.1162
Sanbornite	-8.4613	Pb(N3)2(orth)	-142.1078

Ca-Al_Pyroxene	-8.4900	Pb(N3)2(mono)	-142.5660
UO2FOH:2H2O	-8.5189	Pyrite	-147.6645
Clinochlore-7A	-8.5997	Chalcopyrite	-151.5676
Saleeite	-8.6297	CdCl2(NH3)4	-166.3220
Pb3SO6	-8.6313	PbSO4(NH3)4	-170.5482
Cordierite_anhyd	-8.6374	U4F17	-174.7960
Artinite	-8.8169	U	-175.6177
Cu	-8.8863	UAs	-185.6128
BaUO4	-8.9149	US	-186.2053
UO2FOH:H2O	-8.9823	UC	-203.8066
Manganosite	-9.0285	UH3(beta)	-206.2714
Thenardite	-9.1122	US1.9	-214.2909
Monteponite	-9.1230	US2	-219.4698
Phosgenite	-9.1512	Mayenite	-231.4603
Nitrobarite	-9.2798	UAs2	-236.7694
Grossular	-9.3527	CdCl2(NH3)6	-247.0924
AlF3	-9.3831	UP	-247.5751
UO2FOH	-9.5152	UC1.94(alpha)	-249.6152
Sepiolite	-9.7066	Stibnite	-261.4143
(UO2)3(PO4)2:4H2	-10.0708	US3	-286.0477
UO2.25	-10.1867	Orpiment	-286.4530
Torbernite	-10.1937	Pb(SCN)2	-289.7630
CdSO4:2.667H2O	-10.2062	Bornite	-294.8740
Natron	-10.2284	UP2	-363.3746
UO2.25(beta)	-10.2558	U2S3	-398.3827
Uranocircite	-10.2634	o-Phthalic_acid	-408.1520
CdSO4:H2O	-10.4703	U2C3	-455.6804
Na2CO3:7H2O	-10.8072	U3As4	-608.5652
Mg1.25SO4(OH)0.5	-10.8753	U3S5	-613.0206
Cotunnite	-10.8845	U3P4	-858.5242
Forsterite	-11.0962		

Gases	fugacity	log fug.
N2(g)	0.2577	-0.589
H2O(g)	0.009706	-2.013
CO2(g)	0.001832	-2.737
NO2(g)	2.591e-012	-11.587
HF(g)	4.813e-015	-14.318
HCl(g)	2.506e-019	-18.601
O2(g)	6.928e-030	-29.159
H2(g)	1.855e-030	-29.732
NO(g)	1.530e-031	-30.815
CO(g)	1.140e-036	-35.943
SiF4(g)	4.390e-040	-39.358
NH3(g)	2.707e-042	-41.568
Cl2(g)	2.312e-043	-42.636
SO2(g)	2.374e-044	-43.625
Cd(g)	2.006e-052	-51.698
Pb(g)	9.291e-058	-57.032
UO2F2(g)	3.398e-062	-61.469
Cu(g)	5.202e-065	-64.284
Na(g)	1.297e-073	-72.887
UO2Cl2(g)	7.440e-074	-73.128
K(g)	1.480e-074	-73.830
UO3(g)	6.799e-075	-74.168
UOF4(g)	8.824e-077	-76.054
UF5(g)	6.555e-084	-83.183
UF4(g)	1.455e-086	-85.837
H2S(g)	2.677e-094	-93.572
UF6(g)	6.135e-096	-95.212
CH4(g)	4.794e-097	-96.319
F2(g)	2.212e-101	-100.655

UCl4(g)	2.677e-115	-114.572
UO2(g)	1.285e-116	-115.891
Mg(g)	2.534e-124	-123.596
UCl5(g)	1.070e-128	-127.971
UF3(g)	7.441e-133	-132.128
UCl6(g)	1.961e-136	-135.708
U2F10(g)	4.184e-140	-139.378
UCl3(g)	2.806e-141	-140.552
Ca(g)	8.886e-148	-147.051
S2(g)	1.079e-155	-154.967
C2H4(g)	1.495e-165	-164.825
C(g)	1.109e-171	-170.955
UF2(g)	9.334e-176	-175.030
Al(g)	2.991e-178	-177.524
UCl2(g)	2.018e-185	-184.695
UO(g)	1.516e-191	-190.819
Si(g)	3.238e-205	-204.490
UF(g)	8.035e-212	-211.095
U2Cl8(g)	2.195e-218	-217.659
UCl(g)	5.286e-227	-226.277
U2Cl10(g)	2.063e-228	-227.685
U(g)	4.774e-267	-266.321

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Al+++	3.98e-006	3.98e-006	0.107			
Ba++	6.90e-007	6.90e-007	0.0948			
Ca++	0.000415	0.000415	16.6			
Cd++	7.74e-009	7.74e-009	0.000870			
Cl-	0.000110	0.000110	3.91			
Cu++	4.31e-007	4.31e-007	0.0274			
F-	1.03e-005	1.03e-005	0.195			
Fe++	1.05e-006	1.05e-006	0.0586			
H+	8.45e-005	8.45e-005	0.0851			
H2AsO4-	2.61e-008	2.61e-008	0.00368			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00159	0.00159	96.7			
HPO4--	4.23e-006	4.23e-006	0.406			
K+	0.000675	0.000675	26.4			
Mg++	0.000161	0.000161	3.91			
Mn++	9.85e-006	9.85e-006	0.541			
NH3(aq)	0.000443	0.000443	7.55			
NO3-	0.00123	0.00123	76.1			
Na+	0.00132	0.00132	30.3			
O2(aq)	0.000333	0.000333	10.6			
Pb++	1.23e-008	1.23e-008	0.00254			
S2--	6.10e-007	6.10e-007	0.0391			
SO4--	0.000336	0.000336	32.2			
Sb(OH)3(aq)	3.69e-007	3.69e-007	0.0638			
SiO2(aq)	0.000138	0.000138	8.30			
UO2++	1.19e-008	1.19e-008	0.00321			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Aluminum	3.984e-006	3.984e-006	0.1075		
Antimony	3.692e-007	3.692e-007	0.04494		
Arsenic	2.609e-008	2.609e-008	0.001954		
Barium	6.903e-007	6.903e-007	0.09477		
Cadmium	7.737e-009	7.737e-009	0.0008695		
Calcium	0.0004145	0.0004145	16.61		
Carbon	0.001586	0.001586	19.04		

Chlorine	0.0001103	0.0001103	3.908
Copper	4.306e-007	4.306e-007	0.02736
Fluorine	1.029e-005	1.029e-005	0.1954
Hydrogen	111.0	111.0	1.119e+005
Iron	1.050e-006	1.050e-006	0.05862
Lead	1.226e-008	1.226e-008	0.002540
Magnesium	0.0001608	0.0001608	3.908
Manganese	9.855e-006	9.855e-006	0.5412
Nitrogen	0.001671	0.001671	23.40
Oxygen	55.52	55.52	8.880e+005
Phosphorus	4.228e-006	4.228e-006	0.1309
Potassium	0.0006749	0.0006749	26.38
Silicon	0.0001383	0.0001383	3.882
Sodium	0.001318	0.001318	30.29
Sulfur	0.0003369	0.0003369	10.80
Uranium	1.191e-008	1.191e-008	0.002833

```
Temperature =  25.0 C    Pressure =  1.013 bars
pH =  7.200              log fO2 =  -30.382
Eh =   0.3538 volts      pe =   5.9809
Ionic strength      =    0.002470
Charge imbalance    =    0.000089 eq/kg (5.785% error)
Activity of water   =    1.000000
Solvent mass        =    1.000000 kg
Solution mass       =    1.000136 kg
Solution density    =    1.013    g/cm3
Chlorinity          =    0.000000 molal
Dissolved solids    =         136 mg/kg sol'n
Elect. conductivity =      151.53 uS/cm (or umho/cm)
Hardness            =       81.16 mg/kg sol'n as CaCO3
  carbonate         =       60.86 mg/kg sol'n as CaCO3
  non-carbonate     =       20.30 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       60.86 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3538	5.9809
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5662	9.5714

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001205	73.50	0.9468	-2.9428
Ca++	0.0006018	24.11	0.8082	-3.3131
Mg++	0.0001886	4.584	0.8132	-3.8142
CO2(aq)	0.0001592	7.004	1.0000	-3.7981
SO4--	0.0001330	12.77	0.8029	-3.9716
SiO2(aq)	7.546e-005	4.533	1.0000	-4.1223
NO3-	2.742e-005	1.700	0.9460	-4.5861
CaSO4(aq)	6.706e-006	0.9128	1.0000	-5.1736
CaHCO3+	6.525e-006	0.6595	0.9468	-5.2092
MgSO4(aq)	4.226e-006	0.5086	1.0000	-5.3740
N2(aq)	2.763e-006	0.07738	1.0000	-5.5587
MgHCO3+	2.007e-006	0.1712	0.9468	-5.7213
CO3--	1.054e-006	0.06326	0.8043	-6.0716
CuCO3(aq)	9.471e-007	0.1170	1.0000	-6.0236
CaCO3(aq)	8.758e-007	0.08764	1.0000	-6.0576
OH-	1.694e-007	0.002880	0.9464	-6.7951
Cu++	1.532e-007	0.009733	0.8082	-6.9073
HSiO3-	1.409e-007	0.01086	0.9468	-6.8748
MgCO3(aq)	1.239e-007	0.01045	1.0000	-6.9069
CuOH+	1.069e-007	0.008610	0.9468	-6.9948
Mn++	1.027e-007	0.005642	0.8082	-7.0809
CaNO3+	6.678e-008	0.006816	0.9468	-7.1991
H+	6.638e-008	6.690e-005	0.9505	-7.2000
HAsO4--	5.043e-008	0.007055	0.8029	-7.3927
H2AsO4-	1.547e-008	0.002179	0.9468	-7.8344
CuSO4(aq)	3.028e-009	0.0004832	1.0000	-8.5188
MnCO3(aq)	2.331e-009	0.0002679	1.0000	-8.6325
MnSO4(aq)	1.997e-009	0.0003016	1.0000	-8.6996
Cu(CO3)2--	1.685e-009	0.0003093	0.8029	-8.8686
CaOH+	1.150e-009	6.564e-005	0.9468	-8.9631
MnHCO3+	7.615e-010	8.828e-005	0.9468	-9.1421
HSO4-	6.781e-010	6.581e-005	0.9468	-9.1925
Cu+	7.349e-011	4.669e-006	0.9468	-10.1575
MnOH+	3.572e-011	2.569e-006	0.9468	-10.4709

MnNO3+	3.604e-012	4.214e-007	0.9468	-11.4669
AsO4---	2.629e-012	3.652e-007	0.6101	-11.7948
CuCO3(OH)2--	2.519e-012	3.969e-007	0.8029	-11.6941
H2SiO4--	2.588e-013	2.435e-008	0.8029	-12.6823
H3AsO4(aq)	1.640e-013	2.328e-008	1.0000	-12.7852
HNO3(aq)	8.155e-014	5.138e-009	1.0000	-13.0886
Mn(OH)2(aq)	1.316e-015	1.170e-010	1.0000	-14.8809
H6(H2SiO4)4--	2.323e-016	8.884e-011	0.8029	-15.7292
Mn(NO3)2(aq)	2.223e-016	3.978e-011	1.0000	-15.6530
Mn2(OH)3+	3.648e-017	5.868e-012	0.9468	-16.4617
Mn2OH+++	4.894e-018	6.208e-013	0.6147	-17.5217
CuO2--	3.454e-018	3.300e-013	0.8029	-17.5570
H2SO4(aq)	4.051e-020	3.972e-015	1.0000	-19.3925
HAsO2(aq)	2.240e-020	2.417e-015	1.0000	-19.6498
Mn(OH)3-	2.066e-020	2.189e-015	0.9468	-19.7087
As(OH)3(aq)	1.887e-020	2.376e-015	1.0000	-19.7242
AsO2-	2.022e-022	2.162e-017	0.9468	-21.7179
H2AsO3-	1.971e-022	2.462e-017	0.9468	-21.7290
H4(H2SiO4)4----	5.654e-024	2.151e-018	0.4153	-23.6292
AsO2OH--	3.542e-026	4.388e-021	0.8029	-25.5461
Mg4(OH)4++++	1.467e-026	2.424e-021	0.4236	-26.2066
Mn+++	3.383e-027	1.858e-022	0.6147	-26.6821
Mn(OH)4--	3.269e-027	4.020e-022	0.8029	-26.5809
Formate	8.240e-030	3.709e-025	0.9464	-29.1080
H2(aq)	3.417e-030	6.887e-027	1.0000	-29.4664
Ca(For)+	1.078e-031	9.175e-027	0.9468	-30.9910
Mg(For)+	3.402e-032	2.358e-027	0.9468	-31.4921
NO2-	1.316e-032	6.054e-028	0.9460	-31.9048
Formic_acid(aq)	2.786e-033	1.282e-028	1.0000	-32.5550
O2(aq)	5.243e-034	1.677e-029	1.0000	-33.2804
SO3--	1.377e-034	1.102e-029	0.8043	-33.9558
HSO3-	1.184e-034	9.598e-030	0.9468	-33.9504
NH4+	1.037e-034	1.871e-030	0.9455	-34.0084
Cu(For)+	9.736e-035	1.057e-029	0.9468	-34.0354
Mn(For)+	3.425e-035	3.423e-030	0.9468	-34.4891
CO(aq)	6.269e-036	1.756e-031	1.0000	-35.2028
HNO2(aq)	1.306e-036	6.137e-032	1.0000	-35.8842
NH3(aq)	8.924e-037	1.520e-032	1.0000	-36.0494
Oxalate	2.428e-037	2.137e-032	0.8029	-36.7100
CuNO2+	1.705e-037	1.867e-032	0.9468	-36.7921
HO2-	1.913e-038	6.312e-034	0.9468	-37.7421
CuNH3++	1.506e-039	1.214e-034	0.8043	-38.9167
H2SO3(aq)	7.202e-040	5.910e-035	1.0000	-39.1426
SO2(aq)	5.127e-040	3.284e-035	1.0000	-39.2902
H-Oxalate	2.346e-040	2.088e-035	0.9468	-39.6534
MnO4--	1.316e-044	1.566e-039	0.8029	-43.9759
HSO5-	8.423e-046	9.522e-041	0.9468	-45.0983
Oxalic_acid(aq)	2.611e-046	2.351e-041	1.0000	-45.5831
NH4SO4-	5.530e-047	6.309e-042	0.9468	-46.2810
MnO4-	4.428e-048	5.266e-043	0.9464	-47.3777
S2O6--	9.386e-058	1.503e-052	0.8029	-57.1229
Ca(For)2(aq)	5.903e-060	7.680e-055	1.0000	-59.2289
Mg(For)2(aq)	1.862e-060	2.129e-055	1.0000	-59.7300
S2O8--	4.093e-062	7.862e-057	0.8029	-61.4833
Cu(For)2(aq)	1.502e-062	2.307e-057	1.0000	-61.8233
Mn(For)2(aq)	3.111e-063	4.510e-058	1.0000	-62.5071
Formaldehyde(aq)	3.674e-064	1.103e-059	1.0000	-63.4349
Cu(NO2)2(aq)	2.056e-068	3.199e-063	1.0000	-67.6869
N3-	3.038e-071	1.276e-066	0.9468	-70.5412
Cu(NH3)2++	3.465e-072	3.381e-067	0.8043	-71.5550
S2O5--	2.383e-073	3.435e-068	0.8029	-72.7181
HN3(aq)	9.096e-074	3.914e-069	1.0000	-73.0411
Urea(aq)	2.455e-076	1.474e-071	1.0000	-75.6099

HCN(aq)	4.299e-077	1.162e-072	1.0000	-76.3667
Methanol(aq)	7.468e-079	2.392e-074	1.0000	-78.1268
CN-	4.184e-079	1.088e-074	0.9460	-78.4026
HS-	1.248e-083	4.128e-079	0.9464	-82.9276
H2S(aq)	7.246e-084	2.469e-079	1.0000	-83.1399
Glycolate	4.726e-085	3.546e-080	0.9468	-84.3493
Ca(Glyc)+	1.027e-086	1.182e-081	0.9468	-86.0124
Mg(Glyc)+	1.549e-087	1.538e-082	0.9468	-86.8338
Glycolic_acid(aq	1.924e-088	1.463e-083	1.0000	-87.7157
Methane(aq)	1.892e-088	3.034e-084	1.0000	-87.7232
Cu(Glyc)+	4.544e-089	6.296e-084	0.9468	-88.3664
S--	2.699e-089	8.653e-085	0.8056	-88.6627
S2O3--	5.938e-090	6.657e-085	0.8029	-89.3217
Mn(Glyc)+	1.498e-090	1.946e-085	0.9468	-89.8484
S2O4--	1.641e-091	2.102e-086	0.8056	-90.8788
Acetate	5.616e-094	3.315e-089	0.9472	-93.2742
HS2O3-	3.281e-096	3.711e-091	0.9468	-95.5078
CaCH3COO+	2.330e-096	2.310e-091	0.9468	-95.6563
Acetic_acid(aq)	1.919e-096	1.152e-091	1.0000	-95.7170
MgCH3COO+	1.639e-096	1.366e-091	0.9468	-95.8092
CuCH3COO+	1.187e-098	1.454e-093	0.9468	-97.9494
MnCH3COO+	7.682e-100	8.755e-095	0.9468	-99.1383
Malonate	8.666e-103	8.842e-098	0.8029	-102.1575
CuCH3COO(aq)	7.908e-104	9.693e-099	1.0000	-103.1019
H-Malonate	2.300e-104	2.370e-099	0.9468	-103.6620
AsH3(aq)	2.167e-104	1.689e-099	1.0000	-103.6642
Cu(NH3)3++	2.046e-105	2.345e-100	0.8043	-104.7837
Malonic_acid(aq)	9.756e-109	1.015e-103	1.0000	-108.0107
Methanamine(aq)	1.514e-112	4.701e-108	1.0000	-111.8199
Glycine(aq)	2.594e-115	1.947e-110	1.0000	-114.5860
Cu(Gly)+	3.331e-116	4.583e-111	0.9468	-115.5012
Mg(Gly)+	3.131e-118	3.079e-113	0.9468	-117.5281
Ca(Gly)+	7.882e-120	8.995e-115	0.9468	-119.1271
S3O6--	6.865e-121	1.319e-115	0.8029	-120.2587
Mn(Gly)+	2.745e-121	3.540e-116	0.9468	-120.5852
Acetaldehyde(aq)	3.533e-126	1.556e-121	1.0000	-125.4519
SCN-	8.148e-127	4.732e-122	0.9464	-126.1129
NH4CH3COO(aq)	8.511e-128	6.559e-123	1.0000	-127.0700
Acetamide(aq)	8.477e-128	5.007e-123	1.0000	-127.0717
Ethanol(aq)	2.595e-145	1.195e-140	1.0000	-144.5858
Ethyne(aq)	3.397e-147	8.845e-143	1.0000	-146.4689
Ethylene(aq)	8.881e-150	2.491e-145	1.0000	-149.0515
Lactate	1.880e-151	1.674e-146	0.9468	-150.7497
Ca(Lac)+	2.403e-153	3.103e-148	0.9468	-152.6429
Mg(Lac)+	6.758e-154	7.661e-149	0.9468	-153.1939
Lactic_acid(aq)	8.189e-155	7.375e-150	1.0000	-154.0868
Cu(Lac)+	8.442e-156	1.288e-150	0.9468	-155.0973
Mn(Lac)+	4.201e-157	6.048e-152	0.9468	-156.4004
Ethane(aq)	4.926e-159	1.481e-154	1.0000	-158.3075
Propanoate	1.820e-162	1.329e-157	0.9468	-161.7638
Propanoic_acid(a	8.423e-165	6.239e-160	1.0000	-164.0746
Ca(Prop)+	4.167e-165	4.714e-160	0.9468	-164.4039
Mg(Prop)+	1.440e-165	1.402e-160	0.9468	-164.8654
Cu(Prop)+	3.679e-167	5.026e-162	0.9468	-166.4580
S4O6--	4.046e-168	9.072e-163	0.8029	-167.4883
Mn(Prop)+	2.829e-168	3.621e-163	0.9468	-167.5721
Succinate	9.884e-170	1.147e-164	0.8029	-169.1004
Ca(Glyc)2(aq)	7.560e-170	1.437e-164	1.0000	-169.1215
Mg(Glyc)2(aq)	6.128e-171	1.069e-165	1.0000	-170.2127
H-Succinate	2.254e-171	2.638e-166	0.9468	-170.6709
Cu(Glyc)2(aq)	1.132e-171	2.418e-166	1.0000	-170.9462
Serine(aq)	2.335e-173	2.453e-168	1.0000	-172.6317
Mn(Glyc)2(aq)	4.471e-174	9.166e-169	1.0000	-173.3496

Succinic_acid(aq	2.171e-174	2.563e-169	1.0000	-173.6634
HAsS2(aq)	1.977e-179	2.769e-174	1.0000	-178.7039
Ethanamine(aq)	7.231e-181	3.260e-176	1.0000	-180.1408
Alanine(aq)	1.413e-182	1.259e-177	1.0000	-181.8498
Cu(Ala)+	4.094e-184	6.207e-179	0.9468	-183.4116
Mg(Ala)+	1.429e-187	1.606e-182	0.9468	-186.8687
Ca(Ala)+	8.637e-188	1.107e-182	0.9468	-187.0874
Ca(CH3COO)2(aq)	1.869e-188	2.955e-183	1.0000	-187.7284
Mg(CH3COO)2(aq)	4.774e-189	6.797e-184	1.0000	-188.3211
Mn(Ala)+	1.473e-189	2.107e-184	0.9468	-188.8555
Acetone(aq)	6.884e-190	3.998e-185	1.0000	-189.1621
Cu(CH3COO)2(aq)	1.501e-190	2.726e-185	1.0000	-189.8236
Mn(CH3COO)2(aq)	2.694e-192	4.661e-187	1.0000	-191.5695
Aspartic_acid(aq	1.027e-192	1.367e-187	1.0000	-191.9885
Propanal(aq)	4.058e-194	2.357e-189	1.0000	-193.3916
Cu(CH3COO)2-	4.153e-197	7.542e-192	0.9468	-196.4054
S3--	1.673e-210	1.609e-205	0.8029	-209.8718
1-Propyne(aq)	1.183e-211	4.741e-207	1.0000	-210.9268
1-Propanol(aq)	9.463e-214	5.686e-209	1.0000	-213.0240
1-Propene(aq)	4.786e-216	2.014e-211	1.0000	-215.3200
2-Hydroxybutanoa	2.663e-220	2.745e-215	0.9468	-219.5984
NH4(CH3COO)2-	3.528e-221	4.802e-216	0.9468	-220.4762
2-Hydroxybutanoi	1.031e-223	1.073e-218	1.0000	-222.9868
Asparagine(aq)	5.844e-224	7.720e-219	1.0000	-223.2333
Cu(Gly)2(aq)	3.929e-226	8.314e-221	1.0000	-225.4058
Propane(aq)	7.684e-228	3.388e-223	1.0000	-227.1144
Butanoate	2.002e-231	1.744e-226	0.9468	-230.7222
Mg(Gly)2(aq)	2.077e-232	3.580e-227	1.0000	-231.6827
Diglycine(aq)	1.745e-232	2.305e-227	1.0000	-231.7582
Butanoic_acid(aq	7.696e-234	6.780e-229	1.0000	-233.1137
Ca(But)+	3.158e-234	4.015e-229	0.9468	-233.5244
Diketopiperazine	1.324e-234	1.510e-229	1.0000	-233.8782
Mg(But)+	1.042e-234	1.161e-229	0.9468	-234.0057
Mn(Gly)2(aq)	1.662e-235	3.374e-230	1.0000	-234.7794
Cu(But)+	3.196e-236	4.814e-231	0.9468	-235.5192
Ca(Gly)2(aq)	2.943e-236	5.537e-231	1.0000	-235.5313
Mn(But)+	2.638e-237	3.746e-232	0.9468	-236.6025
Glutarate	8.524e-238	1.109e-232	0.8029	-237.1647
H-Glutarate	1.191e-239	1.562e-234	0.9468	-238.9478
Threonine(aq)	2.701e-242	3.217e-237	1.0000	-241.5684
Glutaric_acid(aq	1.555e-242	2.054e-237	1.0000	-241.8084
Ethylacetate(aq)	1.433e-242	1.262e-237	1.0000	-241.8438
S5O6--	3.140e-244	8.049e-239	0.8029	-243.5983
1-Propanamine(aq	8.739e-249	5.165e-244	1.0000	-248.0586
a-Aminobutyric_a	3.322e-251	3.425e-246	1.0000	-250.4786
Glutamic_acid(aq	1.133e-259	1.666e-254	1.0000	-258.9459
Butanal(aq)	1.870e-264	1.348e-259	1.0000	-263.7282
S4--	2.291e-271	2.938e-266	0.8029	-270.7353
1-Butyne(aq)	1.259e-280	6.809e-276	1.0000	-279.9000
Cu(CH3COO)3-	1.537e-282	3.699e-277	0.9468	-281.8370
1-Butanol(aq)	2.130e-283	1.579e-278	1.0000	-282.6716
1-Butene(aq)	3.338e-285	1.873e-280	1.0000	-284.4765
Mn(CH3COO)3-	3.290e-285	7.635e-280	0.9468	-284.5065
2-Hydroxypentano	5.562e-289	6.514e-284	0.9468	-288.2785
2-Hydroxypentano	1.298e-292	1.533e-287	1.0000	-291.8867
Glutamine(aq)	7.359e-293	1.075e-287	1.0000	-292.1332
n-Butane(aq)	1.054e-296	6.128e-292	1.0000	-295.9770
Alanylglycine(aq	4.285e-300	6.261e-295	1.0000	-299.3681
Pentanoate	2.651e-300	2.681e-295	0.9468	-299.6003
Pentanoic_acid(a	1.109e-302	1.132e-297	1.0000	-300.0000
Ca(Lac)2(aq)	4.648e-303	1.014e-297	1.0000	-300.0000
Ca(Pent)+	2.445e-303	3.451e-298	0.9468	-300.0000
Mg(Lac)2(aq)	1.193e-303	2.415e-298	1.0000	-300.0000

Mg(Pent)+	7.896e-304	9.902e-299	0.9468	-300.0000
Cu(Lac)2(aq)	5.541e-305	1.339e-299	1.0000	-300.0000
Cu(Pent)+	4.112e-305	6.771e-300	0.9468	-300.0000
Mn(Pent)+	2.636e-306	4.113e-301	0.9468	-300.0000
Mn(Lac)2(aq)	8.317e-307	1.938e-301	1.0000	-300.0000
Adipate	3.489e-308	5.028e-303	0.8029	-300.0000
H-Adipate	4.794e-310	6.957e-305	0.9468	-300.0000
Adipic_acid(aq)	7.407e-313	1.082e-307	1.0000	-300.0000
1-Butanamine(aq)	6.095e-318	4.457e-313	1.0000	-300.0000
Valine(aq)	6.168e-320	7.225e-315	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9483	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9468	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.8029	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9468	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9468	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9468	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(o-Phthalate)(	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9468	-300.0000
o-Toluate	0.0000	0.0000	0.9468	-300.0000
o-Phthalate	0.0000	0.0000	0.8029	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000

n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9468	-300.0000
H-Sebacate	0.0000	0.0000	0.9468	-300.0000
Undecanoate	0.0000	0.0000	0.9468	-300.0000
H-Pimelate	0.0000	0.0000	0.9468	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.8029	-300.0000
H-Azelate	0.0000	0.0000	0.9468	-300.0000
Sebacate	0.0000	0.0000	0.8029	-300.0000
H(o-Phthalate)-	0.0000	0.0000	0.9468	-300.0000
S5--	0.0000	0.0000	0.8029	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9468	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.8029	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9468	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9468	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9468	-300.0000
Nonanoate	0.0000	0.0000	0.9468	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9468	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9468	-300.0000
Decanoate	0.0000	0.0000	0.9468	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
o-Phthalic_acid(	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K

Quartz	-0.1230	Mg1.25SO4(OH)0.5	-10.3993
Ice	-0.1387	Manganosite	-10.6049
Tenorite	-0.1633	Periclase	-10.7496
Tridymite	-0.2945	Forsterite	-10.8132
Chalcedony	-0.3942	Mn(OH)3	-11.4233
Cristobalite(alp	-0.6735	Portlandite	-11.4683
Calcite	-0.9046	Mg1.5SO4(OH)	-11.7479
Coesite	-0.9330	Monticellite	-12.0347
Aragonite	-1.0490	Tephroite	-12.5622
Malachite	-1.0972	MgSO4	-12.6638
Cristobalite(bet	-1.1170	Sepiolite	-12.8344
Dolomite	-1.1264	Hausmannite	-13.0048
Dolomite-ord	-1.1264	Gyrolite	-13.1030
SiO2(am)	-1.4087	MnSO4	-13.7086
Monohydrocalcite	-1.7383	Chalcocyanite	-13.8027
Magnesite	-1.8506	Ca3(AsO4)2	-14.6239
Rhodochrosite	-2.6309	Hydromagnesite	-18.4960
Dolomite-dis	-2.6708	Hillebrandite	-18.7674
Dioptase	-2.7069	Tremolite	-19.1121
Gypsum	-2.8024	Dicalcium_silica	-19.1209
Chrysocolla	-2.8438	Larnite	-20.4149
Anhydrite	-2.9783	Akermanite	-20.8039
Bassanite	-3.6232	Lime	-21.4892
CaSO4:0.5H2O(bet	-3.7913	Anthophyllite	-25.6741
Brochantite	-3.8369	Rankinite	-26.8916
Cuprite	-4.0120	As2O5	-32.2288
Lansfordite	-4.3979	Merwinite	-32.9120
Nesquehonite	-4.5525	Tobermorite-14A	-33.1437
Antlerite	-4.6236	Foshagite	-33.9402
Enstatite	-4.8634	Tobermorite-11A	-34.9113
Manganite	-4.9175	Afwillite	-35.0290
Brucite	-5.7122	Arsenolite	-38.0216
Epsomite	-5.8234	Claudetite	-38.0934
Talc	-5.8700	Tobermorite-9A	-38.3790
Hexahydrite	-6.0589	C	-41.0359
Pentahydrite	-6.3985	Todorokite	-43.0443
Rhodonite	-6.5333	Hatrurite	-44.2671
Starkeyite	-6.7858	As	-46.6766
Wollastonite	-6.7959	Xonotlite	-50.0389
Azurite	-6.9681	Birnessite	-52.9858
Pseudowollastoni	-7.0351	Mn	-58.9911
Cu	-7.3788	Covellite	-59.8039
Kieserite	-7.5187	Chalcocite	-61.3085
Diopside	-7.5361	S	-61.6698
Okenite	-7.5393	As4O6(mono)	-75.6787
Chrysotile	-7.6125	As4O6(cubi)	-75.9526
Pyrolusite	-7.8845	Alabandite	-82.4141
Mn(OH)2(am)	-7.9911	Mg	-95.3104
Huntite	-8.0279	Realgar	-96.0268
Chalcanthite	-8.2573	Antigorite	-109.2324
Artinite	-8.6271	Ca	-112.1193
Lammerite	-9.1447	Si	-119.7478
Bixbyite	-9.1987	Orpiment	-248.8250
MnO2(gamma)	-9.4023	o-Phthalic_acid	-364.5975

Gases	fugacity	log fug.
H2O(g)	0.02598	-1.585
CO2(g)	0.004686	-2.329
N2(g)	0.004244	-2.372
NO2(g)	1.468e-012	-11.833
H2(g)	4.351e-027	-26.361

O2(g)	4.148e-031	-30.382
NO(g)	2.883e-032	-31.540
CO(g)	6.368e-033	-32.196
NH3(g)	1.425e-038	-37.846
SO2(g)	3.466e-040	-39.460
Cu(g)	2.959e-060	-59.529
H2S(g)	7.052e-083	-82.152
CH4(g)	1.340e-085	-84.873
Mg(g)	9.477e-116	-115.023
S2(g)	5.857e-138	-137.232
Ca(g)	4.460e-138	-137.351
C2H4(g)	1.871e-147	-146.728
C(g)	2.319e-159	-158.635
Si(g)	1.612e-191	-190.793

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ca++	0.000616	0.000616	24.7			
Cu++	1.21e-006	1.21e-006	0.0770			
H+	0.000155	0.000155	0.156			
H2AsO4-	6.59e-008	6.59e-008	0.00929			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00138	0.00138	83.9			
Mg++	0.000195	0.000195	4.74			
Mn++	1.08e-007	1.08e-007	0.00592			
NH3(aq)	5.53e-006	5.53e-006	0.0941			
NO3-	2.75e-005	2.75e-005	1.70			
O2(aq)	3.88e-006	3.88e-006	0.124			
SO4--	0.000144	0.000144	13.8			
SiO2(aq)	7.56e-005	7.56e-005	4.54			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Arsenic	6.590e-008	6.590e-008	0.004936		
Calcium	0.0006159	0.0006159	24.68		
Carbon	0.001376	0.001376	16.52		
Copper	1.212e-006	1.212e-006	0.07701		
Hydrogen	111.0	111.0	1.119e+005		
Magnesium	0.0001950	0.0001950	4.739		
Manganese	1.078e-007	1.078e-007	0.005924		
Nitrogen	3.301e-005	3.301e-005	0.4623		
Oxygen	55.51	55.51	8.881e+005		
Silicon	7.560e-005	7.560e-005	2.123		
Sulfur	0.0001439	0.0001439	4.614		

```
Temperature =   5.3 C    Pressure =  1.013 bars
pH =  7.800              log fO2 =  -28.736
Eh =   0.4050 volts      pe =   7.3321
Ionic strength      =    0.001989
Charge imbalance    =   -0.000109 eq/kg (-8.459% error)
Activity of water   =    1.000000
Solvent mass        =    1.000000 kg
Solution mass       =    1.000122 kg
Solution density    =    1.026    g/cm3
Chlorinity          =    0.000000 molal
Dissolved solids    =         122 mg/kg sol'n
Hardness            =       53.40 mg/kg sol'n as CaCO3
  carbonate         =       39.68 mg/kg sol'n as CaCO3
  non-carbonate     =       13.73 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       39.68 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.4050	7.3321
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5819	10.5353

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.0007850	47.89	0.9531	-3.1260
Ca++	0.0004042	16.20	0.8290	-3.4749
NO3-	0.0002239	13.88	0.9524	-3.6710
SO4--	0.0001648	15.83	0.8247	-3.8667
SiO2(aq)	0.0001535	9.221	1.0000	-3.8139
Na+	0.0001270	2.919	0.9531	-3.9172
Mg++	0.0001172	2.849	0.8330	-4.0103
N2(aq)	5.858e-005	1.641	1.0000	-4.2323
K+	4.980e-005	1.947	0.9524	-4.3240
CO2(aq)	3.893e-005	1.713	1.0000	-4.4097
Mn++	5.420e-006	0.2977	0.8290	-5.3475
CaSO4(aq)	5.402e-006	0.7354	1.0000	-5.2674
CaHCO3+	3.123e-006	0.3157	0.9531	-5.5263
MgSO4(aq)	2.074e-006	0.2497	1.0000	-5.6831
AlO2-	1.909e-006	0.1126	0.9531	-5.7400
CO3--	1.612e-006	0.09670	0.8258	-5.8759
Cu++	1.288e-006	0.08184	0.8290	-5.9715
HPO4--	1.266e-006	0.1215	0.8247	-5.9813
MgHCO3+	8.793e-007	0.07502	0.9531	-6.0767
CaCO3(aq)	6.468e-007	0.06473	1.0000	-6.1892
HSiO3-	5.797e-007	0.04469	0.9531	-6.2577
Ba++	4.611e-007	0.06331	0.8268	-6.4188
H2PO4-	3.385e-007	0.03282	0.9531	-6.4913
HAlO2(aq)	2.465e-007	0.01479	1.0000	-6.6081
NaHCO3(aq)	1.913e-007	0.01607	1.0000	-6.7183
OH-	1.258e-007	0.002139	0.9528	-6.9214
MnSO4(aq)	1.139e-007	0.01720	1.0000	-6.9435
MgCO3(aq)	1.030e-007	0.008683	1.0000	-6.9872
Sb(OH)3(aq)	6.403e-008	0.01106	1.0000	-7.1936
KSO4-	5.099e-008	0.006892	0.9531	-7.3133
Pb++	3.762e-008	0.007795	0.8258	-7.5077
HAsO4--	2.381e-008	0.003331	0.8247	-7.7070
H+	1.658e-008	1.671e-005	0.9560	-7.8000
Al(OH)2+	1.057e-008	0.0006444	0.9531	-7.9969
Cd++	7.541e-009	0.0008476	0.8268	-8.2051

NaHSiO3(aq)	4.701e-009	0.0004705	1.0000	-8.3278
H2AsO4-	2.205e-009	0.0003107	0.9531	-8.6775
NaCO3-	9.531e-010	7.910e-005	0.9531	-9.0417
UO2(CO3)2--	3.752e-010	0.0001463	0.8247	-9.5094
AlOH++	3.354e-010	1.475e-005	0.8258	-9.5576
UO2(CO3)3----	2.204e-010	9.918e-005	0.4623	-9.9919
BaCO3(aq)	1.488e-010	2.935e-005	1.0000	-9.8275
HSO4-	1.326e-010	1.287e-005	0.9531	-9.8984
NaAlO2(aq)	3.242e-011	2.657e-006	1.0000	-10.4892
PO4---	2.973e-011	2.824e-006	0.6480	-10.7152
UO2CO3(aq)	1.811e-011	5.977e-006	1.0000	-10.7420
Cu+	1.388e-011	8.818e-007	0.9531	-10.8785
NaOH(aq)	2.675e-012	1.070e-007	1.0000	-11.5726
AsO4---	2.663e-012	3.700e-007	0.6480	-11.7630
Al+++	2.381e-012	6.423e-008	0.6663	-11.7996
Sb(OH)4-	1.067e-012	2.025e-007	0.9531	-11.9927
CdSO4(aq)	8.574e-013	1.787e-007	1.0000	-12.0668
H3PO4(aq)	6.268e-013	6.141e-008	1.0000	-12.2029
UO2OH+	3.491e-013	1.002e-007	0.9531	-12.4779
MgP2O7--	1.384e-013	2.744e-008	0.8247	-12.9425
HNO3(aq)	1.096e-013	6.908e-009	1.0000	-12.9601
Sb(OH)2+	7.168e-014	1.116e-008	0.9531	-13.1655
H3AsO4(aq)	4.823e-015	6.846e-010	1.0000	-14.3166
HP2O7---	4.637e-015	8.111e-010	0.6480	-14.5222
UO2++	3.612e-015	9.752e-010	0.8258	-14.5254
KHSO4(aq)	3.282e-016	4.468e-011	1.0000	-15.4839
UO2SO4(aq)	2.912e-016	1.066e-010	1.0000	-15.5359
H2P2O7--	2.558e-016	4.500e-011	0.8247	-15.6758
P2O7----	2.136e-016	3.714e-011	0.4623	-16.0055
KP2O7---	1.308e-018	2.786e-013	0.6480	-18.0719
UO2(SO4)2--	2.709e-019	1.252e-013	0.8247	-18.6509
(UO2)2(OH)2++	3.200e-020	1.837e-014	0.8258	-19.5780
UO2+	3.056e-021	8.252e-016	0.9531	-20.5357
H3P2O7-	7.986e-022	1.413e-016	0.9531	-21.1185
(UO2)3(OH)5+	3.929e-022	3.517e-016	0.9531	-21.4266
(UO2)3(CO3)6(6-)	8.271e-024	9.677e-018	0.1762	-23.8365
HAsO2(aq)	9.906e-025	1.069e-019	1.0000	-24.0041
As(OH)3(aq)	8.966e-025	1.129e-019	1.0000	-24.0474
Mn+++	8.163e-025	4.484e-020	0.6518	-24.2741
U(OH)4(aq)	4.860e-025	1.487e-019	1.0000	-24.3133
H2AsO3-	1.608e-026	2.008e-021	0.9531	-25.8146
AsO2-	1.558e-026	1.666e-021	0.9531	-25.8282
H4P2O7(aq)	2.953e-028	5.254e-023	1.0000	-27.5298
AsO2OH--	5.035e-030	6.239e-025	0.8247	-29.3817
NO2-	1.082e-030	4.976e-026	0.9524	-29.9870
O2(aq)	3.519e-032	1.126e-027	1.0000	-31.4536
Formate	4.088e-034	1.840e-029	0.9528	-33.4095
H2(aq)	1.665e-034	3.357e-031	1.0000	-33.7785
HNO2(aq)	4.361e-035	2.050e-030	1.0000	-34.3604
Ca(For)+	4.296e-036	3.655e-031	0.9531	-35.3878
Mg(For)+	1.625e-036	1.127e-031	0.9531	-35.8099
Mn(For)+	1.191e-037	1.191e-032	0.9531	-36.9448
Cu(For)+	6.032e-038	6.548e-033	0.9531	-37.2404
Na(For)(aq)	5.723e-038	3.891e-033	1.0000	-37.2424
Formic_acid(aq)	3.718e-038	1.711e-033	1.0000	-37.4297
K(For)(aq)	1.880e-038	1.581e-033	1.0000	-37.7259
HO2-	1.286e-038	4.244e-034	0.9531	-37.9116
SO3--	9.905e-039	7.930e-034	0.8258	-38.0873
Ba(For)+	3.491e-039	6.365e-034	0.9531	-38.4779
HSO3-	1.865e-039	1.512e-034	0.9531	-38.7502
NH4+	1.209e-039	2.181e-035	0.9521	-38.9388
Pb(For)+	9.763e-040	2.462e-034	0.9531	-39.0313
Cd(For)+	2.332e-040	3.670e-035	0.9531	-39.6532

MnO4--	1.294e-040	1.539e-035	0.8247	-39.9718
CO(aq)	5.443e-041	1.524e-036	1.0000	-40.2642
NH3(aq)	9.492e-042	1.616e-037	1.0000	-41.0226
Oxalate	6.528e-042	5.746e-037	0.8247	-41.2689
MnO4-	7.522e-044	8.945e-039	0.9528	-43.1447
UOH+++	6.804e-044	1.735e-038	0.6518	-43.3531
U(CO3)5(6-)	5.444e-045	2.929e-039	0.1762	-45.0181
H-Oxalate	1.443e-045	1.285e-040	0.9531	-44.8616
SO2(aq)	1.381e-045	8.848e-041	1.0000	-44.8597
HSO5-	4.381e-047	4.953e-042	0.9531	-46.3793
USO4++	4.451e-048	1.487e-042	0.8258	-47.4347
U(SO4)2(aq)	1.839e-048	7.910e-043	1.0000	-47.7354
U++++	2.073e-050	4.933e-045	0.4696	-50.0118
Oxalic_acid(aq)	3.956e-052	3.562e-047	1.0000	-51.4027
S2O6--	5.023e-064	8.042e-059	0.8247	-63.3828
S2O8--	1.456e-064	2.798e-059	0.8247	-63.9204
Ca(For)2(aq)	1.516e-068	1.972e-063	1.0000	-67.8194
U+++	9.487e-069	2.258e-063	0.6518	-68.2088
Mg(For)2(aq)	7.741e-069	8.850e-064	1.0000	-68.1112
Mn(For)2(aq)	7.773e-070	1.127e-064	1.0000	-69.1094
Cu(For)2(aq)	7.514e-070	1.154e-064	1.0000	-69.1241
Na(For)2-	1.900e-071	2.147e-066	0.9531	-70.7422
Cd(For)2(aq)	1.434e-071	2.904e-066	1.0000	-70.8433
Ba(For)2(aq)	8.666e-072	1.970e-066	1.0000	-71.0622
Pb(For)2(aq)	6.639e-072	1.973e-066	1.0000	-71.1779
K(For)2-	4.972e-072	6.420e-067	0.9531	-71.3243
Formaldehyde(aq)	2.379e-073	7.141e-069	1.0000	-72.6237
N3-	1.548e-074	6.502e-070	0.9531	-73.8312
HN3(aq)	1.838e-077	7.909e-073	1.0000	-76.7356
Cu(NH3)2++	1.138e-080	1.111e-075	0.8258	-80.0270
S2O5--	6.224e-083	8.970e-078	0.8247	-82.2896
Cd(NH3)2++	1.071e-085	1.569e-080	0.8258	-85.0532
Urea(aq)	1.376e-086	8.261e-082	1.0000	-85.8615
HCN(aq)	1.907e-087	5.152e-083	1.0000	-86.7197
CN-	1.893e-089	4.925e-085	0.9524	-88.7440
Methanol(aq)	3.687e-091	1.181e-086	1.0000	-90.4333
Glycolate	1.401e-097	1.051e-092	0.9531	-96.8745
HS-	1.700e-098	5.623e-094	0.9528	-97.7905
H2S(aq)	5.257e-099	1.792e-094	1.0000	-98.2792
Ca(Glyc)+	2.622e-099	3.018e-094	0.9531	-98.6022
Mg(Glyc)+	3.496e-100	3.473e-095	0.9531	-99.4773
Cu(Glyc)+	2.021e-100	2.800e-095	0.9531	-99.7154
Mn(Glyc)+	3.160e-101	4.107e-096	0.9531	-100.5211
Na(Glyc)(aq)	2.031e-101	1.990e-096	1.0000	-100.6924
Glycolic_acid(aq	1.554e-101	1.182e-096	1.0000	-100.8084
K(Glyc)(aq)	6.670e-102	7.612e-097	1.0000	-101.1759
Pb(Glyc)+	9.532e-103	2.690e-097	0.9531	-102.0417
Ba(Glyc)+	5.805e-103	1.233e-097	0.9531	-102.2570
Methane(aq)	1.600e-103	2.566e-099	1.0000	-102.7959
Cd(Glyc)+	8.912e-104	1.670e-098	0.9531	-103.0709
S--	3.577e-104	1.147e-099	0.8268	-103.5290
S2O4--	1.284e-104	1.645e-099	0.8268	-103.9740
S2O3--	3.872e-105	4.341e-100	0.8247	-104.4958
Acetate	2.483e-109	1.466e-104	0.9534	-108.6257
CaCH3COO+	7.722e-112	7.653e-107	0.9531	-111.1331
MgCH3COO+	6.656e-112	5.547e-107	0.9531	-111.1976
Acetic_acid(aq)	2.216e-112	1.331e-107	1.0000	-111.6544
CuCH3COO+	7.060e-113	8.653e-108	0.9531	-112.1721
NaCH3COO(aq)	2.469e-113	2.025e-108	1.0000	-112.6075
MnCH3COO+	2.278e-113	2.596e-108	0.9531	-112.6633
KCH3COO(aq)	5.719e-114	5.613e-109	1.0000	-113.2426
PbCH3COO+	2.147e-114	5.717e-109	0.9531	-113.6890
BaCH3COO+	8.361e-115	1.642e-109	0.9531	-114.0986

CdCH3COO+	1.821e-115	3.121e-110	0.9531	-114.7607
Malonate	1.493e-118	1.523e-113	0.8247	-117.9097
Cu(NH3)3++	1.304e-118	1.495e-113	0.8258	-117.9677
AlCH3COO++	1.057e-118	9.088e-114	0.8258	-118.0592
CuCH3COO(aq)	8.265e-120	1.013e-114	1.0000	-119.0828
H-Malonate	9.538e-121	9.829e-116	0.9531	-120.0414
AsH3(aq)	4.705e-121	3.667e-116	1.0000	-120.3274
Malonic_acid(aq)	1.085e-125	1.129e-120	1.0000	-124.9644
Methanamine(aq)	1.716e-129	5.328e-125	1.0000	-128.7655
Cu(Gly)+	4.310e-132	5.930e-127	0.9531	-131.3864
Glycine(aq)	1.590e-132	1.194e-127	1.0000	-131.7985
Mg(Gly)+	1.797e-135	1.768e-130	0.9531	-134.7662
Mn(Gly)+	1.229e-136	1.585e-131	0.9531	-135.9314
Pb(Gly)+	5.056e-137	1.422e-131	0.9531	-136.3171
Ca(Gly)+	2.677e-137	3.055e-132	0.9531	-136.5933
Cd(Gly)+	2.029e-138	3.783e-133	0.9531	-137.7136
S3O6--	1.867e-138	3.587e-133	0.8247	-137.8127
Ba(Gly)+	3.474e-140	7.342e-135	0.9531	-139.4801
Acetaldehyde(aq)	2.334e-146	1.028e-141	1.0000	-145.6320
SCN-	1.676e-147	9.732e-143	0.9528	-146.7968
NH4CH3COO(aq)	4.500e-148	3.469e-143	1.0000	-147.3468
Acetamide(aq)	3.471e-148	2.050e-143	1.0000	-147.4596
UO2SCN+	1.212e-160	3.975e-155	0.9531	-159.9375
Cd(NH3)4++	4.340e-165	7.835e-160	0.8258	-164.4456
Ethanol(aq)	6.548e-169	3.016e-164	1.0000	-168.1839
Ethyne(aq)	4.677e-169	1.218e-164	1.0000	-168.3301
Ethylene(aq)	7.943e-174	2.228e-169	1.0000	-173.1000
Lactate	2.659e-175	2.368e-170	0.9531	-174.5961
Ca(Lac)+	2.926e-177	3.778e-172	0.9531	-176.5547
Mg(Lac)+	6.471e-178	7.336e-173	0.9531	-177.2099
Cu(Lac)+	1.747e-178	2.666e-173	0.9531	-177.7785
Mn(Lac)+	4.248e-179	6.117e-174	0.9531	-178.3927
Na(Lac)(aq)	3.967e-179	4.445e-174	1.0000	-178.4015
Lactic_acid(aq)	3.070e-179	2.765e-174	1.0000	-178.5128
K(Lac)(aq)	1.303e-179	1.670e-174	1.0000	-178.8849
Pb(Lac)+	1.771e-180	5.246e-175	0.9531	-179.7727
Ba(Lac)+	4.458e-181	1.009e-175	0.9531	-180.3717
Cd(Lac)+	1.145e-181	2.306e-176	0.9531	-180.9622
Ethane(aq)	1.005e-185	3.023e-181	1.0000	-184.9976
Propanoate	2.728e-189	1.994e-184	0.9531	-188.5849
Ca(Prop)+	4.745e-192	5.369e-187	0.9531	-191.3446
Propanoic_acid(a	3.260e-192	2.414e-187	1.0000	-191.4868
Mg(Prop)+	1.980e-192	1.927e-187	0.9531	-191.7243
Cu(Prop)+	7.662e-193	1.047e-187	0.9531	-192.1366
Na(Prop)(aq)	4.017e-193	3.858e-188	1.0000	-192.3961
Mn(Prop)+	2.969e-193	3.800e-188	0.9531	-192.5482
K(Prop)(aq)	1.319e-193	1.480e-188	1.0000	-192.8796
USCN+++	5.122e-194	1.516e-188	0.6518	-193.4765
Pb(Prop)+	2.079e-194	5.827e-189	0.9531	-193.7029
Ca(Glyc)2(aq)	8.016e-195	1.524e-189	1.0000	-194.0960
Cu(Glyc)2(aq)	2.652e-195	5.664e-190	1.0000	-194.5765
Cd(Prop)+	1.851e-195	3.433e-190	0.9531	-194.7535
Ba(Prop)+	1.180e-195	2.483e-190	0.9531	-194.9489
Mg(Glyc)2(aq)	6.861e-196	1.196e-190	1.0000	-195.1636
S4O6--	3.116e-196	6.987e-191	0.8247	-195.5901
Succinate	7.129e-197	8.274e-192	0.8247	-196.2307
Mn(Glyc)2(aq)	3.950e-197	8.097e-192	1.0000	-196.4034
Pb(Glyc)2(aq)	8.301e-198	2.965e-192	1.0000	-197.0809
Na(Glyc)2-	3.645e-198	6.308e-193	0.9531	-197.4592
K(Glyc)2-	9.887e-199	1.870e-193	0.9531	-198.0258
Serine(aq)	4.580e-199	4.812e-194	1.0000	-198.3392
Cd(Glyc)2(aq)	4.555e-199	1.196e-193	1.0000	-198.3415
H-Succinate	4.498e-199	5.266e-194	0.9531	-198.3678

Ba(Glyc)2(aq)	3.849e-199	1.106e-193	1.0000	-198.4147
Succinic_acid(aq	1.255e-202	1.481e-197	1.0000	-201.9015
Ethanamine(aq)	3.138e-209	1.414e-204	1.0000	-208.5034
Alanine(aq)	4.100e-211	3.653e-206	1.0000	-210.3872
Cu(Ala)+	2.521e-211	3.821e-206	0.9531	-210.6194
Mg(Ala)+	2.901e-216	3.260e-211	0.9531	-215.5583
Mn(Ala)+	2.567e-216	3.672e-211	0.9531	-215.6114
Ca(Ala)+	1.299e-216	1.665e-211	0.9531	-215.9071
Pb(Ala)+	1.010e-216	2.983e-211	0.9531	-216.0164
Cd(Ala)+	2.939e-217	5.892e-212	0.9531	-216.5527
Ca(CH3COO)2(aq)	4.027e-219	6.368e-214	1.0000	-218.3950
Mg(CH3COO)2(aq)	1.567e-219	2.231e-214	1.0000	-218.8050
Cu(CH3COO)2(aq)	7.033e-220	1.277e-214	1.0000	-219.1529
Ba(Ala)+	6.129e-220	1.381e-214	0.9531	-219.2335
Mn(CH3COO)2(aq)	5.299e-221	9.168e-216	1.0000	-220.2758
Acetone(aq)	2.760e-221	1.603e-216	1.0000	-220.5592
Pb(CH3COO)2(aq)	4.103e-222	1.335e-216	1.0000	-221.3869
Na(CH3COO)2-	4.026e-222	5.678e-217	0.9531	-221.4160
Aspartic_acid(aq	3.818e-222	5.082e-217	1.0000	-221.4181
Cd(CH3COO)2(aq)	1.082e-222	2.495e-217	1.0000	-221.9656
Ba(CH3COO)2(aq)	6.250e-223	1.596e-217	1.0000	-222.2041
K(CH3COO)2-	5.857e-223	9.205e-218	0.9531	-222.2532
Al(CH3COO)2+	4.002e-225	5.805e-220	0.9531	-224.4186
Propanal(aq)	9.631e-226	5.593e-221	1.0000	-225.0163
Cu(CH3COO)2-	3.434e-228	6.237e-223	0.9531	-227.4850
1-Propyne(aq)	1.036e-244	4.151e-240	1.0000	-243.9846
S3--	7.536e-248	7.249e-243	0.8247	-247.2066
1-Propanol(aq)	8.255e-249	4.960e-244	1.0000	-248.0833
1-Propene(aq)	1.933e-251	8.134e-247	1.0000	-250.7137
2-Hydroxybutanoa	1.164e-255	1.200e-250	0.9531	-254.9549
NH4(CH3COO)2-	1.192e-256	1.622e-251	0.9531	-255.9447
Asparagine(aq)	6.907e-258	9.124e-253	1.0000	-257.1607
Cu(Gly)2(aq)	9.102e-259	1.926e-253	1.0000	-258.0409
2-Hydroxybutanoi	1.187e-259	1.235e-254	1.0000	-258.9257
Propane(aq)	4.932e-266	2.175e-261	1.0000	-265.3070
Mg(Gly)2(aq)	1.241e-266	2.140e-261	1.0000	-265.9061
Diglycine(aq)	5.363e-267	7.085e-262	1.0000	-266.2706
Mn(Gly)2(aq)	6.280e-268	1.275e-262	1.0000	-267.2020
Pb(Gly)2(aq)	4.987e-268	1.772e-262	1.0000	-267.3022
Cd(Gly)2(aq)	6.819e-269	1.776e-263	1.0000	-268.1663
Diketopiperazine	1.614e-269	1.842e-264	1.0000	-268.7920
Butanoate	9.473e-270	8.250e-265	0.9531	-269.0444
Ca(Gly)2(aq)	5.338e-271	1.004e-265	1.0000	-270.2726
Ca(But)+	1.128e-272	1.435e-267	0.9531	-271.9684
Butanoic_acid(aq	8.927e-273	7.865e-268	1.0000	-272.0493
Mg(But)+	4.483e-273	4.993e-268	0.9531	-272.3693
Cu(But)+	2.109e-273	3.176e-268	0.9531	-272.6968
Na(But)(aq)	1.349e-273	1.485e-268	1.0000	-272.8701
Mn(But)+	8.817e-274	1.252e-268	0.9531	-273.0755
Ba(Gly)2(aq)	7.228e-274	2.063e-268	1.0000	-273.1410
K(But)(aq)	4.431e-274	5.591e-269	1.0000	-273.3535
Pb(But)+	1.988e-275	5.850e-270	0.9531	-274.7224
Ba(But)+	2.736e-276	6.140e-271	0.9531	-275.5837
Cd(But)+	2.692e-276	5.370e-271	0.9531	-275.5908
Glutarate	2.132e-276	2.773e-271	0.8247	-275.7550
H-Glutarate	7.684e-279	1.007e-273	0.9531	-278.1353
Threonine(aq)	1.618e-279	1.927e-274	1.0000	-278.7910
Ethylacetate(aq)	4.480e-282	3.946e-277	1.0000	-281.3488
Glutaric_acid(aq	2.649e-282	3.499e-277	1.0000	-281.5769
S5O6--	3.438e-284	8.811e-279	0.8247	-283.5474
1-Propanamine(aq	1.342e-288	7.930e-284	1.0000	-287.8723
a-Aminobutyric_a	3.084e-291	3.180e-286	1.0000	-290.5109
Glutamic_acid(aq	1.271e-300	1.870e-295	1.0000	-299.8957

Butanal(aq)	1.077e-307	7.764e-303	1.0000	-300.0000
UO2(SCN)2(aq)	1.038e-307	4.008e-302	1.0000	-300.0000
S4--	6.199e-320	7.950e-315	0.8247	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9531	-300.0000
K(Pent)2-	0.0000	0.0000	0.9531	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9531	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9531	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9531	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9531	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9531	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9531	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9531	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9531	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butyne(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9531	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9531	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9531	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
U(SCN)2++	0.0000	0.0000	0.8258	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.8247	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.8247	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9531	-300.0000
Sebacate	0.0000	0.0000	0.8247	-300.0000
Sb2S4--	0.0000	0.0000	0.8247	-300.0000
H-Sebacate	0.0000	0.0000	0.9531	-300.0000
H-Pimelate	0.0000	0.0000	0.9531	-300.0000
S5--	0.0000	0.0000	0.8247	-300.0000

H-Azelate	0.0000	0.0000	0.9531	-300.0000
H-Adipate	0.0000	0.0000	0.9531	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butene(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Glutamine(aq)	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)+	0.0000	0.0000	0.9531	-300.0000
Benzoate	0.0000	0.0000	0.9543	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(CH3COO)3-	0.0000	0.0000	0.9531	-300.0000
Pb(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Pentanoate	0.0000	0.0000	0.9531	-300.0000
Dodecanoate	0.0000	0.0000	0.9531	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.8247	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9531	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9531	-300.0000
2-Hydroxypentano	0.0000	0.0000	0.9531	-300.0000
Nonanoate	0.0000	0.0000	0.9531	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9531	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9531	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9531	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9531	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9531	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9531	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9531	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butanol(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9531	-300.0000

Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9531	-300.0000
Cu(CH3COO)3-	0.0000	0.0000	0.9531	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9531	-300.0000
Mn(CH3COO)3-	0.0000	0.0000	0.9531	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9531	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.8247	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9531	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9531	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9531	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
Cd(CH3COO)3-	0.0000	0.0000	0.9531	-300.0000
o-Phthalate	0.0000	0.0000	0.8247	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Stilbite	10.5604s/sat	Saleeite	-11.2705
Muscovite	10.4610s/sat	Thenardite	-11.3703
Beidellite-Ca	7.6939s/sat	Mg1.25SO4(OH)0.5	-11.3920
Beidellite-Mg	7.6053s/sat	UO2.25	-11.4240
Illite	7.4140s/sat	UO2.25(beta)	-11.4955
Beidellite-K	7.2668s/sat	Periclase	-11.6121
Kaolinite	7.0250s/sat	Portlandite	-12.0343
Beidellite-Na	6.9988s/sat	Monticellite	-12.0471
Beidellite-H	6.7466s/sat	Natron	-12.1750
Mesolite	6.5548s/sat	Torbernite	-12.2021
Pyrophyllite	6.5291s/sat	CdSO4	-12.5691
Paragonite	6.5271s/sat	MnSO4	-12.6189

Montmor-Ca	6.4899s/sat	UO2SO4:H2O	-12.8062
Montmor-Mg	6.4784s/sat	MgUO4	-12.8179
Montmor-K	6.1398s/sat	Na2CO3:7H2O	-12.8327
Montmor-Na	5.8662s/sat	Mg1.5SO4(OH)	-12.8454
Scolecite	5.6727s/sat	Uranocircite	-12.8490
Laumontite	4.3936s/sat	BaU2O7	-13.0904
Maximum_Microcli	3.8311s/sat	(UO2)3(PO4)2:4H2	-13.4441
K-Feldspar	3.8283s/sat	Chalcocyanite	-13.6196
Margarite	3.5161s/sat	Przhevalskite	-13.6870
Celadonite	3.3019s/sat	MgSO4	-13.8233
Diaspore	3.0755s/sat	Tremolite	-14.0514
Boehmite	2.6370s/sat	Mordenite-dehy	-14.1277
Lawsonite	2.5935s/sat	UPO5	-14.2789
Gibbsite	2.5820s/sat	UO2.6667	-14.4214
Sanidine_high	2.4941s/sat	Thermonatrite	-14.4581
Mordenite	2.2695s/sat	Na2CO3	-14.8252
Corundum	1.7463s/sat	Na2U2O7	-14.8342
Brochantite	1.5763s/sat	Uraninite	-14.9571
Witherite	1.4749s/sat	Coffinite	-15.1458
Malachite	1.4574s/sat	Autunite-H	-16.0046
Tenorite	1.1693s/sat	Ba(OH)2:8H2O	-16.0911
Kyanite	0.9317s/sat	Ca3(AsO4)2	-16.2386
Albite_low	0.8464s/sat	CaAl2O4	-17.0363
Albite	0.8464s/sat	UO2SO4:3.5H2O	-17.2504
Quartz	0.6643s/sat	UO2SO4:2.5H2O	-17.3385
Andalusite	0.6080s/sat	Ba2Si3O8	-17.3769
Cerussite	0.5749s/sat	UO2SO4:3H2O	-17.4124
Tridymite	0.4656s/sat	NaUO3	-17.8966
Chalcedony	0.3739s/sat	Natrosilite	-18.5105
Sillimanite	0.2041s/sat	Gehlenite	-18.6620
Analcime	0.1438s/sat	Alum-K	-18.7361
Barite	0.0717s/sat	Hillebrandite	-18.8456
Cristobalite(alp	0.0672s/sat	CaAl4O7	-19.0023
Ice	-0.0649	Na2SiO3	-19.2581
Amesite-14A	-0.0745	Dicalcium_silica	-19.3731
Coesite	-0.1996	Hydromagnesite	-20.2824
Cristobalite(bet	-0.4351	Ningyoite	-20.4534
Dioptase	-0.5313	Akermanite	-20.5537
Prehnite	-0.5722	Larnite	-20.7840
Albite_high	-0.6091	UO2.3333(beta)	-20.9962
Wairakite	-0.6696	UO2SO4	-21.3416
Rhodochrosite	-0.7249	Anthophyllite	-21.6402
Dawsonite	-0.7358	Lime	-22.8599
SiO2(am)	-0.7915	Na2UO4(alpha)	-23.3525
Kalsilite	-0.9049	UO2(NO3)2:6H2O	-23.9223
Calcite	-0.9467	UO2(NO3)2:3H2O	-25.6758
Aragonite	-1.0922	Pargasite	-26.0882
Clinozoisite	-1.1006	UO2(PO3)2	-26.4209
Natrolite	-1.1119	Rankinite	-26.7782
Zoisite	-1.1500	Pb	-26.8153
Dolomite-ord	-1.3521	UO2(NO3)2:2H2O	-27.0968
Dolomite	-1.3522	(UO2)2P2O7	-27.5095
Jadeite	-1.4384	(UO2)3(PO4)2	-27.6703
Alamosite	-1.5385	K2UO4	-28.0348
Monohydrocalcite	-1.7382	Tobermorite-14A	-28.6287
Saponite-Ca	-2.0227	U(HPO4)2:4H2O	-28.8182
Saponite-Mg	-2.1088	KAl(SO4)2	-28.8290
Magnesite	-2.1615	UP2O7	-29.3424
Saponite-K	-2.4498	Ettringite	-29.9290
Anorthite	-2.4871	UO2(NO3)2:H2O	-31.0468
Phlogopite	-2.6811	Tobermorite-11A	-31.0494
Saponite-Na	-2.7176	Ba2SiO4	-32.9161
Gypsum	-2.8304	Foshagite	-33.1374

Saponite-H	-2.9701	Merwinite	-33.3820
Lanarkite	-3.0361	UO2(NO3)2	-34.8239
Dolomite-dis	-3.0488	Tobermorite-9A	-35.0360
Alunite	-3.0543	Afwillite	-35.1053
Bixbyite	-3.1781	As2O5	-35.5210
Talc	-3.1999	UO2SO3	-36.5064
Anhydrite	-3.2046	Cd	-37.8931
Hydroxylapatite	-3.2546	Al2(SO4)3:6H2O	-39.3105
Anglesite	-3.3152	UO2(AsO3)2	-40.1357
Azurite	-3.6128	(UO2)2As2O7	-40.2743
Nepheline	-3.7339	(UO2)3(AsO4)2	-41.3282
Bassanite	-3.8562	BaO	-41.9772
Whitlockite	-3.8930	U(SO4)2:8H2O	-45.6205
Berlinite	-3.9040	Hatrurite	-46.1794
Cuprite	-3.9173	Arsenolite	-46.3077
Pyrolusite	-3.9599	Claudetite	-46.3910
Rhodonite	-4.0279	Ba2U2O7	-46.6185
CaSO4:0.5H2O(bet	-4.0503	U(SO4)2:4H2O	-47.0553
CaUO4	-4.3792	U(SO4)2	-47.4018
UO3:2H2O	-4.3974	Xonotlite	-47.7879
Schoepite	-4.3991	C	-48.4694
CdSiO3	-4.5027	U(CO3)2	-50.2997
Enstatite	-4.5106	As	-56.1301
UO2(OH)2(beta)	-4.5836	Al2(SO4)3	-58.5785
Sb2O3	-4.6275	Na	-60.3584
Schoepite-dehy(.	-4.6403	Na3UO4	-61.0112
UO3:.9H2O(alpha)	-4.6578	Na4SiO4	-62.9503
Schoepite-dehy(.	-4.7451	Mn	-63.1790
Schoepite-dehy(1	-4.7661	Ca3Al2O6	-63.8337
Clinochlore-14A	-4.9311	Na2O	-64.0412
Hausmannite	-5.0187	K	-64.5151
PbCO3.PbO	-5.0860	Covellite	-71.8399
Nesquehonite	-5.3600	Ba3UO6	-72.7915
Litharge	-5.3660	S	-72.9308
Massicot	-5.5692	Chalcocite	-74.4310
UO2CO3	-5.9617	CdS	-81.3983
Schoepite-dehy(.	-5.9651	Galena	-81.5789
Rutherfordine	-5.9682	K2O	-82.3937
Okenite	-6.0198	U(SO3)2	-89.0858
Brucite	-6.0968	Antigorite	-90.1764
Mn(OH)2(am)	-6.2818	PbSO4(NH3)2	-91.0205
Wollastonite	-6.3313	Na6Si2O7	-91.7047
Diopside	-6.4024	As4O6(mono)	-92.2962
Cordierite_hydr	-6.4972	As4O6(cubi)	-92.4887
Schoepite-dehy(.	-6.5279	Alabandite	-95.2083
Chrysotile	-6.5655	Mg	-104.4778
Pseudowollastoni	-6.6073	BaS	-113.7961
Pb2SiO4	-6.6488	UN1.73(alpha)	-114.6016
Nahcolite	-6.7063	UN1.59(alpha)	-117.4815
Analcime-dehy	-6.7225	Ca	-122.2118
Pb3SO6	-6.7238	P	-124.8173
Chalcanthite	-7.1416	Ba	-126.4839
UO2HPO4:4H2O	-7.2971	Al	-126.6184
Niter	-7.3246	UN	-131.2706
Cd(OH)2	-7.4413	Si	-131.9304
UO3(gamma)	-7.6418	Pb(N3)2(orth)	-145.3842
Spinel	-7.7675	Pb(N3)2(mono)	-145.8484
Sanbornite	-8.1659	PbSO4(NH3)4	-176.5780
UO3(beta)	-8.2892	U	-180.4839
Tephroite	-8.3168	UAs	-192.0199
Clinochlore-7A	-8.4738	US	-193.1836
Sepiolite	-8.5381	UC	-210.4076
UO3(alpha)	-8.6534	UH3(beta)	-212.3172

Cu	-8.8053	US1.9	-223.4556
Ca-Al_Pyroxene	-8.8680	US2	-228.9066
Grossular	-8.9291	Mayenite	-236.7296
Monteponite	-8.9936	UAs2	-245.3229
Artinite	-9.0171	UP	-255.3584
Huntite	-9.1507	UC1.94(alpha)	-258.1395
Manganosite	-9.1789	Stibnite	-273.9683
Cordierite_anhyd	-9.1902	US3	-298.4432
BaUO4	-9.6159	Orpiment	-299.4082
Mirabilite	-9.6413	Pb(SCN)2	-300.9248
Arcanite	-10.3597	UP2	-374.7331
Pb4SO7	-10.4802	U2S3	-414.6957
CdSO4:2.667H2O	-10.4830	o-Phthalic_acid	-424.2301
Nitrobarite	-10.7513	U2C3	-470.9262
CdSO4:H2O	-10.7779	U3As4	-629.9350
Gyrolite	-10.9404	U3S5	-638.6823
Forsterite	-10.9839	U3P4	-885.4510

Gases	fugacity	log fug.
N2(g)	0.06239	-1.205
H2O(g)	0.007285	-2.138
CO2(g)	0.0005978	-3.223
NO2(g)	1.736e-013	-12.761
O2(g)	1.836e-029	-28.736
H2(g)	1.805e-031	-30.743
NO(g)	7.712e-032	-31.113
CO(g)	3.704e-038	-37.431
NH3(g)	5.428e-044	-43.265
SO2(g)	4.124e-046	-45.385
Cd(g)	1.526e-053	-52.816
Pb(g)	2.150e-058	-57.668
Cu(g)	7.024e-066	-65.153
Na(g)	6.588e-076	-75.181
UO3(g)	6.820e-077	-76.166
K(g)	6.030e-077	-76.220
H2S(g)	2.889e-098	-97.539
CH4(g)	7.177e-101	-100.144
UO2(g)	1.002e-119	-118.999
Mg(g)	9.521e-127	-126.021
Ca(g)	2.212e-150	-149.655
S2(g)	4.463e-162	-161.350
C2H4(g)	9.668e-172	-171.015
C(g)	1.047e-175	-174.980
Al(g)	3.807e-182	-181.419
UO(g)	2.760e-196	-195.559
Si(g)	2.672e-209	-208.573
U(g)	2.106e-273	-272.677

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Al+++	2.17e-006	2.17e-006	0.0585			
Ba++	4.61e-007	4.61e-007	0.0633			
Ca++	0.000413	0.000413	16.6			
Cd++	7.54e-009	7.54e-009	0.000848			
Cu++	1.29e-006	1.29e-006	0.0818			
H+	2.77e-005	2.77e-005	0.0280			
H2AsO4-	2.60e-008	2.60e-008	0.00367			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.000830	0.000830	50.7			
HPO4--	1.60e-006	1.60e-006	0.154			
K+	4.98e-005	4.98e-005	1.95			

Mg++	0.000120	0.000120	2.92
Mn++	5.53e-006	5.53e-006	0.304
NH3(aq)	0.000117	0.000117	2.00
NO3-	0.000224	0.000224	13.9
Na+	0.000127	0.000127	2.92
O2(aq)	8.79e-005	8.79e-005	2.81
Pb++	3.76e-008	3.76e-008	0.00779
SO4--	0.000172	0.000172	16.6
Sb(OH)3(aq)	6.40e-008	6.40e-008	0.0111
SiO2(aq)	0.000154	0.000154	9.26
UO2++	6.14e-010	6.14e-010	0.000166

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Aluminum	2.167e-006	2.167e-006	0.05846		
Antimony	6.403e-008	6.403e-008	0.007795		
Arsenic	2.601e-008	2.601e-008	0.001949		
Barium	4.612e-007	4.612e-007	0.06333		
Cadmium	7.542e-009	7.542e-009	0.0008477		
Calcium	0.0004133	0.0004133	16.56		
Carbon	0.0008305	0.0008305	9.973		
Copper	1.288e-006	1.288e-006	0.08184		
Hydrogen	111.0	111.0	1.119e+005		
Lead	3.762e-008	3.762e-008	0.007795		
Magnesium	0.0001203	0.0001203	2.923		
Manganese	5.534e-006	5.534e-006	0.3040		
Nitrogen	0.0003411	0.0003411	4.777		
Oxygen	55.51	55.51	8.881e+005		
Phosphorus	1.605e-006	1.605e-006	0.04969		
Potassium	4.985e-005	4.985e-005	1.949		
Silicon	0.0001541	0.0001541	4.327		
Sodium	0.0001272	0.0001272	2.923		
Sulfur	0.0001724	0.0001724	5.529		
Uranium	6.141e-010	6.141e-010	0.0001462		

```
Temperature =   6.0 C    Pressure =  1.013 bars
pH =  7.800              log fO2 =  -29.280
Eh =   0.3950 volts      pe =   7.1308
Ionic strength      =    0.003519
Charge imbalance    =   -0.000033 eq/kg (-1.414% error)
Activity of water   =    1.000000
Solvent mass        =    1.000000 kg
Solution mass       =    1.000204 kg
Solution density    =    1.026    g/cm3
Chlorinity          =    0.000000 molal
Dissolved solids    =         204 mg/kg sol'n
Hardness            =      106.00 mg/kg sol'n as CaCO3
  carbonate         =       73.41 mg/kg sol'n as CaCO3
  non-carbonate     =       32.59 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       73.41 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3950	7.1308
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5795	10.4608

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001445	88.14	0.9392	-2.8675
Ca++	0.0007574	30.35	0.7841	-3.2263
NO3-	0.0005562	34.48	0.9381	-3.2825
Mg++	0.0002726	6.623	0.7906	-3.6666
Na+	0.0001692	3.889	0.9392	-3.7989
SO4--	0.0001594	15.31	0.7773	-3.9068
SiO2(aq)	0.0001245	7.476	1.0000	-3.9050
N2(aq)	8.590e-005	2.406	1.0000	-4.0660
CO2(aq)	6.927e-005	3.048	1.0000	-4.1594
K+	4.983e-005	1.948	0.9381	-4.3303
CaHCO3+	1.014e-005	1.025	0.9392	-5.0211
CaSO4(aq)	8.752e-006	1.191	1.0000	-5.0579
MgSO4(aq)	4.257e-006	0.5123	1.0000	-5.3709
MgHCO3+	3.557e-006	0.3034	0.9392	-5.4762
CO3--	3.171e-006	0.1902	0.7791	-5.6073
AlO2-	2.887e-006	0.1703	0.9392	-5.5668
Mn++	2.841e-006	0.1560	0.7841	-5.6521
HPO4--	2.411e-006	0.2314	0.7773	-5.7272
CaCO3(aq)	2.159e-006	0.2161	1.0000	-5.6657
Fe++	8.303e-007	0.04636	0.7841	-6.1864
Cu++	6.291e-007	0.03997	0.7841	-6.3069
H2PO4-	6.107e-007	0.05922	0.9392	-6.2414
Ba++	4.967e-007	0.06820	0.7808	-6.4114
HSiO3-	4.916e-007	0.03789	0.9392	-6.3356
NaHCO3(aq)	4.483e-007	0.03765	1.0000	-6.3485
MgCO3(aq)	4.246e-007	0.03579	1.0000	-6.3721
HAlO2(aq)	3.501e-007	0.02100	1.0000	-6.4559
OH-	1.372e-007	0.002333	0.9386	-6.8901
Sb(OH)3(aq)	1.201e-007	0.02075	1.0000	-6.9204
MnSO4(aq)	5.184e-008	0.007826	1.0000	-7.2853
KSO4-	4.646e-008	0.006279	0.9392	-7.3601
FeCO3+	4.259e-008	0.004933	0.9392	-7.3980
HAsO4--	2.392e-008	0.003347	0.7773	-7.7306
Cd++	1.908e-008	0.002144	0.7808	-7.8269
H+	1.679e-008	1.692e-005	0.9441	-7.8000

Al(OH)2+	1.440e-008	0.0008781	0.9392	-7.8689
Pb++	9.411e-009	0.001950	0.7791	-8.1348
NaHSiO3(aq)	5.057e-009	0.0005060	1.0000	-8.2961
UO2(CO3)3----	2.881e-009	0.001296	0.3647	-8.9785
UO2(CO3)2--	2.386e-009	0.0009303	0.7773	-8.7318
NaCO3-	2.309e-009	0.0001916	0.9392	-8.6638
H2AsO4-	2.102e-009	0.0002961	0.9392	-8.7047
AlOH++	4.502e-010	1.980e-005	0.7791	-9.4550
BaCO3(aq)	2.853e-010	5.630e-005	1.0000	-9.5446
HSO4-	1.250e-010	1.213e-005	0.9392	-9.9303
NaAlO2(aq)	6.392e-011	5.238e-006	1.0000	-10.1944
PO4---	6.235e-011	5.920e-006	0.5671	-10.4515
UO2CO3(aq)	5.790e-011	1.910e-005	1.0000	-10.2373
Cu+	1.065e-011	6.765e-007	0.9392	-11.0000
NaOH(aq)	3.745e-012	1.498e-007	1.0000	-11.4265
Al+++	3.191e-012	8.608e-008	0.5942	-11.7221
AsO4---	2.956e-012	4.105e-007	0.5671	-11.7757
Sb(OH)4-	2.173e-012	4.124e-007	0.9392	-11.6901
CdSO4(aq)	1.867e-012	3.892e-007	1.0000	-11.7288
H3PO4(aq)	1.122e-012	1.099e-007	1.0000	-11.9500
MgP2O7--	1.089e-012	2.158e-007	0.7773	-12.0725
Fe+++	7.381e-013	4.121e-008	0.5942	-12.3579
UO2OH+	6.444e-013	1.849e-007	0.9392	-12.2181
HNO3(aq)	2.728e-013	1.718e-008	1.0000	-12.5642
Sb(OH)2+	1.321e-013	2.057e-008	0.9392	-12.9065
HP2O7---	1.730e-014	3.026e-009	0.5671	-14.0083
UO2++	6.605e-015	1.783e-009	0.7791	-14.2886
H3AsO4(aq)	4.566e-015	6.480e-010	1.0000	-14.3404
FeSO4+	2.713e-015	4.121e-010	0.9392	-14.5938
P2O7----	8.939e-016	1.555e-010	0.3647	-15.4868
H2P2O7--	8.876e-016	1.561e-010	0.7773	-15.1612
UO2SO4(aq)	4.668e-016	1.709e-010	1.0000	-15.3308
KHSO4(aq)	3.031e-016	4.126e-011	1.0000	-15.5184
KP2O7---	4.888e-018	1.041e-012	0.5671	-17.5572
UO2(SO4)2--	4.256e-019	1.967e-013	0.7773	-18.4804
(UO2)2(OH)2++	1.061e-019	6.088e-014	0.7791	-19.0828
UO2+	8.630e-021	2.330e-015	0.9392	-20.0913
H3P2O7-	2.644e-021	4.678e-016	0.9392	-20.6050
(UO2)3(CO3)6(6-)	2.610e-021	3.053e-015	0.1033	-21.5692
(UO2)3(OH)5+	2.321e-021	2.077e-015	0.9392	-20.6615
HAsO2(aq)	2.130e-024	2.298e-019	1.0000	-23.6717
U(OH)4(aq)	2.030e-024	6.210e-019	1.0000	-23.6926
As(OH)3(aq)	1.920e-024	2.418e-019	1.0000	-23.7166
Mn+++	3.094e-025	1.700e-020	0.5728	-24.7514
H2AsO3-	3.627e-026	4.531e-021	0.9392	-25.4677
AsO2-	3.530e-026	3.773e-021	0.9392	-25.4795
H4P2O7(aq)	9.736e-028	1.732e-022	1.0000	-27.0116
AsO2OH--	1.230e-029	1.524e-024	0.7773	-29.0196
NO2-	5.510e-031	2.534e-026	0.9381	-30.2866
O2(aq)	9.867e-033	3.157e-028	1.0000	-32.0058
Formate	1.940e-033	8.729e-029	0.9386	-32.7398
H2(aq)	4.371e-034	8.809e-031	1.0000	-33.3594
Ca(For)+	3.584e-035	3.049e-030	0.9392	-34.4729
HNO2(aq)	2.153e-035	1.012e-030	1.0000	-34.6670
Mg(For)+	1.670e-035	1.157e-030	0.9392	-34.8046
Na(For)(aq)	3.499e-037	2.379e-032	1.0000	-36.4561
Mn(For)+	2.768e-037	2.766e-032	0.9392	-36.5851
Formic_acid(aq)	1.731e-037	7.966e-033	1.0000	-36.7617
Cu(For)+	1.300e-037	1.411e-032	0.9392	-36.9133
Fe(For)+	1.227e-037	1.237e-032	0.9392	-36.9384
K(For)(aq)	8.674e-038	7.295e-033	1.0000	-37.0618
SO3--	2.497e-038	1.998e-033	0.7791	-37.7111
Ba(For)+	1.687e-038	3.076e-033	0.9392	-37.8001

HO2-	8.157e-039	2.692e-034	0.9392	-38.1157
NH4+	5.489e-039	9.899e-035	0.9375	-38.2885
HSO3-	4.521e-039	3.665e-034	0.9392	-38.3720
Cd(For)+	2.608e-039	4.105e-034	0.9392	-38.6109
Pb(For)+	1.092e-039	2.754e-034	0.9392	-38.9890
CO(aq)	2.577e-040	7.217e-036	1.0000	-39.5889
Oxalate	5.919e-041	5.209e-036	0.7773	-40.3371
NH3(aq)	4.516e-041	7.689e-037	1.0000	-40.3453
MnO4--	2.318e-041	2.757e-036	0.7773	-40.7442
U(CO3)5(6-)	7.387e-043	3.974e-037	0.1033	-43.1173
UOH+++	3.141e-043	8.009e-038	0.5728	-42.7449
H-Oxalate	1.255e-044	1.117e-039	0.9392	-43.9284
MnO4-	9.037e-045	1.075e-039	0.9386	-44.0715
SO2(aq)	3.348e-045	2.145e-040	1.0000	-44.4752
HSO5-	2.528e-047	2.858e-042	0.9392	-46.6244
USO4++	1.650e-047	5.512e-042	0.7791	-46.8909
U(SO4)2(aq)	6.014e-048	2.587e-042	1.0000	-47.2208
U++++	9.945e-050	2.367e-044	0.3745	-49.4289
Oxalic_acid(aq)	3.391e-051	3.052e-046	1.0000	-50.4697
S2O6--	1.274e-063	2.039e-058	0.7773	-63.0043
S2O8--	8.538e-065	1.640e-059	0.7773	-64.1780
Ca(For)2(aq)	5.758e-067	7.491e-062	1.0000	-66.2397
Mg(For)2(aq)	3.575e-067	4.087e-062	1.0000	-66.4467
U+++	7.605e-068	1.810e-062	0.5728	-67.3609
Mn(For)2(aq)	8.183e-069	1.186e-063	1.0000	-68.0871
Cu(For)2(aq)	7.302e-069	1.121e-063	1.0000	-68.1365
Fe(For)2(aq)	5.140e-069	7.497e-064	1.0000	-68.2890
Cd(For)2(aq)	7.225e-070	1.462e-064	1.0000	-69.1412
Na(For)2-	5.405e-070	6.108e-065	0.9392	-69.2944
Ba(For)2(aq)	1.929e-070	4.384e-065	1.0000	-69.7148
K(For)2-	1.076e-070	1.390e-065	0.9392	-69.9953
Pb(For)2(aq)	3.413e-071	1.014e-065	1.0000	-70.4668
Formaldehyde(aq)	2.909e-072	8.733e-068	1.0000	-71.5362
N3-	6.511e-074	2.735e-069	0.9392	-73.2136
HN3(aq)	7.502e-077	3.227e-072	1.0000	-76.1248
Cu(NH3)2++	1.200e-079	1.171e-074	0.7791	-79.0291
S2O5--	3.761e-082	5.420e-077	0.7773	-81.5341
Cd(NH3)2++	5.970e-084	8.742e-079	0.7791	-83.3325
Urea(aq)	5.385e-085	3.234e-080	1.0000	-84.2688
HCN(aq)	4.433e-086	1.198e-081	1.0000	-85.3533
CN-	4.741e-088	1.233e-083	0.9381	-87.3519
Methanol(aq)	1.054e-089	3.378e-085	1.0000	-88.9770
Glycolate	7.400e-096	5.552e-091	0.9392	-95.1580
HS-	5.650e-097	1.868e-092	0.9386	-96.2755
Ca(Glyc)+	2.428e-097	2.794e-092	0.9392	-96.6420
H2S(aq)	1.665e-097	5.672e-093	1.0000	-96.7787
Mg(Glyc)+	4.038e-098	4.011e-093	0.9392	-97.4211
Cu(Glyc)+	4.810e-099	6.664e-094	0.9392	-98.3451
Na(Glyc)(aq)	1.380e-099	1.352e-094	1.0000	-98.8602
Fe(Glyc)+	1.143e-099	1.496e-094	0.9392	-98.9691
Mn(Glyc)+	8.168e-100	1.061e-094	0.9392	-99.1152
Glycolic_acid(aq	8.055e-100	6.125e-095	1.0000	-99.0939
K(Glyc)(aq)	3.421e-100	3.904e-095	1.0000	-99.4659
Ba(Glyc)+	3.103e-101	6.589e-096	0.9392	-100.5355
Pb(Glyc)+	1.182e-101	3.335e-096	0.9392	-100.9547
Cd(Glyc)+	1.108e-101	2.076e-096	0.9392	-100.9828
Methane(aq)	1.033e-101	1.657e-097	1.0000	-100.9857
S--	1.314e-102	4.211e-098	0.7808	-101.9890
S2O4--	1.884e-103	2.413e-098	0.7808	-102.8325
S2O3--	1.203e-103	1.349e-098	0.7773	-103.0292
Acetate	2.981e-107	1.760e-102	0.9397	-106.5526
MgCH3COO+	1.734e-109	1.445e-104	0.9392	-108.7883
CaCH3COO+	1.635e-109	1.620e-104	0.9392	-108.8138

Acetic_acid(aq)	2.615e-110	1.570e-105	1.0000	-109.5825
CuCH3COO+	3.837e-111	4.702e-106	0.9392	-110.4433
NaCH3COO(aq)	3.817e-111	3.131e-106	1.0000	-110.4183
MnCH3COO+	1.341e-111	1.529e-106	0.9392	-110.8997
KCH3COO(aq)	6.681e-112	6.556e-107	1.0000	-111.1751
FeCH3COO+	4.674e-112	5.370e-107	0.9392	-111.3575
BaCH3COO+	1.024e-112	2.010e-107	0.9392	-112.0171
PbCH3COO+	6.047e-113	1.610e-107	0.9392	-112.2457
CdCH3COO+	5.141e-113	8.813e-108	0.9392	-112.3162
Malonate	3.478e-116	3.548e-111	0.7773	-115.5681
AlCH3COO++	1.535e-116	1.320e-111	0.7791	-115.9223
Cu(NH3)3++	6.390e-117	7.324e-112	0.7791	-116.3030
CuCH3COO(aq)	7.317e-118	8.968e-113	1.0000	-117.1357
H-Malonate	2.126e-118	2.191e-113	0.9392	-117.6996
AsH3(aq)	1.731e-119	1.349e-114	1.0000	-118.7618
Malonic_acid(aq)	2.374e-123	2.470e-118	1.0000	-122.6244
Methanamine(aq)	2.260e-127	7.018e-123	1.0000	-126.6459
Cu(Gly)+	4.680e-130	6.439e-125	0.9392	-129.3570
Glycine(aq)	3.613e-130	2.712e-125	1.0000	-129.4422
Mg(Gly)+	9.526e-133	9.368e-128	0.9392	-132.0483
Fe(Gly)+	1.957e-134	2.542e-129	0.9392	-133.7356
Mn(Gly)+	1.468e-134	1.894e-129	0.9392	-133.8604
Ca(Gly)+	1.169e-134	1.334e-129	0.9392	-133.9595
Pb(Gly)+	2.886e-135	8.115e-130	0.9392	-134.5670
Cd(Gly)+	1.163e-135	2.168e-130	0.9392	-134.9616
S3O6--	5.976e-137	1.148e-131	0.7773	-136.3330
Ba(Gly)+	8.775e-138	1.855e-132	0.9392	-137.0840
Acetaldehyde(aq)	7.184e-144	3.164e-139	1.0000	-143.1436
SCN-	4.827e-145	2.803e-140	0.9386	-144.3439
NH4CH3COO(aq)	2.376e-145	1.831e-140	1.0000	-144.6242
Acetamide(aq)	1.852e-145	1.094e-140	1.0000	-144.7323
UO2SCN+	6.024e-158	1.976e-152	0.9392	-157.2474
Cd(NH3)4++	5.363e-162	9.680e-157	0.7791	-161.3790
Ethanol(aq)	4.852e-166	2.235e-161	1.0000	-165.3141
Ethyne(aq)	1.694e-166	4.410e-162	1.0000	-165.7711
Ethylene(aq)	6.148e-171	1.724e-166	1.0000	-170.2113
Lactate	3.651e-172	3.251e-167	0.9392	-171.4648
Ca(Lac)+	7.039e-174	9.089e-169	0.9392	-173.1797
Mg(Lac)+	1.952e-174	2.212e-169	0.9392	-173.7368
Cu(Lac)+	1.082e-175	1.651e-170	0.9392	-174.9931
Na(Lac)(aq)	6.996e-176	7.839e-171	1.0000	-175.1551
Fe(Lac)+	5.010e-176	7.259e-171	0.9392	-175.3274
Lactic_acid(aq)	4.140e-176	3.728e-171	1.0000	-175.3830
Mn(Lac)+	2.852e-176	4.107e-171	0.9392	-175.5721
K(Lac)(aq)	1.735e-176	2.223e-171	1.0000	-175.7607
Ba(Lac)+	6.212e-178	1.406e-172	0.9392	-177.2340
Pb(Lac)+	5.698e-178	1.688e-172	0.9392	-177.2715
Cd(Lac)+	3.697e-178	7.447e-173	0.9392	-177.4594
Ethane(aq)	1.737e-182	5.223e-178	1.0000	-181.7601
Propanoate	8.636e-186	6.309e-181	0.9392	-185.0909
Ca(Prop)+	2.646e-188	2.994e-183	0.9392	-187.6046
Mg(Prop)+	1.359e-188	1.323e-183	0.9392	-187.8940
Propanoic_acid(a	1.015e-188	7.515e-184	1.0000	-187.9937
Na(Prop)(aq)	1.633e-189	1.568e-184	1.0000	-188.7870
Cu(Prop)+	1.096e-189	1.497e-184	0.9392	-188.9875
Mn(Prop)+	4.600e-190	5.887e-185	0.9392	-189.3645
K(Prop)(aq)	4.048e-190	4.540e-185	1.0000	-189.3927
Fe(Prop)+	3.335e-190	4.298e-185	0.9392	-189.5042
USCN+++	6.104e-191	1.807e-185	0.5728	-190.4564
Ca(Glyc)2(aq)	3.748e-191	7.126e-186	1.0000	-190.4262
Pb(Prop)+	1.542e-191	4.320e-186	0.9392	-190.8392
Cd(Prop)+	1.376e-191	2.552e-186	0.9392	-190.8886
Mg(Glyc)2(aq)	3.972e-192	6.925e-187	1.0000	-191.4010

Ba(Prop)+	3.826e-192	8.047e-187	0.9392	-191.4446
Cu(Glyc)2(aq)	3.155e-192	6.739e-187	1.0000	-191.5010
Fe(Glyc)2(aq)	6.043e-193	1.244e-187	1.0000	-192.2188
Succinate	4.341e-193	5.038e-188	0.7773	-192.4718
S4O6--	1.171e-193	2.625e-188	0.7773	-193.0410
Mn(Glyc)2(aq)	5.152e-194	1.056e-188	1.0000	-193.2880
Na(Glyc)2-	1.281e-194	2.218e-189	0.9392	-193.9195
Pb(Glyc)2(aq)	5.241e-195	1.872e-189	1.0000	-194.2806
Cd(Glyc)2(aq)	2.846e-195	7.470e-190	1.0000	-194.5457
K(Glyc)2-	2.641e-195	4.994e-190	0.9392	-194.6056
H-Succinate	2.605e-195	3.050e-190	0.9392	-194.6114
Serine(aq)	1.190e-195	1.250e-190	1.0000	-194.9246
Ba(Glyc)2(aq)	1.052e-195	3.022e-190	1.0000	-194.9781
Succinic_acid(aq	7.109e-199	8.393e-194	1.0000	-198.1482
Ethanamine(aq)	1.084e-205	4.886e-201	1.0000	-204.9650
Alanine(aq)	2.421e-207	2.157e-202	1.0000	-206.6159
Cu(Ala)+	7.111e-208	1.078e-202	0.9392	-207.1753
Fe(Ala)+	1.651e-211	2.375e-206	0.9392	-210.8096
Mg(Ala)+	4.045e-212	4.545e-207	0.9392	-211.4203
Ca(Ala)+	1.479e-212	1.895e-207	0.9392	-211.8574
Mn(Ala)+	8.039e-213	1.149e-207	0.9392	-212.1221
Cd(Ala)+	4.380e-213	8.781e-208	0.9392	-212.3857
Pb(Ala)+	1.507e-213	4.448e-208	0.9392	-212.8492
Ca(CH3COO)2(aq)	9.764e-215	1.544e-209	1.0000	-214.0104
Mg(CH3COO)2(aq)	4.630e-215	6.592e-210	1.0000	-214.3344
Cu(CH3COO)2(aq)	4.342e-216	7.885e-211	1.0000	-215.3623
Ba(Ala)+	4.046e-216	9.119e-211	0.9392	-215.4202
Mn(CH3COO)2(aq)	3.570e-217	6.177e-212	1.0000	-216.4473
Fe(CH3COO)2(aq)	3.452e-217	6.004e-212	1.0000	-216.4619
Acetone(aq)	2.185e-217	1.269e-212	1.0000	-216.6605
Na(CH3COO)2-	7.318e-218	1.032e-212	0.9392	-217.1628
Aspartic_acid(aq	4.130e-218	5.496e-213	1.0000	-217.3840
Cd(CH3COO)2(aq)	3.488e-218	8.039e-213	1.0000	-217.4574
Pb(CH3COO)2(aq)	1.355e-218	4.406e-213	1.0000	-217.8682
Ba(CH3COO)2(aq)	8.899e-219	2.273e-213	1.0000	-218.0506
K(CH3COO)2-	8.102e-219	1.273e-213	0.9392	-218.1187
Al(CH3COO)2+	6.315e-221	9.160e-216	0.9392	-220.2269
Propanal(aq)	7.798e-222	4.528e-217	1.0000	-221.1080
Cu(CH3COO)2-	3.556e-224	6.457e-219	0.9392	-223.4763
1-Propyne(aq)	9.638e-241	3.861e-236	1.0000	-240.0160
S3--	4.377e-244	4.210e-239	0.7773	-243.4682
1-Propanol(aq)	1.611e-244	9.681e-240	1.0000	-243.7928
1-Propene(aq)	3.898e-247	1.640e-242	1.0000	-246.4091
2-Hydroxybutanoa	4.230e-251	4.360e-246	0.9392	-250.4009
NH4(CH3COO)2-	7.423e-252	1.010e-246	0.9392	-251.1567
Asparagine(aq)	3.394e-253	4.483e-248	1.0000	-252.4693
Cu(Gly)2(aq)	2.240e-254	4.740e-249	1.0000	-253.6498
2-Hydroxybutanoi	4.237e-255	4.410e-250	1.0000	-254.3729
Propane(aq)	2.255e-261	9.940e-257	1.0000	-260.6469
Mg(Gly)2(aq)	1.525e-261	2.630e-256	1.0000	-260.8166
Diglycine(aq)	2.789e-262	3.684e-257	1.0000	-261.5546
Fe(Gly)2(aq)	4.508e-263	9.193e-258	1.0000	-262.3460
Mn(Gly)2(aq)	1.755e-263	3.564e-258	1.0000	-262.7556
Cd(Gly)2(aq)	9.075e-264	2.364e-258	1.0000	-263.0422
Pb(Gly)2(aq)	6.749e-264	2.397e-258	1.0000	-263.1708
Diketopiperazine	8.729e-265	9.958e-260	1.0000	-264.0590
Butanoate	7.932e-265	6.907e-260	0.9392	-264.1279
Ca(Gly)2(aq)	5.559e-266	1.046e-260	1.0000	-265.2550
Ca(But)+	1.664e-267	2.116e-262	0.9392	-266.8060
Mg(But)+	8.142e-268	9.069e-263	0.9392	-267.1165
Butanoic_acid(aq	7.367e-268	6.489e-263	1.0000	-267.1327
Na(But)(aq)	1.449e-268	1.595e-263	1.0000	-267.8389
Cu(But)+	7.977e-269	1.201e-263	0.9392	-268.1254

Ba(Gly)2(aq)	4.399e-269	1.255e-263	1.0000	-268.3566
Mn(But)+	3.611e-269	5.129e-264	0.9392	-268.4696
K(But)(aq)	3.593e-269	4.534e-264	1.0000	-268.4445
Fe(But)+	3.186e-269	4.554e-264	0.9392	-268.5240
Cd(But)+	5.301e-271	1.057e-265	0.9392	-270.3029
Pb(But)+	3.909e-271	1.150e-265	0.9392	-270.4351
Glutarate	3.420e-271	4.449e-266	0.7773	-270.5753
Ba(But)+	2.346e-271	5.264e-266	0.9392	-270.6569
H-Glutarate	1.176e-273	1.542e-268	0.9392	-272.9568
Threonine(aq)	1.113e-274	1.326e-269	1.0000	-273.9534
Glutaric_acid(aq	3.983e-277	5.261e-272	1.0000	-276.3998
Ethylacetate(aq)	3.905e-277	3.440e-272	1.0000	-276.4083
S5O6--	1.721e-280	4.412e-275	0.7773	-279.8735
1-Propanamine(aq	1.220e-283	7.211e-279	1.0000	-282.9136
a-Aminobutyric_a	4.814e-286	4.963e-281	1.0000	-285.3175
Glutamic_acid(aq	3.644e-295	5.361e-290	1.0000	-294.4384
Butanal(aq)	2.332e-302	1.681e-297	1.0000	-300.0000
UO2(SCN)2(aq)	1.453e-302	5.611e-297	1.0000	-300.0000
S4--	4.512e-315	5.787e-310	0.7773	-300.0000
1-Butyne(aq)	8.257e-320	4.465e-315	1.0000	-300.0000
Cu(CH3COO)3-	5.830e-321	1.403e-315	0.9392	-300.0000
Pb(CH3COO)3-	5.435e-323	2.088e-317	0.9392	-300.0000
Mn(CH3COO)3-	4.941e-323	1.146e-317	0.9392	-300.0000
1-Butanol(aq)	4.941e-324	3.661e-319	1.0000	-300.0000
Cd(CH3COO)3-	4.941e-324	1.430e-318	0.9392	-300.0000
Heptanoate	0.0000	0.0000	0.9392	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9392	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9392	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9392	-300.0000
o-Phthalate	0.0000	0.0000	0.7773	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9392	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9392	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9392	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9392	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9392	-300.0000
H-Sebacate	0.0000	0.0000	0.9392	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
H-Pimelate	0.0000	0.0000	0.9392	-300.0000
U(SCN)2++	0.0000	0.0000	0.7791	-300.0000
H-Azelate	0.0000	0.0000	0.9392	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000

Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
H-Adipate	0.0000	0.0000	0.9392	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7773	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7773	-300.0000
Sb2S4--	0.0000	0.0000	0.7773	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Glutamine(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7773	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.7773	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7773	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)+	0.0000	0.0000	0.9392	-300.0000
Fe(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)+	0.0000	0.0000	0.9392	-300.0000
Pb(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butene(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9392	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9412	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9392	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9392	-300.0000
Pentanoate	0.0000	0.0000	0.9392	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9392	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9392	-300.0000
Dodecanoate	0.0000	0.0000	0.9392	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9392	-300.0000
Decanoate	0.0000	0.0000	0.9392	-300.0000
2-Hydroxypentano	0.0000	0.0000	0.9392	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000

Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9392	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9392	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9392	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9392	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9392	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9392	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9392	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.7773	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9392	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9392	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9392	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9392	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9392	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9392	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9392	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9392	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000

Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Nontronite-Ca	25.0427s/sat	UO3(alpha)	-8.3706
Nontronite-Mg	24.9716s/sat	Monteponite	-8.5601
Nontronite-K	24.5663s/sat	Pb3SO6	-8.6065
Nontronite-Na	24.3425s/sat	Cu	-8.7528
Nontronite-H	24.0497s/sat	Tephroite	-8.9353
Hematite	20.4604s/sat	BaUO4	-9.3011
Ferrite-Cu	18.5653s/sat	Manganosite	-9.4198
Magnetite	18.4744s/sat	Mirabilite	-9.4813
Cronstedtite-7A	17.9267s/sat	Saleeite	-9.8912
Delafossite	14.0424s/sat	Nitrobarite	-9.9915
Clinoptilolite-h	12.3715s/sat	CdSO4:2.667H2O	-10.1361
Clinoptilolite-C	12.2620s/sat	Forsterite	-10.2820
Andradite	10.7947s/sat	CdSO4:H2O	-10.4253
Muscovite	10.5320s/sat	Arcanite	-10.4284
Stilbite	10.4023s/sat	Gyrolite	-10.6804
Epidote-ord	10.1308s/sat	UO2.25	-10.8904
Epidote	10.1295s/sat	Mg1.25SO4(OH)0.5	-10.9546
Ferrite-Ca	9.8103s/sat	UO2.25(beta)	-10.9614
Goethite	9.7727s/sat	Thenardite	-11.1754
Ferrite-Mg	9.6584s/sat	Periclase	-11.1893
Clinoptilolite-K	8.4743s/sat	Monticellite	-11.4458
Clinoptilolite-h	8.0349s/sat	Torbernite	-11.5090
Beidellite-Ca	7.6552s/sat	Natron	-11.7039
Beidellite-Mg	7.5839s/sat	Portlandite	-11.7178
Illite	7.4350s/sat	Uranocircite	-11.8268
Beidellite-K	7.1789s/sat	MgUO4	-12.1325
Kaolinite	7.0715s/sat	(UO2)3(PO4)2:4H2	-12.2027
Beidellite-Na	6.9548s/sat	CdSO4	-12.2064
Mesolite	6.7642s/sat	Mg1.5SO4(OH)	-12.3070
Paragonite	6.7399s/sat	Na2CO3:7H2O	-12.3466
Beidellite-H	6.6629s/sat	Tremolite	-12.3726
Montmor-Mg	6.4556s/sat	BaU2O7	-12.5034
Montmor-Ca	6.4501s/sat	UO2SO4:H2O	-12.5921
Pyrophyllite	6.3612s/sat	MnSO4	-12.9331
Montmor-K	6.0505s/sat	Pb4SO7	-12.9596
Scolecite	5.9021s/sat	Przhevalskite	-13.3000
Montmor-Na	5.8209s/sat	MgSO4	-13.4756
Clinoptilolite-N	5.7142s/sat	FeSO4	-13.5631
Clinoptilolite-h	5.7111s/sat	UPO5	-13.6010
Jarosite	4.7575s/sat	UO2.6667	-13.6474
Laumontite	4.5183s/sat	Thermonatrite	-13.9487
Fe(OH)3	4.3894s/sat	Chalcocyanite	-13.9597
Smectite-low-Fe-	4.2255s/sat	Na2U2O7	-14.0325
Margarite	4.1596s/sat	Bassetite	-14.1918
Maximum_Microcli	3.6325s/sat	Na2CO3	-14.3097
K-Feldspar	3.6299s/sat	Uraninite	-14.3327
Smectite-high-Fe	3.4151s/sat	Mordenite-dehy	-14.3708
Celadonite	3.3806s/sat	Coffinite	-14.6309
Diaspore	3.2107s/sat	Autunite-H	-15.0106
Lawsonite	2.9374s/sat	Ca3(AsO4)2	-15.4689
Boehmite	2.7736s/sat	Ferrite-Dicalciu	-15.6348
Gibbsite	2.7126s/sat	Ba(OH)2:8H2O	-16.0472
Sanidine_high	2.3013s/sat	CaAl2O4	-16.4043

Corundum	2.0324s/sat	UO2SO4:3.5H2O	-17.0391
Mordenite	1.9731s/sat	UO2SO4:2.5H2O	-17.1233
Amesite-14A	1.8412s/sat	UO2SO4:3H2O	-17.1976
Witherite	1.7309s/sat	NaUO3	-17.3036
Chamosite-7A	1.1799s/sat	Hydromagnesite	-17.3749
Kyanite	1.1130s/sat	Ba2Si3O8	-17.5943
Malachite	1.0846s/sat	Gehlenite	-17.8474
Tenorite	0.8681s/sat	CaAl4O7	-18.0639
Andalusite	0.7917s/sat	Hillebrandite	-18.3351
Albite_low	0.7874s/sat	Natrosilite	-18.4339
Albite	0.7874s/sat	Alum-K	-18.7561
Strengite	0.6743s/sat	Dicalcium_silica	-18.8555
Quartz	0.5530s/sat	Na2SiO3	-19.0713
Daphnite-14A	0.4760s/sat	Ningyoite	-19.0990
Sillimanite	0.3895s/sat	Anthophyllite	-19.7305
Tridymite	0.3539s/sat	Akermanite	-19.7490
Brochantite	0.2821s/sat	UO2.3333(beta)	-19.9887
Chalcedony	0.2634s/sat	Larnite	-20.2614
Cerussite	0.1974s/sat	UO2SO4	-21.1047
Analcime	0.1801s/sat	Lime	-22.5094
Barite	0.0216s/sat	Na2UO4(alpha)	-22.7871
Prehnite	-0.0387	UO2(NO3)2:6H2O	-22.9201
Cristobalite(alp	-0.0421	Pargasite	-23.9668
Ice	-0.0677	UO2(NO3)2:3H2O	-24.6588
Hercynite	-0.1768	UO2(PO3)2	-25.6526
Dolomite-ord	-0.2138	Rankinite	-26.0615
Dolomite	-0.2139	UO2(NO3)2:2H2O	-26.0718
Dawsonite	-0.2410	Clinoptilolite-d	-26.3793
Coesite	-0.3087	(UO2)3(PO4)2	-26.3802
Clinozoisite	-0.4135	(UO2)2P2O7	-26.4805
Calcite	-0.4275	Pb	-27.0209
Zoisite	-0.4628	K2UO4	-27.7164
Wairakite	-0.5176	U(HPO4)2:4H2O	-27.7417
Cristobalite(bet	-0.5419	Tobermorite-14A	-27.8232
Aragonite	-0.5729	Ettringite	-28.1840
Albite_high	-0.6624	UP2O7	-28.2387
Annite	-0.6779	KAl(SO4)2	-28.7724
Rhodochrosite	-0.7611	UO2(NO3)2:H2O	-30.0046
Kalsilite	-0.8712	Clinoptilolite-d	-30.2167
SiO2(am)	-0.8955	Tobermorite-11A	-30.2174
Natrolite	-0.9034	Foshagite	-32.2352
Dioptase	-0.9471	Merwinite	-32.2543
Hydroxylapatite	-1.1593	Ba2SiO4	-32.8711
Saponite-Ca	-1.1598	Clinoptilolite-d	-32.9452
Monohydrocalcite	-1.2201	UO2(NO3)2	-33.7681
Saponite-Mg	-1.2287	Tobermorite-9A	-34.1824
Ripidolite-14A	-1.3066	Afwillite	-34.3803
Jadeite	-1.3863	As2O5	-35.5596
Siderite	-1.4259	UO2SO3	-35.8998
Magnesite	-1.5371	Cd	-37.0527
Saponite-K	-1.6361	Fe	-38.0312
Phlogopite	-1.6971	Al2(SO4)3:6H2O	-39.1760
Saponite-Na	-1.8601	(UO2)2As2O7	-39.7819
Dolomite-dis	-1.9041	UO2(AsO3)2	-39.8990
Anorthite	-2.1132	(UO2)3(AsO4)2	-40.5773
Saponite-H	-2.1523	BaO	-41.8282
Alamosite	-2.2519	Fe2(SO4)3	-42.4304
Minnesotaite	-2.3453	U(SO4)2:8H2O	-45.0996
Talc	-2.4657	Hatrurite	-45.2991
Ferrosilite	-2.5575	Ba2U2O7	-45.5832
Whitlockite	-2.5851	Arsenolite	-45.6614
Gypsum	-2.6240	Claudetite	-45.7437
Alunite	-2.7944	U(SO4)2:4H2O	-46.5184

Anhydrite	-2.9900	Xonotlite	-46.6010
Clinochlore-14A	-3.0168	U(SO4)2	-46.8520
Daphnite-7A	-3.0758	C	-47.4561
Berlinite	-3.5259	U(CO3)2	-49.1106
Nepheline	-3.5613	As	-55.2266
Bassanite	-3.6413	Al2(SO4)3	-58.3649
CaUO4	-3.8246	Ca4Al2Fe2O10	-59.1310
CaSO4:0.5H2O(bet	-3.8343	Na	-59.9023
Anglesite	-3.9922	Na3UO4	-60.0562
Bixbyite	-4.0310	Na4SiO4	-62.3974
Azurite	-4.0395	Ca3Al2O6	-62.4908
Greenalite	-4.0787	Mn	-62.9456
Sb2O3	-4.1148	Na2O	-63.6192
UO3:2H2O	-4.1335	K	-64.1775
Schoepite	-4.1349	Covellite	-70.7152
Cuprite	-4.1741	S	-71.8310
CdSiO3	-4.1923	Ba3UO6	-72.2318
Enstatite	-4.2172	Chalcocite	-73.2684
UO2(OH)2(beta)	-4.3167	Antigorite	-75.0871
Lanarkite	-4.3221	CdS	-79.5439
Schoepite-dehy(.	-4.3740	Galena	-80.7365
UO3:.9H2O(alpha)	-4.3897	K2O	-82.1822
Rhodonite	-4.3925	U(SO3)2	-87.7685
Schoepite-dehy(.	-4.4768	PbSO4(NH3)2	-90.3497
Schoepite-dehy(1	-4.4971	Troilite	-90.9049
Wustite	-4.5400	Na6Si2O7	-90.9328
Pyrolusite	-4.5436	As4O6(mono)	-91.0017
Nesquehonite	-4.7212	Pyrrhotite	-91.0106
Ripidolite-7A	-4.8476	As4O6(cubi)	-91.1965
FeO	-5.3785	Alabandite	-93.9872
UO2CO3	-5.4563	Mg	-103.4671
Rutherfordine	-5.4640	BaS	-112.2267
Chrysotile	-5.6066	UN1.73(alpha)	-112.9211
Fe(OH)2	-5.6283	UN1.59(alpha)	-115.8029
Cordierite_hydr	-5.6512	Ca	-121.2558
Schoepite-dehy(.	-5.6921	P	-123.4337
Brucite	-5.6942	Al	-125.6256
Diopside	-5.9275	Ba	-125.7723
Fayalite	-5.9319	UN	-129.5825
Okenite	-5.9466	Si	-131.0195
Litharge	-5.9581	Pb(N3)2(orth)	-144.8163
PbCO3.PbO	-6.0532	Pb(N3)2(mono)	-145.2794
Hausmannite	-6.1352	Pyrite	-151.5805
Wollastonite	-6.1365	Chalcopyrite	-155.3169
Massicot	-6.1604	PbSO4(NH3)4	-174.5523
Schoepite-dehy(.	-6.2531	U	-178.7457
Nahcolite	-6.3395	UAs	-189.5013
Pseudowollastoni	-6.4109	US	-190.5149
Mn(OH)2(am)	-6.5337	UC	-207.7075
Clinochlore-7A	-6.5523	UH3(beta)	-210.0086
Analcime-dehy	-6.6650	US1.9	-219.8957
Huntite	-6.7519	US2	-225.2422
NaFeO2	-6.7917	Mayenite	-230.5117
UO2HPO4:4H2O	-6.8136	UAs2	-241.9100
Niter	-6.9625	UP	-252.3783
Hedenbergite	-6.9766	UC1.94(alpha)	-254.4803
Cd(OH)2	-7.0157	Stibnite	-269.0514
Spinel	-7.0605	US3	-293.6891
UO3(gamma)	-7.3624	Orpiment	-294.3908
Chalcanthite	-7.5197	Pb(SCN)2	-296.6520
Melanterite	-7.5785	Bornite	-301.5776
Sepiolite	-7.6417	UP2	-370.3874
Pb2SiO4	-7.9534	U2S3	-408.3817

Artinite	-8.0026	o-Phthalic_acid	-416.3540
UO3(beta)	-8.0079	U2C3	-464.5062
Grossular	-8.0841	U3As4	-621.4843
Sanbornite	-8.3303	U3S5	-628.7206
Cordierite_anhyd	-8.3353	U3P4	-875.1448
Ca-Al_Pyroxene	-8.3694		

Gases	fugacity	log fug.
N2(g)	0.09304	-1.031
H2O(g)	0.007689	-2.114
CO2(g)	0.001095	-2.961
NO2(g)	6.132e-013	-12.212
O2(g)	5.246e-030	-29.280
H2(g)	4.775e-031	-30.321
NO(g)	5.481e-032	-31.261
CO(g)	1.786e-037	-36.748
NH3(g)	2.698e-043	-42.569
SO2(g)	1.036e-045	-44.985
Cd(g)	1.213e-052	-51.916
Pb(g)	1.700e-058	-57.769
Cu(g)	1.196e-065	-64.922
Na(g)	2.153e-075	-74.667
UO3(g)	2.169e-076	-75.664
K(g)	1.466e-076	-75.834
H2S(g)	9.378e-097	-96.028
CH4(g)	4.733e-099	-98.325
UO2(g)	8.792e-119	-118.056
Mg(g)	1.174e-125	-124.930
Ca(g)	2.499e-149	-148.602
S2(g)	8.252e-160	-159.083
C2H4(g)	7.670e-169	-168.115
C(g)	2.584e-174	-173.588
Al(g)	5.635e-181	-180.249
UO(g)	8.375e-195	-194.077
Si(g)	3.771e-208	-207.424
U(g)	2.195e-271	-270.659

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Al+++	3.25e-006	3.25e-006	0.0877			
Ba++	4.97e-007	4.97e-007	0.0682			
Ca++	0.000778	0.000778	31.2			
Cd++	1.91e-008	1.91e-008	0.00214			
Cu++	6.29e-007	6.29e-007	0.0400			
Fe++	8.73e-007	8.73e-007	0.0487			
H+	5.08e-005	5.08e-005	0.0512			
H2AsO4-	2.60e-008	2.60e-008	0.00367			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00153	0.00153	93.6			
HPO4--	3.02e-006	3.02e-006	0.290			
K+	4.99e-005	4.99e-005	1.95			
Mg++	0.000281	0.000281	6.82			
Mn++	2.89e-006	2.89e-006	0.159			
NH3(aq)	0.000172	0.000172	2.93			
NO3-	0.000556	0.000556	34.5			
Na+	0.000170	0.000170	3.90			
O2(aq)	0.000129	0.000129	4.12			
Pb++	9.41e-009	9.41e-009	0.00195			
SO4--	0.000173	0.000173	16.6			
Sb(OH)3(aq)	1.20e-007	1.20e-007	0.0207			
SiO2(aq)	0.000125	0.000125	7.51			

UO2++	5.33e-009	5.33e-009	0.00144

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Aluminum	3.252e-006	3.252e-006	0.08773		
Antimony	1.201e-007	1.201e-007	0.01462		
Arsenic	2.603e-008	2.603e-008	0.001950		
Barium	4.970e-007	4.970e-007	0.06824		
Cadmium	1.908e-008	1.908e-008	0.002145		
Calcium	0.0007785	0.0007785	31.19		
Carbon	0.001534	0.001534	18.42		
Copper	6.291e-007	6.291e-007	0.03997		
Hydrogen	111.0	111.0	1.119e+005		
Iron	8.729e-007	8.729e-007	0.04874		
Lead	9.411e-009	9.411e-009	0.001950		
Magnesium	0.0002808	0.0002808	6.824		
Manganese	2.893e-006	2.893e-006	0.1589		
Nitrogen	0.0007280	0.0007280	10.19		
Oxygen	55.52	55.52	8.880e+005		
Phosphorus	3.022e-006	3.022e-006	0.09358		
Potassium	4.987e-005	4.987e-005	1.950		
Silicon	0.0001250	0.0001250	3.509		
Sodium	0.0001696	0.0001696	3.899		
Sulfur	0.0001725	0.0001725	5.532		
Uranium	5.325e-009	5.325e-009	0.001267		

```
Temperature =  25.0 C    Pressure =  1.013 bars
pH =  7.300              log fO2 =  -30.442
Eh =   0.3470 volts      pe =   5.8659
Ionic strength      =    0.002847
Charge imbalance    =    0.000124 eq/kg (6.787% error)
Activity of water   =    1.000000
Solvent mass        =    1.000000 kg
Solution mass       =    1.000163 kg
Solution density    =    1.013    g/cm3
Chlorinity          =    0.000000 molal
Dissolved solids    =         163 mg/kg sol'n
Elect. conductivity =      172.28 uS/cm (or umho/cm)
Hardness            =       96.28 mg/kg sol'n as CaCO3
  carbonate         =       80.74 mg/kg sol'n as CaCO3
  non-carbonate     =       15.54 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       80.74 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
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Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3470	5.8659
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5596	9.4597

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001596	97.35	0.9432	-2.8224
Ca++	0.0006747	27.04	0.7968	-3.2695
Mg++	0.0002651	6.443	0.8024	-3.6721
CO2(aq)	0.0001668	7.341	1.0000	-3.7777
SiO2(aq)	0.0001295	7.781	1.0000	-3.8876
SO4--	7.112e-005	6.830	0.7909	-4.2499
NO3-	2.883e-005	1.787	0.9423	-4.5660
CaHCO3+	9.553e-006	0.9656	0.9432	-5.0452
CaSO4(aq)	3.905e-006	0.5316	1.0000	-5.4083
MgHCO3+	3.686e-006	0.3144	0.9432	-5.4588
MgSO4(aq)	3.088e-006	0.3716	1.0000	-5.5103
N2(aq)	2.390e-006	0.06693	1.0000	-5.6217
CO3--	1.778e-006	0.1067	0.7924	-5.8512
CaCO3(aq)	1.608e-006	0.1609	1.0000	-5.7936
Mn++	8.329e-007	0.04575	0.7968	-6.1781
CuCO3(aq)	5.360e-007	0.06621	1.0000	-6.2709
HSiO3-	3.057e-007	0.02356	0.9432	-6.5401
MgCO3(aq)	2.855e-007	0.02407	1.0000	-6.5444
OH-	2.140e-007	0.003640	0.9428	-6.6951
Zn++	2.114e-007	0.01382	0.7968	-6.7735
CaNO3+	7.760e-008	0.007920	0.9432	-7.1355
Cu++	5.293e-008	0.003363	0.7968	-7.3750
H+	5.290e-008	5.331e-005	0.9474	-7.3000
CuOH+	4.602e-008	0.003706	0.9432	-7.3625
MnCO3(aq)	3.096e-008	0.003558	1.0000	-7.5093
MnSO4(aq)	8.413e-009	0.001270	1.0000	-8.0751
MnHCO3+	8.063e-009	0.0009349	0.9432	-8.1189
ZnHCO3+	7.071e-009	0.0008937	0.9432	-8.1759
ZnOH+	3.907e-009	0.0003219	0.9432	-8.4335
ZnSO4(aq)	1.918e-009	0.0003096	1.0000	-8.7172
ZnCO3(aq)	1.885e-009	0.0002363	1.0000	-8.7247
Cu(CO3)2--	1.608e-009	0.0002952	0.7909	-8.8955
CaOH+	1.606e-009	9.169e-005	0.9432	-8.8195
CuSO4(aq)	5.434e-010	8.672e-005	1.0000	-9.2649

MnOH+	3.609e-010	2.596e-005	0.9432	-9.4681
Zn(OH)2(aq)	3.150e-010	3.131e-005	1.0000	-9.5017
HSO4-	2.848e-010	2.764e-005	0.9432	-9.5708
Cu+	3.274e-011	2.080e-006	0.9432	-10.5103
MnNO3+	3.029e-011	3.542e-006	0.9432	-10.5441
CuCO3(OH)2--	2.294e-012	3.613e-007	0.7909	-11.7414
H2SiO4--	7.149e-013	6.726e-008	0.7909	-12.2476
HNO3(aq)	6.784e-014	4.274e-009	1.0000	-13.1685
Zn(OH)3-	2.065e-014	2.404e-009	0.9432	-13.7104
Mn(OH)2(aq)	1.667e-014	1.483e-009	1.0000	-13.7781
Mn2(OH)3+	4.670e-015	7.512e-010	0.9432	-14.3561
H6(H2SiO4)4--	3.245e-015	1.241e-009	0.7909	-14.5906
Mn(NO3)2(aq)	1.949e-015	3.488e-010	1.0000	-14.7101
Mn2OH+++	4.070e-016	5.163e-011	0.5948	-15.6161
CuO2--	3.001e-018	2.866e-013	0.7909	-17.6247
Mn(OH)3-	3.308e-019	3.504e-014	0.9432	-18.5059
Zn(OH)4--	8.379e-020	1.118e-014	0.7909	-19.1787
H2SO4(aq)	1.346e-020	1.320e-015	1.0000	-19.8708
H4(H2SiO4)4----	1.310e-022	4.982e-017	0.3910	-22.2906
Mg4(OH)4++++	1.444e-025	2.386e-020	0.3999	-25.2385
Mn(OH)4--	6.665e-026	8.195e-021	0.7909	-25.2781
Mn+++	2.145e-026	1.178e-021	0.5948	-25.8942
Formate	1.169e-029	5.263e-025	0.9428	-28.9577
H2(aq)	3.660e-030	7.378e-027	1.0000	-29.4365
Ca(For)+	1.692e-031	1.439e-026	0.9432	-30.7971
Mg(For)+	6.694e-032	4.640e-027	0.9432	-31.1997
NO2-	1.395e-032	6.417e-028	0.9423	-31.8812
Formic_acid(aq)	3.128e-033	1.440e-028	1.0000	-32.5047
O2(aq)	4.568e-034	1.462e-029	1.0000	-33.3402
Mn(For)+	3.886e-034	3.883e-029	0.9432	-33.4359
Zn(For)+	1.160e-034	1.280e-029	0.9432	-33.9610
NH4+	8.529e-035	1.538e-030	0.9418	-34.0951
SO3--	7.886e-035	6.313e-030	0.7924	-34.2042
HSO3-	5.328e-035	4.319e-030	0.9432	-34.2988
Cu(For)+	4.706e-035	5.108e-030	0.9432	-34.3527
CO(aq)	7.039e-036	1.971e-031	1.0000	-35.1525
HNO2(aq)	1.095e-036	5.147e-032	1.0000	-35.9606
NH3(aq)	9.202e-037	1.567e-032	1.0000	-36.0361
Oxalate	4.598e-037	4.047e-032	0.7909	-36.4393
CuNO2+	6.155e-038	6.742e-033	0.9432	-37.2361
HO2-	2.256e-038	7.445e-034	0.9432	-37.6720
CuNH3++	5.370e-040	4.326e-035	0.7924	-39.3711
H-Oxalate	3.489e-040	3.106e-035	0.9432	-39.4827
H2SO3(aq)	2.565e-040	2.105e-035	1.0000	-39.5910
SO2(aq)	1.826e-040	1.169e-035	1.0000	-39.7386
Zn(NH3)++	2.209e-041	1.820e-036	0.7924	-40.7569
MnO4--	2.339e-043	2.781e-038	0.7909	-42.7329
HSO5-	3.303e-046	3.734e-041	0.9432	-45.5065
Oxalic_acid(aq)	3.073e-046	2.767e-041	1.0000	-45.5124
MnO4-	5.969e-047	7.099e-042	0.9428	-46.2497
NH4SO4-	2.395e-047	2.733e-042	0.9432	-46.6460
S2O6--	1.788e-058	2.862e-053	0.7909	-57.8496
Ca(For)2(aq)	1.304e-059	1.697e-054	1.0000	-58.8847
Mg(For)2(aq)	5.161e-060	5.900e-055	1.0000	-59.2873
Mn(For)2(aq)	4.970e-062	7.204e-057	1.0000	-61.3036
Zn(For)2(aq)	1.704e-062	2.648e-057	1.0000	-61.7686
Cu(For)2(aq)	1.023e-062	1.570e-057	1.0000	-61.9903
S2O8--	6.793e-063	1.305e-057	0.7909	-62.2698
Formaldehyde(aq)	4.419e-064	1.327e-059	1.0000	-63.3547
Cu(NO2)2(aq)	7.810e-069	1.215e-063	1.0000	-68.1073
N3-	3.196e-071	1.343e-066	0.9432	-70.5208
Cu(NH3)2++	1.274e-072	1.243e-067	0.7924	-71.9960
HN3(aq)	7.573e-074	3.258e-069	1.0000	-73.1207

S2O5--	4.863e-074	7.008e-069	0.7909	-73.4150
Zn(NH3)2++	3.268e-075	3.250e-070	0.7924	-74.5867
Urea(aq)	2.736e-076	1.643e-071	1.0000	-75.5628
HCN(aq)	4.977e-077	1.345e-072	1.0000	-76.3030
ZnN3+	1.490e-077	1.600e-072	0.9432	-76.8523
Methanol(aq)	9.623e-079	3.083e-074	1.0000	-78.0167
CN-	6.122e-079	1.593e-074	0.9423	-78.2389
HS-	6.907e-084	2.284e-079	0.9428	-83.1863
H2S(aq)	3.172e-084	1.081e-079	1.0000	-83.4986
Glycolate	8.066e-085	6.052e-080	0.9432	-84.1187
Ca(Glyc)+	1.937e-086	2.230e-081	0.9432	-85.7383
Mg(Glyc)+	3.666e-087	3.642e-082	0.9432	-86.4612
Methane(aq)	2.612e-088	4.189e-084	1.0000	-87.5831
Glycolic_acid(aq	2.599e-088	1.977e-083	1.0000	-87.5851
Zn(Glyc)+	3.259e-089	4.577e-084	0.9432	-88.5122
Cu(Glyc)+	2.642e-089	3.661e-084	0.9432	-88.6035
Mn(Glyc)+	2.044e-089	2.656e-084	0.9432	-88.7150
S--	1.900e-089	6.092e-085	0.7939	-88.8214
S2O3--	1.390e-090	1.559e-085	0.7909	-89.9587
S2O4--	3.585e-092	4.593e-087	0.7939	-91.5457
Acetate	1.027e-093	6.061e-089	0.9437	-93.0137
Zn(For)3-	7.366e-094	1.476e-088	0.9432	-93.1581
CaCH3COO+	4.710e-096	4.668e-091	0.9432	-95.3523
MgCH3COO+	4.156e-096	3.463e-091	0.9432	-95.4067
Acetic_acid(aq)	2.776e-096	1.667e-091	1.0000	-95.5565
HS2O3-	6.033e-097	6.825e-092	0.9432	-96.2448
MnCH3COO+	1.123e-098	1.280e-093	0.9432	-97.9750
CuCH3COO+	7.391e-099	9.059e-094	0.9432	-98.1567
ZnCH3COO+	6.974e-099	8.676e-094	0.9432	-98.1819
Malonate	2.115e-102	2.158e-097	0.7909	-101.7766
CuCH3COO(aq)	6.394e-104	7.837e-099	1.0000	-103.1942
H-Malonate	4.408e-104	4.542e-099	0.9432	-103.3811
Cu(NH3)3++	7.756e-106	8.890e-101	0.7924	-105.2114
Malonic_acid(aq)	1.480e-108	1.540e-103	1.0000	-107.8298
Zn(NH3)3++	4.836e-109	5.632e-104	0.7924	-108.4165
Methanamine(aq)	2.012e-112	6.247e-108	1.0000	-111.6964
Glycine(aq)	3.614e-115	2.712e-110	1.0000	-114.4421
Cu(Gly)+	1.997e-116	2.747e-111	0.9432	-115.7250
Mg(Gly)+	7.642e-118	7.516e-113	0.9432	-117.1422
Zn(Gly)+	5.150e-119	7.181e-114	0.9432	-118.3136
Ca(Gly)+	1.534e-119	1.750e-114	0.9432	-118.8397
Mn(Gly)+	3.863e-120	4.982e-115	0.9432	-119.4385
S3O6--	5.344e-122	1.027e-116	0.7909	-121.3740
Zn(For)4--	1.718e-122	4.217e-117	0.7909	-121.8668
Acetaldehyde(aq)	5.477e-126	2.412e-121	1.0000	-125.2615
SCN-	4.873e-127	2.830e-122	0.9428	-126.3378
NH4CH3COO(aq)	1.270e-127	9.787e-123	1.0000	-126.8962
Acetamide(aq)	1.265e-127	7.471e-123	1.0000	-126.8979
Zn(NH3)4++	3.605e-143	4.812e-138	0.7924	-142.5441
Ethanol(aq)	4.310e-145	1.985e-140	1.0000	-144.3656
Ethyne(aq)	5.266e-147	1.371e-142	1.0000	-146.2785
Zn(N3)2(aq)	2.400e-147	3.586e-142	1.0000	-146.6198
Ethylene(aq)	1.475e-149	4.137e-145	1.0000	-148.8313
Lactate	4.134e-151	3.682e-146	0.9432	-150.4090
Ca(Lac)+	5.844e-153	7.546e-148	0.9432	-152.2587
Mg(Lac)+	2.062e-153	2.337e-148	0.9432	-152.7112
Lactic_acid(aq)	1.425e-154	1.284e-149	1.0000	-153.8461
Zn(Lac)+	1.103e-155	1.704e-150	0.9432	-154.9828
Mn(Lac)+	7.387e-156	1.064e-150	0.9432	-155.1569
Cu(Lac)+	6.325e-156	9.651e-151	0.9432	-155.2243
Ethane(aq)	8.763e-159	2.635e-154	1.0000	-158.0573
Propanoate	4.288e-162	3.133e-157	0.9432	-161.3931
Propanoic_acid(a	1.571e-164	1.163e-159	1.0000	-163.8039

Ca(Prop)+	1.085e-164	1.228e-159	0.9432	-163.9898
Mg(Prop)+	4.706e-165	4.581e-160	0.9432	-164.3528
Mn(Prop)+	5.329e-167	6.821e-162	0.9432	-166.2987
Cu(Prop)+	2.953e-167	4.034e-162	0.9432	-166.5551
Zn(Prop)+	1.262e-167	1.748e-162	0.9432	-166.9242
Succinate	3.108e-169	3.607e-164	0.7909	-168.6094
Ca(Glyc)2(aq)	2.417e-169	4.595e-164	1.0000	-168.6168
S4O6--	1.287e-169	2.886e-164	0.7909	-168.9923
Mg(Glyc)2(aq)	2.458e-170	4.285e-165	1.0000	-169.6095
H-Succinate	5.566e-171	6.515e-166	0.9432	-170.2799
Zn(Glyc)2(aq)	1.656e-171	3.568e-166	1.0000	-170.7809
Cu(Glyc)2(aq)	1.115e-171	2.382e-166	1.0000	-170.9527
Mn(Glyc)2(aq)	1.034e-172	2.119e-167	1.0000	-171.9856
Serine(aq)	3.912e-173	4.111e-168	1.0000	-172.4076
Succinic_acid(aq	4.243e-174	5.009e-169	1.0000	-173.3724
Ethanamine(aq)	1.238e-180	5.582e-176	1.0000	-179.9072
Alanine(aq)	2.536e-182	2.259e-177	1.0000	-181.5958
Cu(Ala)+	3.163e-184	4.796e-179	0.9432	-183.5252
Mg(Ala)+	4.495e-187	5.052e-182	0.9432	-186.3726
Zn(Ala)+	3.479e-187	5.338e-182	0.9432	-186.4840
Ca(Ala)+	2.166e-187	2.775e-182	0.9432	-186.6898
Ca(CH3COO)2(aq)	6.856e-188	1.084e-182	1.0000	-187.1639
Mn(Ala)+	2.671e-188	3.820e-183	0.9432	-187.5986
Mg(CH3COO)2(aq)	2.197e-188	3.128e-183	1.0000	-187.6582
Acetone(aq)	1.375e-189	7.986e-185	1.0000	-188.8616
Zn(CH3COO)2(aq)	4.482e-190	8.222e-185	1.0000	-189.3485
Cu(CH3COO)2(aq)	1.697e-190	3.081e-185	1.0000	-189.7704
Mn(CH3COO)2(aq)	7.149e-191	1.237e-185	1.0000	-190.1458
Aspartic_acid(aq	1.932e-192	2.571e-187	1.0000	-191.7140
Propanal(aq)	8.107e-194	4.708e-189	1.0000	-193.0911
Cu(CH3COO)2-	6.140e-197	1.115e-191	0.9432	-196.2372
1-Propyne(aq)	2.364e-211	9.470e-207	1.0000	-210.6263
S3--	1.969e-211	1.894e-206	0.7909	-210.8077
1-Propanol(aq)	2.025e-213	1.217e-208	1.0000	-212.6936
1-Propene(aq)	1.024e-215	4.309e-211	1.0000	-214.9896
2-Hydroxybutanoa	7.549e-220	7.781e-215	0.9432	-219.1475
NH4(CH3COO)2-	9.626e-221	1.310e-215	0.9432	-220.0419
2-Hydroxybutanoi	2.313e-223	2.407e-218	1.0000	-222.6359
Asparagine(aq)	1.134e-223	1.498e-218	1.0000	-222.9455
Cu(Gly)2(aq)	4.115e-226	8.708e-221	1.0000	-225.3857
Propane(aq)	1.762e-227	7.767e-223	1.0000	-226.7541
Butanoate	6.080e-231	5.295e-226	0.9432	-230.2415
Zn(Gly)2(aq)	1.569e-231	3.349e-226	1.0000	-230.8044
Mg(Gly)2(aq)	8.855e-232	1.527e-226	1.0000	-231.0528
Diglycine(aq)	3.385e-232	4.472e-227	1.0000	-231.4704
Butanoic_acid(aq	1.849e-233	1.629e-228	1.0000	-232.7330
Ca(But)+	1.060e-233	1.348e-228	0.9432	-233.0001
Mg(But)+	4.390e-234	4.890e-229	0.9432	-233.3829
Mn(Gly)2(aq)	4.086e-234	8.295e-229	1.0000	-233.3888
Diketopiperazine	2.568e-234	2.930e-229	1.0000	-233.5904
Ca(Gly)2(aq)	1.000e-235	1.882e-230	1.0000	-234.9999
Mn(But)+	6.404e-236	9.094e-231	0.9432	-235.2189
Cu(But)+	3.306e-236	4.979e-231	0.9432	-235.5061
Zn(But)+	2.823e-236	4.304e-231	0.9432	-235.5747
Glutarate	3.454e-237	4.494e-232	0.7909	-236.5635
H-Glutarate	3.791e-239	4.970e-234	0.9432	-238.4466
Threonine(aq)	5.833e-242	6.947e-237	1.0000	-241.2341
Glutaric_acid(aq	3.916e-242	5.172e-237	1.0000	-241.4072
Ethylacetate(aq)	3.443e-242	3.033e-237	1.0000	-241.4631
S5O6--	4.083e-246	1.046e-240	0.7909	-245.4909
1-Propanamine(aq	1.928e-248	1.140e-243	1.0000	-247.7148
a-Aminobutyric_a	7.684e-251	7.922e-246	1.0000	-250.1144
Glutamic_acid(aq	2.746e-259	4.039e-254	1.0000	-258.5613

Zn(SCN)2(aq)	2.697e-259	4.895e-254	1.0000	-258.5692
Butanal(aq)	4.813e-264	3.470e-259	1.0000	-263.3176
S4--	1.102e-272	1.413e-267	0.7909	-272.0598
1-Butyne(aq)	3.241e-280	1.753e-275	1.0000	-279.4894
Cu(CH3COO)3-	3.177e-282	7.646e-277	0.9432	-281.5233
Zn(CH3COO)3-	2.575e-282	6.245e-277	0.9432	-281.6145
1-Butanol(aq)	5.874e-283	4.354e-278	1.0000	-282.2310
Mn(CH3COO)3-	1.596e-283	3.704e-278	0.9432	-282.8223
1-Butene(aq)	9.206e-285	5.164e-280	1.0000	-284.0359
2-Hydroxypentano	2.032e-288	2.379e-283	0.9432	-287.7175
2-Hydroxypentano	3.752e-292	4.432e-287	1.0000	-291.4257
Glutamine(aq)	1.840e-292	2.688e-287	1.0000	-291.7352
n-Butane(aq)	3.115e-296	1.810e-291	1.0000	-295.5065
Alanylglycine(aq	1.071e-299	1.565e-294	1.0000	-298.9701
Pentanoate	1.037e-299	1.049e-294	0.9432	-299.0094
Pentanoic_acid(a	3.434e-302	3.507e-297	1.0000	-300.0000
Ca(Lac)2(aq)	2.467e-302	5.383e-297	1.0000	-300.0000
Ca(Pent)+	1.057e-302	1.493e-297	0.9432	-300.0000
Mg(Lac)2(aq)	7.946e-303	1.608e-297	1.0000	-300.0000
Mg(Pent)+	4.285e-303	5.374e-298	0.9432	-300.0000
Zn(CN)4--	1.193e-303	2.022e-298	0.7909	-300.0000
Zn(Lac)2(aq)	1.441e-304	3.508e-299	1.0000	-300.0000
Cu(Lac)2(aq)	9.063e-305	2.190e-299	1.0000	-300.0000
Mn(Pent)+	8.245e-305	1.287e-299	0.9432	-300.0000
Cu(Pent)+	5.482e-305	9.025e-300	0.9432	-300.0000
Zn(Pent)+	3.988e-305	6.640e-300	0.9432	-300.0000
Mn(Lac)2(aq)	3.193e-305	7.441e-300	1.0000	-300.0000
Adipate	1.822e-307	2.626e-302	0.7909	-300.0000
H-Adipate	1.966e-309	2.853e-304	0.9432	-300.0000
Adipic_acid(aq)	2.404e-312	3.513e-307	1.0000	-300.0000
1-Butanamine(aq)	1.733e-317	1.267e-312	1.0000	-300.0000
Valine(aq)	1.838e-319	2.153e-314	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9432	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9432	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9432	-300.0000
Benzoate	0.0000	0.0000	0.9450	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.7909	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000

Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9432	-300.0000
o-Phthalic_acid(	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9432	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9432	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9432	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(SCN)4--	0.0000	0.0000	0.7909	-300.0000
Zn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(o-Phthalate)(	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9432	-300.0000
H-Sebacate	0.0000	0.0000	0.9432	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
H-Pimelate	0.0000	0.0000	0.9432	-300.0000
Undecanoate	0.0000	0.0000	0.9432	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9432	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7909	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7909	-300.0000
H(o-Phthalate)-	0.0000	0.0000	0.9432	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9432	-300.0000
S5--	0.0000	0.0000	0.7909	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9432	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7909	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000

1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9432	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9432	-300.0000
Nonanoate	0.0000	0.0000	0.9432	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9432	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7909	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9432	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Quartz	0.1117s/sat	Chalcanthite	-9.0034
Tridymite	-0.0598	ZnSO4:7H2O	-9.1551
Ice	-0.1387	ZnSO4:6H2O	-9.3388
Chalcedony	-0.1595	Manganosite	-9.5021
Tenorite	-0.4310	Hausmannite	-9.7263
Cristobalite(alp	-0.4388	Forsterite	-9.8945
Dolomite	-0.5000	Sepiolite	-10.0583
Dolomite-ord	-0.5000	Tephroite	-10.1219
Calcite	-0.6406	Mn(OH)3	-10.3354
Coesite	-0.6983	Periclase	-10.4075
Aragonite	-0.7850	Mg1.25SO4(OH)0.5	-10.4501
Cristobalite(bet	-0.8823	ZnSO4:H2O	-10.4851
SiO2(am)	-1.1740	Zn2SO4(OH)2	-10.7785
Monohydrocalcite	-1.4743	Monticellite	-11.2145
Magnesite	-1.4881	Portlandite	-11.2247
Rhodochrosite	-1.5077	Hydrozincite	-11.4199
Malachite	-1.6122	Mg1.5SO4(OH)	-11.7132
Dolomite-dis	-2.0444	Gyrolite	-11.9119
Zn2SiO4	-2.1042	MgSO4	-12.8001
ZnCO3:H2O	-2.4357	MnSO4	-13.0841
Dioptase	-2.7399	Chalcocyanite	-14.5488
Smithsonite	-2.7592	ZnSO4	-14.5686
Chrysocolla	-2.8768	Tremolite	-15.0375
Gypsum	-3.0371	Hydromagnesite	-16.7041
Anhydrite	-3.2130	Hillebrandite	-18.0457
Zincite	-3.3822	Dicalcium_silica	-18.3992
Manganite	-3.8296	Zn(NO3)2:6H2O	-19.3157
Zn(OH)2(epsilon)	-3.8360	Akermanite	-19.5055
Bassanite	-3.8579	Larnite	-19.6932
Talc	-3.9053	Lime	-21.2456
CaSO4:0.5H2O(bet	-4.0260	Anthophyllite	-21.4025
Lansfordite	-4.0354	Rankinite	-25.6917
Zn(OH)2(gamma)	-4.0567	Zn5(NO3)2(OH)8	-27.2669
Zn(OH)2(beta)	-4.1076	Tobermorite-14A	-30.5180
Nesquehonite	-4.1900	Merwinite	-31.3700

Enstatite	-4.2867	Foshagite	-32.2620
Cuprite	-4.5175	Tobermorite-11A	-32.2856
Rhodonite	-5.1958	Zn3O(SO4)2	-33.3391
Brucite	-5.3701	Afwillite	-33.8291
Brochantite	-5.3860	Todorokite	-35.4741
Antlerite	-5.9050	Tobermorite-9A	-35.7533
Epsomite	-5.9597	C	-40.9557
Chrysotile	-6.1171	Hatrurite	-43.3018
Hexahydrite	-6.1952	Zn	-44.3069
Wollastonite	-6.3177	Birnessite	-44.3427
Diopside	-6.4812	Xonotlite	-47.1697
Pentahydrite	-6.5348	Mn	-57.8584
Pseudowollastoni	-6.5569	Covellite	-60.4303
Huntite	-6.6765	S	-62.0584
Pyrolusite	-6.8116	Chalcocite	-62.1727
Okenite	-6.8264	Sphalerite	-71.2198
Mn(OH)2(am)	-6.8883	Wurtzite	-73.5192
Starkeyite	-6.9221	Alabandite	-81.6700
Bixbyite	-7.0229	Antigorite	-84.8362
Cu	-7.6166	Mg	-94.9385
Kieserite	-7.6550	Ca	-111.8459
Azurite	-7.7304	Si	-119.4533
Artinite	-7.9227	o-Phthalic_acid	-363.9855
MnO2(gamma)	-8.3294		

Gases	fugacity	log fug.
H2O(g)	0.02598	-1.585
CO2(g)	0.004911	-2.309
N2(g)	0.003670	-2.435
NO2(g)	1.264e-012	-11.898
H2(g)	4.661e-027	-26.331
O2(g)	3.615e-031	-30.442
NO(g)	2.503e-032	-31.602
CO(g)	7.150e-033	-32.146
NH3(g)	1.470e-038	-37.833
SO2(g)	1.234e-040	-39.909
Cu(g)	1.711e-060	-59.767
Zn(g)	1.210e-061	-60.917
H2S(g)	3.087e-083	-82.510
CH4(g)	1.850e-085	-84.733
Mg(g)	2.232e-115	-114.651
Ca(g)	8.372e-138	-137.077
S2(g)	9.783e-139	-138.010
C2H4(g)	3.107e-147	-146.508
C(g)	2.790e-159	-158.554
Si(g)	3.175e-191	-190.498

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ca++	0.000690	0.000690	27.6			
Cu++	6.37e-007	6.37e-007	0.0405			
H+	0.000161	0.000161	0.162			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00178	0.00178	109.			
Mg++	0.000272	0.000272	6.61			
Mn++	8.81e-007	8.81e-007	0.0484			
NH3(aq)	4.78e-006	4.78e-006	0.0814			
NO3-	2.89e-005	2.89e-005	1.79			
O2(aq)	3.24e-006	3.24e-006	0.104			
SO4--	7.81e-005	7.81e-005	7.50			
SiO2(aq)	0.000130	0.000130	7.80			

Zn++	2.27e-007	2.27e-007	0.0148

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Calcium	0.0006899	0.0006899	27.64		
Carbon	0.001780	0.001780	21.38		
Copper	6.371e-007	6.371e-007	0.04048		
Hydrogen	111.0	111.0	1.119e+005		
Magnesium	0.0002722	0.0002722	6.615		
Manganese	8.807e-007	8.807e-007	0.04838		
Nitrogen	3.368e-005	3.368e-005	0.4717		
Oxygen	55.51	55.51	8.881e+005		
Silicon	0.0001298	0.0001298	3.646		
Sulfur	7.812e-005	7.812e-005	2.505		
Zinc	2.265e-007	2.265e-007	0.01481		

```
Temperature =  22.2 C    Pressure =  1.013 bars
pH =  7.300              log fO2 =  -24.587
Eh =   0.4420 volts      pe =   7.5432
Ionic strength      =    0.004698
Charge imbalance    =   -0.000095 eq/kg (-2.69% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000320 kg
Solution density    =    1.015    g/cm3
Chlorinity          =    0.000111 molal
Dissolved solids    =         320 mg/kg sol'n
Elect. conductivity =      358.14 uS/cm (or umho/cm)
Hardness            =       81.80 mg/kg sol'n as CaCO3
  carbonate         =       81.80 mg/kg sol'n as CaCO3
  non-carbonate     =        0.00 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       83.83 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.4420	7.5432
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.6033	10.2957

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001658	101.2	0.9295	-2.8121
Na+	0.001326	30.48	0.9295	-2.9092
NO3-	0.0009922	61.50	0.9281	-3.0358
Ca++	0.0005886	23.58	0.7542	-3.3527
K+	0.0005534	21.63	0.9281	-3.2894
SO4--	0.0003922	37.66	0.7455	-3.5340
SiO2(aq)	0.0002013	12.09	1.0000	-3.6962
Mg++	0.0001897	4.609	0.7624	-3.8398
CO2(aq)	0.0001822	8.014	1.0000	-3.7396
N2(aq)	0.0001189	3.329	1.0000	-3.9249
Cl-	0.0001112	3.940	0.9281	-3.9865
CaSO4(aq)	1.662e-005	2.263	1.0000	-4.7792
F-	1.032e-005	0.1960	0.9288	-5.0185
MgSO4(aq)	1.019e-005	1.226	1.0000	-4.9918
Mn++	8.399e-006	0.4613	0.7542	-5.1983
CaHCO3+	8.360e-006	0.8449	0.9295	-5.1095
NaHCO3(aq)	2.875e-006	0.2414	1.0000	-5.5414
MgHCO3+	2.664e-006	0.2272	0.9295	-5.6062
CO3--	1.783e-006	0.1070	0.7477	-5.8751
KSO4-	1.234e-006	0.1668	0.9295	-5.9403
CaCO3(aq)	1.195e-006	0.1195	1.0000	-5.9228
Fe++	1.059e-006	0.05911	0.7542	-6.0977
Ba++	7.604e-007	0.1044	0.7499	-6.2439
HSiO3-	4.568e-007	0.03521	0.9295	-6.3720
MnSO4(aq)	4.088e-007	0.06171	1.0000	-6.3885
Sb(OH)3(aq)	2.105e-007	0.03635	1.0000	-6.6768
HPO4--	1.909e-007	0.01832	0.7455	-6.8467
MgCO3(aq)	1.801e-007	0.01518	1.0000	-6.7444
OH-	1.709e-007	0.002906	0.9288	-6.7993
H2PO4-	1.273e-007	0.01234	0.9295	-6.9269
Cu++	1.086e-007	0.006897	0.7542	-7.0868
H+	5.355e-008	5.396e-005	0.9359	-7.3000
MgF+	3.418e-008	0.001479	0.9295	-7.4980
NaHSiO3(aq)	2.498e-008	0.002499	1.0000	-7.6024

CaF+	2.196e-008	0.001297	0.9295	-7.6901
NaCl(aq)	2.101e-008	0.001227	1.0000	-7.6776
MgCl+	1.212e-008	0.0007240	0.9295	-7.9482
CaCl+	1.001e-008	0.0007558	0.9295	-8.0313
UO2(CO3)2--	6.828e-009	0.002663	0.7455	-8.2932
NaCO3-	6.275e-009	0.0005206	0.9295	-8.2342
KCl(aq)	1.603e-009	0.0001194	1.0000	-8.7952
HSO4-	1.419e-009	0.0001377	0.9295	-8.8798
MnCl+	1.335e-009	0.0001207	0.9295	-8.9061
UO2(CO3)3----	1.218e-009	0.0005480	0.3085	-9.4251
NaF(aq)	1.167e-009	4.900e-005	1.0000	-8.9328
HF(aq)	6.766e-010	1.353e-005	1.0000	-9.1697
BaCO3(aq)	3.180e-010	6.274e-005	1.0000	-9.4975
UO2CO3(aq)	2.308e-010	7.613e-005	1.0000	-9.6369
FeCl+	6.163e-011	5.625e-006	0.9295	-10.2419
NaOH(aq)	3.196e-011	1.278e-006	1.0000	-10.4955
BaCl+	1.948e-011	3.364e-006	0.9295	-10.7423
Sb(OH)4-	4.280e-012	8.119e-007	0.9295	-11.4003
UO2OH+	4.111e-012	1.180e-006	0.9295	-11.4178
BaF+	3.776e-012	5.901e-007	0.9295	-11.4547
PO4---	2.431e-012	2.308e-007	0.5161	-11.9015
HNO3(aq)	2.171e-012	1.368e-007	1.0000	-11.6633
Cu+	1.228e-012	7.804e-008	0.9295	-11.9424
Sb(OH)2F(aq)	1.181e-012	2.063e-007	1.0000	-11.9277
CaCl2(aq)	1.131e-012	1.255e-007	1.0000	-11.9466
HCl(aq)	1.062e-012	3.873e-008	1.0000	-11.9737
H3PO4(aq)	8.551e-013	8.377e-008	1.0000	-12.0680
Sb(OH)2+	3.917e-013	6.099e-008	0.9295	-12.4388
UO2++	4.946e-014	1.335e-008	0.7477	-13.4320
KHSO4(aq)	4.504e-014	6.131e-009	1.0000	-13.3464
UO2F+	4.266e-014	1.233e-008	0.9295	-13.4017
UO2SO4(aq)	1.191e-014	4.358e-009	1.0000	-13.9242
MgP2O7--	1.013e-014	2.007e-009	0.7455	-14.1221
HF2-	1.629e-015	6.350e-011	0.9295	-14.8199
UO2F2(aq)	1.182e-015	3.638e-010	1.0000	-14.9276
HP2O7---	5.049e-016	8.830e-011	0.5161	-15.5840
H2P2O7--	7.674e-017	1.350e-011	0.7455	-16.2425
UO2(SO4)2--	3.587e-017	1.657e-011	0.7455	-16.5729
FeCl2(aq)	3.000e-017	3.802e-012	1.0000	-16.5228
P2O7----	1.040e-017	1.809e-012	0.3085	-17.4937
UO2Cl+	5.719e-018	1.746e-012	0.9295	-17.2744
UO2F3-	2.116e-018	6.916e-013	0.9295	-17.7063
(UO2)2(OH)2++	1.440e-018	8.266e-013	0.7477	-17.9678
KP2O7---	6.594e-019	1.404e-013	0.5161	-18.4681
UO2+	3.255e-020	8.787e-015	0.9295	-19.5192
(UO2)3(OH)5+	2.942e-020	2.633e-014	0.9295	-19.5631
(UO2)3(CO3)6(6-)	4.524e-021	5.292e-015	0.0709	-21.4940
H3P2O7-	6.897e-022	1.220e-016	0.9295	-21.1931
UO2F4--	1.461e-022	5.055e-017	0.7455	-21.9628
UO2Cl2(aq)	2.802e-023	9.551e-018	1.0000	-22.5525
Mn+++	8.971e-024	4.927e-019	0.5231	-23.3286
FeCl4--	1.351e-024	2.670e-019	0.7455	-23.9969
U(OH)4(aq)	1.039e-024	3.179e-019	1.0000	-23.9834
NO2-	2.025e-027	9.315e-023	0.9281	-26.7259
H4P2O7(aq)	9.721e-028	1.729e-022	1.0000	-27.0123
O2(aq)	3.486e-028	1.115e-023	1.0000	-27.4577
HNO2(aq)	1.782e-031	8.376e-027	1.0000	-30.7491
Formate	4.934e-033	2.221e-028	0.9288	-32.3388
H2(aq)	1.411e-033	2.843e-030	1.0000	-32.8505
ClO-	1.238e-033	6.365e-029	0.9295	-32.9392
Ca(For)+	6.097e-035	5.187e-030	0.9295	-34.2466
Mg(For)+	2.068e-035	1.433e-030	0.9295	-34.7161
HO2-	1.154e-035	3.807e-031	0.9295	-34.9696

Na(For)(aq)	6.481e-036	4.406e-031	1.0000	-35.1883
K(For)(aq)	2.523e-036	2.122e-031	1.0000	-35.5980
Mn(For)+	1.648e-036	1.646e-031	0.9295	-35.8149
Formic_acid(aq)	1.317e-036	6.059e-032	1.0000	-35.8805
MnO4--	9.528e-037	1.133e-031	0.7455	-36.1485
SiF6--	3.694e-037	5.247e-032	0.7455	-36.5600
Fe(For)+	2.834e-037	2.858e-032	0.9295	-36.5793
SO3--	1.709e-037	1.368e-032	0.7477	-36.8936
HSO3-	1.092e-037	8.853e-033	0.9295	-36.9934
Ba(For)+	6.760e-038	1.232e-032	0.9295	-37.2018
Cu(For)+	4.123e-038	4.474e-033	0.9295	-37.4166
MnO4-	7.791e-039	9.264e-034	0.9288	-38.1405
NH4+	7.374e-039	1.330e-034	0.9273	-38.1650
CO(aq)	2.822e-039	7.903e-035	1.0000	-38.5494
Oxalate	2.026e-040	1.783e-035	0.7455	-39.8209
NH3(aq)	6.358e-041	1.083e-036	1.0000	-40.1966
UOH+++	2.947e-042	7.514e-037	0.5231	-41.8120
UF3+	9.565e-043	2.821e-037	0.9295	-42.0511
HSO5-	8.903e-043	1.006e-037	0.9295	-42.0822
UF2++	5.872e-043	1.620e-037	0.7477	-42.3575
SO2(aq)	3.508e-043	2.247e-038	1.0000	-42.4549
U(CO3)5(6-)	1.853e-043	9.968e-038	0.0709	-43.8816
H-Oxalate	1.458e-043	1.297e-038	0.9295	-42.8681
UF4(aq)	7.843e-044	2.462e-038	1.0000	-43.1055
UF+++	1.081e-044	2.777e-039	0.5231	-44.2476
U(SO4)2(aq)	5.590e-046	2.404e-040	1.0000	-45.2526
USO4++	3.991e-046	1.333e-040	0.7477	-45.5252
U++++	1.032e-048	2.456e-043	0.3196	-48.4817
Oxalic_acid(aq)	1.259e-049	1.134e-044	1.0000	-48.8998
UCl+++	3.574e-051	9.770e-046	0.5231	-50.7283
ClO2-	1.881e-055	1.268e-050	0.9295	-54.7573
S2O8--	8.068e-059	1.550e-053	0.7455	-58.2208
S2O6--	1.466e-060	2.347e-055	0.7455	-59.9613
ClO3-	2.799e-063	2.335e-058	0.9288	-62.5851
U+++	4.904e-066	1.167e-060	0.5231	-65.5909
Ca(For)2(aq)	2.021e-066	2.628e-061	1.0000	-65.6945
Mg(For)2(aq)	7.156e-067	8.179e-062	1.0000	-66.1454
Mn(For)2(aq)	9.210e-068	1.335e-062	1.0000	-67.0357
Fe(For)2(aq)	2.025e-068	2.953e-063	1.0000	-67.6936
Na(For)2-	1.809e-068	2.044e-063	0.9295	-67.7742
K(For)2-	6.539e-069	8.441e-064	0.9295	-68.2163
Cu(For)2(aq)	3.977e-069	6.106e-064	1.0000	-68.4004
Ba(For)2(aq)	1.966e-069	4.468e-064	1.0000	-68.7065
Formaldehyde(aq)	7.136e-071	2.142e-066	1.0000	-70.1466
N3-	6.595e-071	2.771e-066	0.9295	-70.2125
HN3(aq)	1.712e-073	7.365e-069	1.0000	-72.7665
ClO4-	1.989e-075	1.978e-070	0.9288	-74.7334
UO2ClO3+	3.268e-076	1.155e-070	0.9295	-75.5174
S2O5--	2.113e-079	3.045e-074	0.7455	-78.8026
Cu(NH3)2++	1.520e-080	1.483e-075	0.7477	-79.9445
Urea(aq)	1.561e-084	9.371e-080	1.0000	-83.8066
HCN(aq)	1.242e-084	3.356e-080	1.0000	-83.9058
CN-	1.271e-086	3.306e-082	0.9281	-85.9282
Methanol(aq)	8.791e-089	2.816e-084	1.0000	-88.0560
Glycolate	7.590e-095	5.694e-090	0.9295	-94.1515
HS-	2.020e-096	6.678e-092	0.9288	-95.7268
Ca(Glyc)+	1.576e-096	1.814e-091	0.9295	-95.8341
H2S(aq)	1.021e-096	3.477e-092	1.0000	-95.9911
Mg(Glyc)+	2.451e-097	2.434e-092	0.9295	-96.6424
Na(Glyc)(aq)	1.005e-097	9.846e-093	1.0000	-96.9980
K(Glyc)(aq)	3.911e-098	4.463e-093	1.0000	-97.4077
Glycolic_acid(aq	2.433e-098	1.850e-093	1.0000	-97.6139
Mn(Glyc)+	1.941e-098	2.523e-093	0.9295	-97.7436

Fe(Glyc)+	9.907e-099	1.296e-093	0.9295	-98.0358
Cu(Glyc)+	5.309e-099	7.355e-094	0.9295	-98.3068
Ba(Glyc)+	4.436e-100	9.418e-095	0.9295	-99.3847
S2O4--	7.693e-101	9.854e-096	0.7499	-100.2389
Methane(aq)	1.523e-101	2.443e-097	1.0000	-100.8172
S--	4.733e-102	1.517e-097	0.7499	-101.4499
S2O3--	2.357e-102	2.642e-097	0.7455	-101.7553
Acetate	5.989e-107	3.535e-102	0.9302	-106.2540
CaCH3COO+	2.330e-109	2.309e-104	0.9295	-108.6644
MgCH3COO+	1.767e-109	1.473e-104	0.9295	-108.7844
Acetic_acid(aq)	1.601e-109	9.610e-105	1.0000	-108.7957
NaCH3COO(aq)	5.554e-110	4.555e-105	1.0000	-109.2554
KCH3COO(aq)	1.558e-110	1.529e-105	1.0000	-109.8073
MnCH3COO+	6.557e-111	7.472e-106	0.9295	-110.2150
FeCH3COO+	9.787e-112	1.124e-106	0.9295	-111.0411
CuCH3COO+	9.066e-112	1.111e-106	0.9295	-111.0743
BaCH3COO+	3.333e-112	6.543e-107	0.9295	-111.5089
Malonate	1.236e-115	1.261e-110	0.7455	-115.0355
H-Malonate	2.435e-117	2.508e-112	0.9295	-116.6453
Cu(NH3)3++	6.997e-118	8.019e-113	0.7477	-117.2813
CuCH3COO(aq)	1.418e-118	1.738e-113	1.0000	-117.8483
Malonic_acid(aq)	8.113e-122	8.440e-117	1.0000	-121.0908
Methanamine(aq)	1.416e-126	4.397e-122	1.0000	-125.8489
Glycine(aq)	3.074e-129	2.307e-124	1.0000	-128.5123
Cu(Gly)+	3.182e-130	4.377e-125	0.9295	-129.5291
Mg(Gly)+	3.976e-132	3.910e-127	0.9295	-131.4323
S3O6--	3.148e-133	6.049e-128	0.7455	-132.6295
Mn(Gly)+	2.784e-133	3.590e-128	0.9295	-132.5871
Fe(Gly)+	1.595e-133	2.071e-128	0.9295	-132.8291
Ca(Gly)+	8.868e-134	1.012e-128	0.9295	-133.0839
Ba(Gly)+	1.528e-136	3.229e-131	0.9295	-135.8477
Acetaldehyde(aq)	1.239e-142	5.456e-138	1.0000	-141.9069
SCN-	9.791e-144	5.685e-139	0.9288	-143.0413
NH4CH3COO(aq)	6.311e-145	4.863e-140	1.0000	-144.1999
Acetamide(aq)	5.970e-145	3.525e-140	1.0000	-144.2241
UO2SCN+	9.150e-156	3.001e-150	0.9295	-155.0703
Ethyne(aq)	6.987e-164	1.819e-159	1.0000	-163.1557
Ethanol(aq)	5.005e-165	2.305e-160	1.0000	-164.3006
Ethylene(aq)	1.493e-169	4.187e-165	1.0000	-168.8259
Lactate	4.893e-171	4.357e-166	0.9295	-170.3422
Ca(Lac)+	6.020e-173	7.772e-168	0.9295	-172.2522
Mg(Lac)+	1.717e-173	1.946e-168	0.9295	-172.7971
Na(Lac)(aq)	6.546e-174	7.333e-169	1.0000	-173.1840
K(Lac)(aq)	2.549e-174	3.266e-169	1.0000	-173.5937
Lactic_acid(aq)	1.674e-174	1.508e-169	1.0000	-173.7761
Mn(Lac)+	8.889e-175	1.280e-169	0.9295	-174.0829
Fe(Lac)+	5.623e-175	8.146e-170	0.9295	-174.2818
Cu(Lac)+	1.603e-175	2.446e-170	0.9295	-174.8267
Ba(Lac)+	1.244e-176	2.814e-171	0.9295	-175.9371
Ethane(aq)	5.864e-182	1.763e-177	1.0000	-181.2318
Propanoate	2.998e-185	2.190e-180	0.9295	-184.5549
Propanoic_acid(a	1.084e-187	8.027e-183	1.0000	-186.9650
Ca(Prop)+	6.503e-188	7.356e-183	0.9295	-187.2186
Na(Prop)(aq)	3.953e-188	3.796e-183	1.0000	-187.4031
Mg(Prop)+	2.419e-188	2.355e-183	0.9295	-187.6481
K(Prop)(aq)	1.539e-188	1.726e-183	1.0000	-187.8127
USCN+++	6.061e-189	1.794e-183	0.5231	-188.4989
Mn(Prop)+	3.785e-189	4.843e-184	0.9295	-188.4537
Ca(Glyc)2(aq)	1.917e-189	3.644e-184	1.0000	-188.7174
Fe(Prop)+	1.037e-189	1.336e-184	0.9295	-189.0161
S4O6--	6.950e-190	1.558e-184	0.7455	-189.2856
Cu(Prop)+	4.399e-190	6.007e-185	0.9295	-189.3884
Mg(Glyc)2(aq)	1.643e-190	2.865e-185	1.0000	-189.7843

Fe(Glyc)2(aq)	3.360e-191	6.917e-186	1.0000	-190.4737
Ba(Prop)+	2.360e-191	4.964e-186	0.9295	-190.6588
Cu(Glyc)2(aq)	2.259e-191	4.825e-186	1.0000	-190.6460
Mn(Glyc)2(aq)	9.594e-192	1.966e-186	1.0000	-191.0180
Na(Glyc)2-	6.739e-192	1.166e-186	0.9295	-191.2032
K(Glyc)2-	2.447e-192	4.629e-187	0.9295	-191.6431
Succinate	2.244e-192	2.604e-187	0.7455	-191.7765
Ba(Glyc)2(aq)	1.492e-193	4.287e-188	1.0000	-192.8262
Serine(aq)	6.754e-194	7.096e-189	1.0000	-193.1704
H-Succinate	3.871e-194	4.531e-189	0.9295	-193.4439
Succinic_acid(aq	2.965e-197	3.500e-192	1.0000	-196.5280
Ethanamine(aq)	1.064e-204	4.795e-200	1.0000	-203.9731
Alanine(aq)	2.713e-206	2.417e-201	1.0000	-205.5665
Cu(Ala)+	6.386e-208	9.680e-203	0.9295	-207.2265
Fe(Ala)+	1.535e-210	2.209e-205	0.9295	-209.8456
Mg(Ala)+	2.844e-211	3.195e-206	0.9295	-210.5779
Mn(Ala)+	2.372e-211	3.391e-206	0.9295	-210.6567
Ca(Ala)+	1.571e-211	2.013e-206	0.9295	-210.8355
Ca(CH3COO)2(aq)	2.063e-214	3.262e-209	1.0000	-213.6855
Ba(Ala)+	1.042e-214	2.349e-209	0.9295	-214.0138
Mg(CH3COO)2(aq)	5.865e-215	8.349e-210	1.0000	-214.2317
Acetone(aq)	4.051e-216	2.352e-211	1.0000	-215.3924
Mn(CH3COO)2(aq)	2.549e-216	4.410e-211	1.0000	-215.5936
Aspartic_acid(aq	2.043e-216	2.719e-211	1.0000	-215.6896
Na(CH3COO)2-	1.506e-216	2.124e-211	0.9295	-215.8540
Cu(CH3COO)2(aq)	1.301e-216	2.363e-211	1.0000	-215.8857
Fe(CH3COO)2(aq)	8.807e-217	1.531e-211	1.0000	-216.0552
K(CH3COO)2-	3.038e-217	4.773e-212	0.9295	-216.5492
Ba(CH3COO)2(aq)	5.736e-218	1.465e-212	1.0000	-217.2414
Propanal(aq)	2.221e-220	1.290e-215	1.0000	-219.6534
Cu(CH3COO)2-	8.814e-225	1.601e-219	0.9295	-224.0865
1-Propyne(aq)	4.120e-238	1.650e-233	1.0000	-237.3851
S3--	2.643e-242	2.542e-237	0.7455	-241.7054
1-Propanol(aq)	2.829e-243	1.700e-238	1.0000	-242.5483
1-Propene(aq)	1.298e-245	5.461e-241	1.0000	-244.8867
2-Hydroxybutanoa	1.057e-249	1.090e-244	0.9295	-249.0076
NH4(CH3COO)2-	3.004e-251	4.088e-246	0.9295	-250.5540
Asparagine(aq)	9.670e-252	1.277e-246	1.0000	-251.0146
2-Hydroxybutanoi	3.218e-253	3.349e-248	1.0000	-252.4924
Cu(Gly)2(aq)	5.350e-254	1.132e-248	1.0000	-253.2717
Mg(Gly)2(aq)	3.485e-260	6.007e-255	1.0000	-259.4578
Diglycine(aq)	2.393e-260	3.161e-255	1.0000	-259.6210
Propane(aq)	1.403e-260	6.187e-256	1.0000	-259.8528
Fe(Gly)2(aq)	2.226e-261	4.540e-256	1.0000	-260.6524
Mn(Gly)2(aq)	2.164e-261	4.393e-256	1.0000	-260.6647
Diketopiperazine	1.592e-262	1.816e-257	1.0000	-261.7980
Butanoate	5.047e-264	4.395e-259	0.9295	-263.3287
Ca(Gly)2(aq)	3.982e-264	7.492e-259	1.0000	-263.3999
Butanoic_acid(aq	1.509e-266	1.329e-261	1.0000	-265.8213
Ba(Gly)2(aq)	8.735e-267	2.493e-261	1.0000	-266.0587
Ca(But)+	7.564e-267	9.617e-262	0.9295	-266.1530
Na(But)(aq)	6.367e-267	7.007e-262	1.0000	-266.1960
Mg(But)+	2.687e-267	2.993e-262	0.9295	-266.6024
K(But)(aq)	2.479e-267	3.128e-262	1.0000	-266.6057
Mn(But)+	5.429e-268	7.708e-263	0.9295	-267.2971
Fe(But)+	1.791e-268	2.559e-263	0.9295	-267.7787
Cu(But)+	5.873e-269	8.845e-264	0.9295	-268.2629
Glutarate	2.999e-270	3.900e-265	0.7455	-269.6506
Ba(But)+	2.680e-270	6.013e-265	0.9295	-269.6036
H-Glutarate	3.139e-272	4.115e-267	0.9295	-271.5349
Threonine(aq)	1.191e-272	1.418e-267	1.0000	-271.9241
Glutaric_acid(aq	3.220e-275	4.253e-270	1.0000	-274.4921
Ethylacetate(aq)	2.341e-275	2.062e-270	1.0000	-274.6305

S5O6--	1.321e-275	3.385e-270	0.7455	-275.0067
1-Propanamine(aq	2.000e-282	1.182e-277	1.0000	-281.6990
a-Aminobutyric_a	9.783e-285	1.009e-279	1.0000	-284.0095
Glutamic_acid(aq	3.425e-293	5.038e-288	1.0000	-292.4653
UO2(SCN)2(aq)	5.042e-299	1.947e-293	1.0000	-298.2974
Butanal(aq)	1.512e-300	1.090e-295	1.0000	-299.8206
S4--	1.089e-312	1.396e-307	0.7455	-300.0000
1-Butyne(aq)	6.690e-317	3.618e-312	1.0000	-300.0000
Cu(CH3COO)3-	1.665e-321	4.006e-316	0.9295	-300.0000
Mn(CH3COO)3-	3.755e-322	8.711e-317	0.9295	-300.0000
1-Butanol(aq)	9.387e-323	6.956e-318	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9295	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9295	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9295	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9295	-300.0000
Azelate	0.0000	0.0000	0.7455	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9295	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9295	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
HSb2S4-	0.0000	0.0000	0.9295	-300.0000
o-Toluate	0.0000	0.0000	0.9295	-300.0000
o-Phthalate	0.0000	0.0000	0.7455	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9295	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9295	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9295	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.7455	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9295	-300.0000
H-Suberate	0.0000	0.0000	0.9295	-300.0000
U(SCN)2++	0.0000	0.0000	0.7477	-300.0000

H-Sebacate	0.0000	0.0000	0.9295	-300.0000
H-Pimelate	0.0000	0.0000	0.9295	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7455	-300.0000
H-Azelate	0.0000	0.0000	0.9295	-300.0000
H-Adipate	0.0000	0.0000	0.9295	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7455	-300.0000
Sb2S4--	0.0000	0.0000	0.7455	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butene(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7455	-300.0000
Glutamine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7455	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Pentanoate	0.0000	0.0000	0.9295	-300.0000
Fe(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)+	0.0000	0.0000	0.9295	-300.0000
Octanoate	0.0000	0.0000	0.9295	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9295	-300.0000
2-Hydroxypentano	0.0000	0.0000	0.9295	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9295	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9295	-300.0000
Benzoate	0.0000	0.0000	0.9322	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9295	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9295	-300.0000
Fe(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9295	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9295	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000

Dodecanoate	0.0000	0.0000	0.9295	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9295	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9295	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9295	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9295	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9295	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9295	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9295	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9295	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9295	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Fluorapatite	4.4547s/sat	UO2F2	-16.2942
Witherite	1.2729s/sat	BaCl2	-16.5006
Quartz	0.3897s/sat	MgOHCl	-16.6410
Barite	0.2517s/sat	Natrosilite	-16.7756
Tridymite	0.1935s/sat	MnCl2:2H2O	-17.2331
Chalcedony	0.1158s/sat	Na2SiO3	-17.2704
Ice	-0.1278	Ba2Si3O8	-17.7791
Cristobalite(alp	-0.1674	Hydromagnesite	-18.0045
Tenorite	-0.2538	Hillebrandite	-18.3446
Coesite	-0.4278	Dicalcium_silica	-18.7223
Rhodochrosite	-0.5504	MnCl2:H2O	-18.8051
Cristobalite(bet	-0.6194	CuCl2	-18.8686
Calcite	-0.7543	UO2SO4	-19.0692
Dolomite	-0.8253	MgCl2:4H2O	-19.2401
Dolomite-ord	-0.8253	Akermanite	-19.8965
Aragonite	-0.8987	Larnite	-20.0326

SiO2(am)	-0.9211	UO2.3333(beta)	-20.0910
Malachite	-1.1531	Na2UO4(alpha)	-20.3766
Siderite	-1.4690	Ningyoite	-21.1976
Monohydrocalcite	-1.5807	Anthophyllite	-21.6380
Magnesite	-1.7176	Lime	-21.6653
Bixbyite	-2.2272	UO2(NO3)2:6H2O	-21.7848
Dioptase	-2.2938	Scacchite	-22.0679
Dolomite-dis	-2.3910	UOFOH:.5H2O	-22.3350
Gypsum	-2.3961	UOFOH	-22.8005
Anhydrite	-2.5994	UO2Cl	-23.0213
Ferrosilite	-2.7104	UO2(NO3)2:3H2O	-23.2317
Pyrolusite	-2.8799	Hydrophilite	-23.2499
Bassanite	-3.2454	Lawrencite	-23.3025
Minnesotaite	-3.3193	UO2(NO3)2:2H2O	-24.4872
Fluorite	-3.3208	MgCl2:2H2O	-24.7399
CaSO4:0.5H2O(bet	-3.4171	K2UO4	-24.9758
Schoepite	-3.7538	UOF2:H2O	-25.2756
CaUO4	-3.7567	UO2(PO3)2	-25.5274
UO3:2H2O	-3.7567	(UO2)3(PO4)2	-25.6110
Talc	-3.7783	UOF2	-25.8492
Brochantite	-3.7876	Rankinite	-26.0237
UO2(OH)2(beta)	-3.8789	(UO2)2P2O7	-26.0379
UO3:.9H2O(alpha)	-3.9434	UO2Cl2:3H2O	-27.0967
Schoepite-dehy(.	-3.9480	UO2(NO3)2:H2O	-28.1034
Schoepite-dehy(.	-4.0246	MgCl2:H2O	-28.1290
Schoepite-dehy(1	-4.0326	UP2O7	-29.2314
Hausmannite	-4.0858	U(HPO4)2:4H2O	-29.2675
Rhodonite	-4.1070	UO2Cl2:H2O	-29.8236
Sb2O3	-4.2838	Tobermorite-14A	-30.0174
Enstatite	-4.3756	UO2(NO3)2	-31.5982
Sellaite	-4.5025	Tobermorite-11A	-31.8766
Nesquehonite	-4.7243	Ba2SiO4	-31.9576
Greenalite	-4.7811	Merwinite	-32.0898
UO2CO3	-4.8489	Foshagite	-32.5575
Rutherfordine	-4.8701	KMgCl3:2H2O	-33.1885
Whitlockite	-5.1054	UO2Cl2	-33.7288
Schoepite-dehy(.	-5.1491	Chloromagnesite	-33.9389
FeO	-5.2121	Afwillite	-34.1880
Hydroxylapatite	-5.3279	UO2SO3	-34.3260
Fe(OH)2	-5.5669	UF4:2.5H2O	-35.1321
Nahcolite	-5.5804	Tobermorite-9A	-35.4173
Schoepite-dehy(.	-5.6734	BaSiF6	-36.8928
Brucite	-5.7304	Fe	-37.4435
Fayalite	-6.0349	UF4	-39.3737
Niter	-6.0523	BaO	-39.9161
Mn(OH)2(am)	-6.0722	KMgCl3	-40.5681
Wollastonite	-6.3127	U(SO4)2:8H2O	-43.0557
Okenite	-6.5054	Hatrurite	-44.0852
Diopside	-6.5211	U(SO4)2:4H2O	-44.1418
Chrysotile	-6.5536	U(SO4)2	-44.2019
Pseudowollastoni	-6.5569	Ba2U2O7	-44.5887
UO3(gamma)	-6.6821	Xonotlite	-47.2993
Atacamite	-7.0223	U(CO3)2	-47.3224
Azurite	-7.0482	C	-47.5000
UO2HPO4:4H2O	-7.2276	UOCl2	-47.5549
Melanterite	-7.2530	UClF3	-50.1276
UO3(beta)	-7.2908	UOF4	-52.9249
Cuprite	-7.3348	U5O12Cl	-53.5951
Hedenbergite	-7.4048	Na3UO4	-55.8125
Huntite	-7.4994	Na	-56.7817
UO3(alpha)	-7.6251	Na4SiO4	-57.3170
Chalcanthite	-7.9858	(UO2)2Cl3	-57.8778
Mirabilite	-8.0789	UOCl3	-58.8764

Sylvite	-8.0864	Na2O	-59.2564
Tephroite	-8.2194	Mn	-60.6862
Arcanite	-8.2577	UF5(beta)	-60.6958
Artinite	-8.4696	K	-60.7858
Halite	-8.4699	UF5(alpha)	-61.0437
Sanbornite	-8.5051	UF3	-61.2138
UO2FOH:2H2O	-8.5262	UCl2F2	-63.1970
Manganosite	-8.7320	UOCl	-65.5539
BaUO4	-8.9111	Ba3UO6	-69.0843
UO2FOH:H2O	-8.9188	U2O3F6	-69.3692
Thenardite	-9.0336	S	-71.1977
Nantokite	-9.0945	Covellite	-72.4994
UO2FOH	-9.3768	UCl3F	-76.0894
Sepiolite	-9.6744	K2O	-76.7607
Nitrobarite	-9.7821	Chalcocite	-77.2196
Mg1.25SO4(OH)0.5	-10.0986	Na6Si2O7	-83.4274
Forsterite	-10.3629	U(SO3)2	-85.4773
Saleeite	-10.5181	UCl4	-86.8123
Cu	-10.6376	UF6	-90.6009
Periclase	-10.8344	Troilite	-90.7117
Natron	-10.8550	UCl3	-90.7695
UO2.25	-10.9973	Pyrrhotite	-90.8117
UO2SO4:H2O	-11.0019	Antigorite	-91.1631
UO2.25(beta)	-11.0596	U3O5F8	-92.7224
Na2CO3:7H2O	-11.2313	Alabandite	-93.2655
MgUO4	-11.4207	U2F9	-96.9070
Mg1.5SO4(OH)	-11.4530	Mg	-99.3397
MnSO4	-11.4883	UCl5	-106.3783
Portlandite	-11.5319	U2O2Cl5	-107.6342
Gyrolite	-11.5617	UN1.73(alpha)	-110.6359
Monticellite	-11.5824	BaS	-111.0869
BaU2O7	-11.5956	UN1.59(alpha)	-113.3393
Na2U2O7	-11.7777	Ca	-116.2982
Thermonatrite	-12.3372	Ba	-120.5791
MgSO4	-12.3956	P	-120.6842
FeSO4	-12.4013	UCl6	-124.7834
(UO2)3(PO4)2:4H2	-12.4256	UN	-126.1350
UO2ClOH:2H2O	-12.4805	Si	-126.6145
Uranocircite	-12.5094	Pyrite	-151.4714
Na2CO3	-12.5768	Chalcopyrite	-157.2407
Torbernite	-12.8778	U	-172.6566
UO2.6667	-13.1946	U4F17	-174.7821
Chalcocyanite	-13.6621	US	-187.0692
FeF2	-13.8313	UC	-202.6594
UPO5	-14.0213	UH3(beta)	-204.3249
BaCl2:2H2O	-14.4252	US1.9	-217.7894
Bassetite	-14.5164	US2	-223.1791
Uraninite	-14.5859	UP	-246.2837
Tremolite	-14.9731	UC1.94(alpha)	-249.3459
Coffinite	-15.0078	Stibnite	-268.7128
BaCl2:H2O	-15.0630	US3	-291.1878
Autunite-H	-15.2668	Bornite	-311.2840
UO2SO4:3.5H2O	-15.5292	UP2	-361.8918
UO2SO4:2.5H2O	-15.5328	U2S3	-403.2440
UO2SO4:3H2O	-15.6189	o-Phthalic_acid	-413.5692
MnCl2:4H2O	-15.9436	U2C3	-454.3266
UO2F2:3H2O	-16.1192	U3S5	-621.8341
Ba(OH)2:8H2O	-16.2318	U3P4	-854.4535
NaUO3	-16.2612		

Gases	fugacity	log fug.
N2(g)	0.1724	-0.763

H2O(g)	0.02175	-1.663
CO2(g)	0.004857	-2.314
NO2(g)	1.096e-012	-11.960
HF(g)	2.925e-014	-13.534
HCl(g)	1.921e-018	-17.716
O2(g)	2.586e-025	-24.587
NO(g)	1.045e-028	-27.981
H2(g)	1.750e-030	-29.757
CO(g)	2.691e-036	-35.570
SiF4(g)	1.531e-038	-37.815
Cl2(g)	4.159e-040	-39.381
NH3(g)	8.807e-043	-42.055
SO2(g)	2.105e-043	-42.677
UO2F2(g)	1.923e-059	-58.716
Cu(g)	4.395e-064	-63.357
UO2Cl2(g)	9.420e-071	-70.026
Na(g)	3.679e-071	-70.434
UO3(g)	2.176e-071	-70.662
K(g)	3.014e-072	-71.521
UOF4(g)	1.208e-073	-72.918
UF5(g)	2.820e-081	-80.550
UF4(g)	1.919e-084	-83.717
UF6(g)	3.083e-092	-91.511
F2(g)	1.860e-095	-94.731
H2S(g)	9.132e-096	-95.039
CH4(g)	1.004e-098	-97.998
UCl4(g)	2.608e-112	-111.584
UO2(g)	7.356e-113	-112.133
Mg(g)	5.345e-120	-119.272
UCl5(g)	1.356e-124	-123.868
UF3(g)	2.300e-129	-128.638
UCl6(g)	1.543e-131	-130.812
U2F10(g)	1.996e-136	-135.700
UCl3(g)	1.083e-137	-136.966
Ca(g)	1.602e-142	-141.795
S2(g)	3.080e-157	-156.511
C(g)	4.893e-167	-166.310
C2H4(g)	2.892e-167	-166.539
UF2(g)	4.461e-171	-170.351
UCl2(g)	1.676e-180	-179.776
UO(g)	4.664e-186	-185.331
Si(g)	3.858e-199	-198.414
UF(g)	2.561e-206	-205.592
U2Cl8(g)	2.642e-213	-212.578
UCl(g)	6.228e-221	-220.206
U2Cl10(g)	8.280e-222	-221.082
U(g)	7.106e-260	-259.148

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ba++	7.61e-007	7.61e-007	0.104			
Ca++	0.000615	0.000615	24.6			
Cl-	0.000111	0.000111	3.94			
Cu++	1.09e-007	1.09e-007	0.00690			
F-	1.04e-005	1.04e-005	0.197			
Fe++	1.06e-006	1.06e-006	0.0591			
H+	0.000178	0.000178	0.180			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00186	0.00186	113.			
HPO4--	3.18e-007	3.18e-007	0.0305			
K+	0.000555	0.000555	21.7			
Mg++	0.000203	0.000203	4.93			

Mn++	8.81e-006	8.81e-006	0.484
NH3(aq)	0.000238	0.000238	4.05
NO3-	0.000992	0.000992	61.5
Na+	0.00133	0.00133	30.5
O2(aq)	0.000178	0.000178	5.70
SO4--	0.000421	0.000421	40.4
Sb(OH)3(aq)	2.10e-007	2.10e-007	0.0364
SiO2(aq)	0.000202	0.000202	12.1
UO2++	8.28e-009	8.28e-009	0.00224

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Antimony	2.105e-007	2.105e-007	0.02562		
Barium	7.608e-007	7.608e-007	0.1044		
Calcium	0.0006148	0.0006148	24.63		
Carbon	0.001858	0.001858	22.30		
Chlorine	0.0001112	0.0001112	3.941		
Copper	1.086e-007	1.086e-007	0.006897		
Fluorine	1.038e-005	1.038e-005	0.1971		
Hydrogen	111.0	111.0	1.119e+005		
Iron	1.059e-006	1.059e-006	0.05912		
Magnesium	0.0002028	0.0002028	4.926		
Manganese	8.809e-006	8.809e-006	0.4838		
Nitrogen	0.001230	0.001230	17.22		
Oxygen	55.52	55.52	8.880e+005		
Phosphorus	3.182e-007	3.182e-007	0.009853		
Potassium	0.0005546	0.0005546	21.68		
Silicon	0.0002018	0.0002018	5.665		
Sodium	0.001329	0.001329	30.54		
Sulfur	0.0004207	0.0004207	13.48		
Uranium	8.281e-009	8.281e-009	0.001971		

```
Temperature =   4.1 C    Pressure =  1.013 bars
pH =  7.500              log fO2 =  -34.124
Eh =   0.3510 volts      pe =   6.3808
Ionic strength      =    0.004546
Charge imbalance    =   -0.000016 eq/kg (-0.4658% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000307 kg
Solution density    =    1.027    g/cm3
Chlorinity          =    0.000110 molal
Dissolved solids    =         307 mg/kg sol'n
Hardness            =       75.96 mg/kg sol'n as CaCO3
  carbonate         =       75.61 mg/kg sol'n as CaCO3
  non-carbonate     =        0.35 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       75.61 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3510	6.3808
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5785	10.5161
14*e- + 16*H+ + 2*SO4-- = 8*H2O + S2--	-0.2387	-4.3391

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001495	91.19	0.9320	-2.8560
Na+	0.001352	31.06	0.9320	-2.8997
NO3-	0.001008	62.49	0.9306	-3.0277
K+	0.0005716	22.34	0.9306	-3.2741
Ca++	0.0005365	21.50	0.7619	-3.3885
SO4--	0.0003931	37.75	0.7535	-3.5284
Mg++	0.0001910	4.640	0.7697	-3.8327
SiO2(aq)	0.0001844	11.08	1.0000	-3.7342
CO2(aq)	0.0001488	6.548	1.0000	-3.8273
N2(aq)	0.0001340	3.754	1.0000	-3.8727
Cl-	0.0001098	3.893	0.9306	-3.9905
F-	1.529e-005	0.2905	0.9313	-4.8464
CaSO4(aq)	1.432e-005	1.949	1.0000	-4.8440
Mn++	7.946e-006	0.4364	0.7619	-5.2180
CaHCO3+	7.307e-006	0.7385	0.9320	-5.1669
MgSO4(aq)	6.614e-006	0.7959	1.0000	-5.1795
NaHCO3(aq)	3.798e-006	0.3189	1.0000	-5.4205
MgHCO3+	2.537e-006	0.2164	0.9320	-5.6263
CO3--	1.589e-006	0.09530	0.7557	-5.9207
KSO4-	1.277e-006	0.1725	0.9320	-5.9244
Ba++	7.586e-007	0.1041	0.7578	-6.2405
CaCO3(aq)	6.970e-007	0.06974	1.0000	-6.1568
S2--	6.074e-007	0.03894	0.7535	-6.3394
HPO4--	5.220e-007	0.05009	0.7535	-6.4052
HSiO3-	3.416e-007	0.02632	0.9320	-6.4971
MnSO4(aq)	3.313e-007	0.05001	1.0000	-6.4798
H2PO4-	2.640e-007	0.02560	0.9320	-6.6090
Sb(OH)3(aq)	2.320e-007	0.04006	1.0000	-6.6346
MgCO3(aq)	1.386e-007	0.01168	1.0000	-6.8584
Cu++	1.379e-007	0.008761	0.7619	-6.9785
OH-	5.803e-008	0.0009866	0.9313	-7.2673
MgF+	5.289e-008	0.002290	0.9320	-7.3072
H+	3.371e-008	3.397e-005	0.9381	-7.5000
NaHSiO3(aq)	2.904e-008	0.002905	1.0000	-7.5370

CaF+	2.800e-008	0.001654	0.9320	-7.5834
NaCl(aq)	1.936e-008	0.001131	1.0000	-7.7132
MgCl+	1.360e-008	0.0008122	0.9320	-7.8972
NaCO3-	9.432e-009	0.0007826	0.9320	-8.0560
CaCl+	9.285e-009	0.0007011	0.9320	-8.0628
UO2(CO3)2--	4.031e-009	0.001572	0.7535	-8.5175
UO2(CO3)3----	3.131e-009	0.001409	0.3220	-8.9964
NaF(aq)	1.525e-009	6.402e-005	1.0000	-8.8167
KCl(aq)	1.154e-009	8.600e-005	1.0000	-8.9378
MnCl+	8.440e-010	7.627e-005	0.9320	-9.1042
HSO4-	5.738e-010	5.568e-005	0.9320	-9.2719
HF(aq)	4.633e-010	9.266e-006	1.0000	-9.3342
UO2CO3(aq)	1.999e-010	6.596e-005	1.0000	-9.6992
BaCO3(aq)	1.978e-010	3.901e-005	1.0000	-9.7038
BaCl+	1.538e-011	2.656e-006	0.9320	-10.8437
NaOH(aq)	1.271e-011	5.081e-007	1.0000	-10.8959
Cu+	1.196e-011	7.600e-007	0.9320	-10.9527
PO4---	6.659e-012	6.323e-007	0.5288	-11.4533
BaF+	4.741e-012	7.409e-007	0.9320	-11.3547
Sb(OH)2F(aq)	3.159e-012	5.518e-007	1.0000	-11.5005
UO2OH+	2.020e-012	5.795e-007	0.9320	-11.7253
Sb(OH)4-	1.794e-012	3.404e-007	0.9320	-11.7768
CaCl2(aq)	1.357e-012	1.506e-007	1.0000	-11.8674
H3PO4(aq)	9.443e-013	9.251e-008	1.0000	-12.0249
HNO3(aq)	9.387e-013	5.913e-008	1.0000	-12.0275
HCl(aq)	7.053e-013	2.571e-008	1.0000	-12.1516
Sb(OH)2+	5.560e-013	8.658e-008	0.9320	-12.2855
UO2F+	6.240e-014	1.803e-008	0.9320	-13.2354
UO2++	4.815e-014	1.300e-008	0.7557	-13.4390
MgP2O7--	3.046e-014	6.038e-009	0.7535	-13.6391
KHSO4(aq)	1.539e-014	2.095e-009	1.0000	-13.8129
UO2SO4(aq)	7.532e-015	2.756e-009	1.0000	-14.1231
UO2F2(aq)	2.652e-015	8.166e-010	1.0000	-14.5765
HP2O7---	1.580e-015	2.764e-010	0.5288	-15.0779
HF2-	1.343e-015	5.239e-011	0.9320	-14.9024
H2P2O7--	1.549e-016	2.725e-011	0.7535	-15.9328
P2O7----	4.202e-017	7.307e-012	0.3220	-16.8687
UO2(SO4)2--	1.641e-017	7.583e-012	0.7535	-16.9077
UO2F3-	6.854e-018	2.241e-012	0.9320	-17.1946
UO2Cl+	4.738e-018	1.447e-012	0.9320	-17.3550
KP2O7---	2.445e-018	5.208e-013	0.5288	-17.8884
(UO2)2(OH)2++	1.216e-018	6.978e-013	0.7557	-18.0367
UO2+	3.337e-019	9.009e-014	0.9320	-18.5072
(UO2)3(CO3)6(6-)	2.204e-020	2.578e-014	0.0781	-20.7643
(UO2)3(OH)5+	1.919e-020	1.717e-014	0.9320	-19.7476
H3P2O7-	9.054e-022	1.602e-016	0.9320	-21.0738
UO2F4--	7.818e-022	2.704e-016	0.7535	-21.2298
U(OH)4(aq)	5.049e-022	1.545e-016	1.0000	-21.2968
UO2Cl2(aq)	1.861e-023	6.343e-018	1.0000	-22.7303
Mn+++	1.360e-025	7.469e-021	0.5355	-25.1377
H4P2O7(aq)	6.429e-028	1.144e-022	1.0000	-27.1918
Formate	2.407e-031	1.083e-026	0.9313	-30.6494
H2(aq)	5.011e-032	1.010e-028	1.0000	-31.3001
Ca(For)+	3.120e-033	2.654e-028	0.9320	-32.5364
Mg(For)+	1.480e-033	1.026e-028	0.9320	-32.8603
Na(For)(aq)	3.448e-034	2.344e-029	1.0000	-33.4624
K(For)(aq)	1.210e-034	1.018e-029	1.0000	-33.9171
Mn(For)+	9.620e-035	9.613e-030	0.9320	-34.0474
NO2-	7.017e-035	3.227e-030	0.9306	-34.1851
Formic_acid(aq)	4.296e-035	1.976e-030	1.0000	-34.3670
NH4+	2.398e-035	4.325e-031	0.9299	-34.6517
SO3--	7.165e-036	5.735e-031	0.7557	-35.2665
SiF6--	4.921e-036	6.989e-031	0.7535	-35.4308

Cu(For)+	3.581e-036	3.886e-031	0.9320	-35.4766
Ba(For)+	3.091e-036	5.634e-031	0.9320	-35.5406
HSO3-	2.503e-036	2.028e-031	0.9320	-35.6322
O2(aq)	1.483e-037	4.743e-033	1.0000	-36.8289
NH3(aq)	8.412e-038	1.432e-033	1.0000	-37.0751
CO(aq)	6.136e-038	1.718e-033	1.0000	-37.2121
Oxalate	7.566e-039	6.657e-034	0.7535	-38.2440
HNO2(aq)	5.645e-039	2.653e-034	1.0000	-38.2483
ClO-	4.224e-039	2.172e-034	0.9320	-38.4049
UF3+	1.946e-039	5.738e-034	0.9320	-38.7416
UF2++	8.459e-040	2.334e-034	0.7557	-39.1943
UOH+++	7.124e-040	1.816e-034	0.5355	-39.4186
UF4(aq)	3.024e-040	9.495e-035	1.0000	-39.5193
U(CO3)5(6-)	1.496e-040	8.045e-035	0.0781	-40.9326
HO2-	1.061e-041	3.501e-037	0.9320	-41.0049
UF+++	1.046e-041	2.689e-036	0.5355	-41.2515
SO2(aq)	3.542e-042	2.268e-037	1.0000	-41.4508
H-Oxalate	3.105e-042	2.763e-037	0.9320	-41.5386
USO4++	1.976e-043	6.601e-038	0.7557	-42.8258
U(SO4)2(aq)	1.571e-043	6.754e-038	1.0000	-42.8039
U++++	5.465e-046	1.300e-040	0.3329	-45.7400
MnO4--	3.810e-047	4.530e-042	0.7535	-46.5420
UCl+++	3.339e-048	9.129e-043	0.5355	-47.7476
Oxalic_acid(aq)	1.662e-048	1.496e-043	1.0000	-47.7794
HSO5-	3.147e-049	3.558e-044	0.9320	-48.5326
MnO4-	1.979e-051	2.353e-046	0.9313	-50.7345
S2O6--	2.738e-060	4.383e-055	0.7535	-59.6854
Ca(For)2(aq)	6.304e-063	8.200e-058	1.0000	-62.2004
Mg(For)2(aq)	4.112e-063	4.700e-058	1.0000	-62.3860
U+++	1.557e-063	3.704e-058	0.5355	-63.0791
Mn(For)2(aq)	3.618e-064	5.244e-059	1.0000	-63.4415
Na(For)2-	6.929e-065	7.829e-060	0.9320	-64.1899
Cu(For)2(aq)	2.590e-065	3.976e-060	1.0000	-64.5867
K(For)2-	1.915e-065	2.472e-060	0.9320	-64.7484
S2O8--	4.438e-066	8.524e-061	0.7535	-65.4757
Ba(For)2(aq)	4.321e-066	9.821e-061	1.0000	-65.3644
ClO2-	3.767e-066	2.540e-061	0.9320	-65.4546
Formaldehyde(aq)	8.256e-068	2.478e-063	1.0000	-67.0832
N3-	2.786e-073	1.171e-068	0.9320	-72.5855
Cu(NH3)2++	1.033e-073	1.008e-068	0.7557	-73.1076
HN3(aq)	6.608e-076	2.843e-071	1.0000	-75.1799
S2O5--	1.176e-076	1.695e-071	0.7535	-76.0524
Urea(aq)	4.305e-078	2.585e-073	1.0000	-77.3660
ClO3-	2.616e-078	2.183e-073	0.9313	-77.6132
HCN(aq)	1.818e-080	4.913e-076	1.0000	-79.7403
CN-	8.490e-083	2.208e-078	0.9306	-82.1023
Methanol(aq)	4.560e-083	1.461e-078	1.0000	-82.3410
HS-	9.329e-088	3.085e-083	0.9313	-87.0611
H2S(aq)	5.909e-088	2.013e-083	1.0000	-87.2284
Glycolate	3.281e-089	2.461e-084	0.9320	-88.5146
Ca(Glyc)+	7.623e-091	8.773e-086	0.9320	-90.1485
UO2ClO3+	3.407e-091	1.204e-085	0.9320	-90.4983
Mg(Glyc)+	1.250e-091	1.242e-086	0.9320	-90.9335
Na(Glyc)(aq)	4.886e-092	4.789e-087	1.0000	-91.3110
K(Glyc)(aq)	1.715e-092	1.957e-087	1.0000	-91.7657
Mn(Glyc)+	1.018e-092	1.323e-087	0.9320	-92.0229
Methane(aq)	7.419e-093	1.190e-088	1.0000	-92.1297
Glycolic_acid(aq	7.154e-093	5.439e-088	1.0000	-92.1454
Cu(Glyc)+	4.835e-093	6.698e-088	0.9320	-92.3462
S2O3--	1.017e-093	1.140e-088	0.7535	-93.1157
S--	9.645e-094	3.092e-089	0.7578	-93.1361
Ba(Glyc)+	2.068e-094	4.389e-089	0.9320	-93.7151
ClO4-	6.217e-095	6.181e-090	0.9313	-94.2373

S2O4--	8.136e-096	1.042e-090	0.7578	-95.2101
Acetate	2.160e-098	1.275e-093	0.9326	-97.6958
MgCH3COO+	8.947e-101	7.455e-096	0.9320	-100.0789
CaCH3COO+	8.268e-101	8.193e-096	0.9320	-100.1132
Acetic_acid(aq)	3.779e-101	2.268e-096	1.0000	-100.4227
NaCH3COO(aq)	2.204e-101	1.807e-096	1.0000	-100.6569
KCH3COO(aq)	5.447e-102	5.344e-097	1.0000	-101.2639
MnCH3COO+	2.715e-102	3.094e-097	0.9320	-101.5968
CuCH3COO+	6.232e-103	7.638e-098	0.9320	-102.2360
BaCH3COO+	1.094e-103	2.147e-098	0.9320	-102.9917
Malonate	2.502e-107	2.553e-102	0.7535	-106.7245
Cu(NH3)3++	1.087e-107	1.245e-102	0.7557	-107.0856
CuCH3COO(aq)	6.021e-109	7.378e-104	1.0000	-108.2204
H-Malonate	2.981e-109	3.071e-104	0.9320	-108.5562
Malonic_acid(aq)	6.660e-114	6.929e-109	1.0000	-113.1765
Methanamine(aq)	1.972e-117	6.123e-113	1.0000	-116.7050
Glycine(aq)	7.311e-120	5.486e-115	1.0000	-119.1360
Cu(Gly)+	9.714e-121	1.336e-115	0.9320	-120.0432
Mg(Gly)+	6.006e-123	5.906e-118	0.9320	-122.2520
Mn(Gly)+	3.656e-124	4.715e-119	0.9320	-123.4675
Ca(Gly)+	6.985e-125	7.970e-120	0.9320	-124.1864
S3O6--	3.557e-126	6.834e-121	0.7535	-125.5718
Ba(Gly)+	1.107e-127	2.339e-122	0.9320	-126.9864
SCN-	3.008e-132	1.747e-127	0.9313	-131.5526
Acetaldehyde(aq)	1.208e-132	5.319e-128	1.0000	-131.9180
NH4CH3COO(aq)	7.443e-133	5.735e-128	1.0000	-132.1283
Acetamide(aq)	5.648e-133	3.335e-128	1.0000	-132.2481
UO2SCN+	2.649e-144	8.690e-139	0.9320	-143.6075
Ethanol(aq)	1.158e-152	5.331e-148	1.0000	-151.9365
Ethyne(aq)	1.907e-155	4.965e-151	1.0000	-154.7195
Ethylene(aq)	1.317e-157	3.694e-153	1.0000	-156.8803
Lactate	8.864e-159	7.893e-154	0.9320	-158.0830
Ca(Lac)+	1.211e-160	1.563e-155	0.9320	-159.9476
Mg(Lac)+	3.270e-161	3.707e-156	0.9320	-160.5160
Na(Lac)(aq)	1.361e-161	1.525e-156	1.0000	-160.8660
K(Lac)(aq)	4.779e-162	6.123e-157	1.0000	-161.3207
Lactic_acid(aq)	2.007e-162	1.807e-157	1.0000	-161.6974
Mn(Lac)+	1.948e-162	2.805e-157	0.9320	-161.7410
Cu(Lac)+	5.941e-163	9.065e-158	0.9320	-162.2567
Ba(Lac)+	2.250e-164	5.091e-159	0.9320	-163.6785
Ethane(aq)	6.359e-167	1.912e-162	1.0000	-166.1966
Propanoate	3.309e-170	2.417e-165	0.9320	-169.5109
Propanoic_acid(a	7.737e-173	5.730e-168	1.0000	-172.1114
Ca(Prop)+	7.089e-173	8.019e-168	0.9320	-172.1800
Na(Prop)(aq)	5.016e-173	4.817e-168	1.0000	-172.2996
Mg(Prop)+	3.709e-173	3.610e-168	0.9320	-172.4613
K(Prop)(aq)	1.761e-173	1.974e-168	1.0000	-172.7543
Mn(Prop)+	4.947e-174	6.331e-169	0.9320	-173.3362
USCN+++	2.157e-174	6.386e-169	0.5355	-173.9374
Cu(Prop)+	9.447e-175	1.290e-169	0.9320	-174.0553
S4O6--	2.310e-175	5.178e-170	0.7535	-174.7593
Ba(Prop)+	2.139e-176	4.499e-171	0.9320	-175.7004
Succinate	1.686e-177	1.957e-172	0.7535	-176.8959
Ca(Glyc)2(aq)	5.346e-178	1.016e-172	1.0000	-177.2720
Mg(Glyc)2(aq)	5.692e-179	9.923e-174	1.0000	-178.2447
H-Succinate	2.001e-179	2.342e-174	0.9320	-178.7294
Cu(Glyc)2(aq)	1.477e-179	3.155e-174	1.0000	-178.8306
Mn(Glyc)2(aq)	2.920e-180	5.985e-175	1.0000	-179.5346
Na(Glyc)2-	2.120e-180	3.668e-175	0.9320	-179.7043
Serine(aq)	8.063e-181	8.471e-176	1.0000	-180.0935
K(Glyc)2-	6.086e-181	1.151e-175	0.9320	-180.2462
Ba(Glyc)2(aq)	3.088e-182	8.872e-177	1.0000	-181.5103
Succinic_acid(aq	1.101e-182	1.299e-177	1.0000	-181.9583

Ethanamine(aq)	5.061e-189	2.281e-184	1.0000	-188.2957
Alanine(aq)	2.681e-190	2.388e-185	1.0000	-189.5717
Cu(Ala)+	8.088e-192	1.226e-186	0.9320	-191.1228
Mg(Ala)+	1.355e-195	1.522e-190	0.9320	-194.8987
Mn(Ala)+	1.074e-195	1.536e-190	0.9320	-194.9995
Ca(Ala)+	4.806e-196	6.158e-191	0.9320	-195.3488
Ca(CH3COO)2(aq)	3.685e-197	5.827e-192	1.0000	-196.4336
Mg(CH3COO)2(aq)	1.824e-197	2.597e-192	1.0000	-196.7389
Mn(CH3COO)2(aq)	5.407e-199	9.352e-194	1.0000	-198.2671
Cu(CH3COO)2(aq)	5.370e-199	9.751e-194	1.0000	-198.2700
Na(CH3COO)2-	3.226e-199	4.550e-194	0.9320	-198.5220
Ba(Ala)+	2.757e-199	6.212e-194	0.9320	-198.5902
Acetone(aq)	2.063e-199	1.198e-194	1.0000	-198.6856
K(CH3COO)2-	4.955e-200	7.786e-195	0.9320	-199.3356
Aspartic_acid(aq	9.147e-201	1.217e-195	1.0000	-200.0387
Ba(CH3COO)2(aq)	6.832e-201	1.744e-195	1.0000	-200.1655
Propanal(aq)	6.968e-204	4.046e-199	1.0000	-203.1569
Cu(CH3COO)2-	2.265e-206	4.112e-201	0.9320	-205.6756
S3--	2.523e-220	2.427e-215	0.7535	-219.7209
1-Propyne(aq)	6.120e-223	2.451e-218	1.0000	-222.2133
1-Propanol(aq)	2.035e-224	1.223e-219	1.0000	-223.6913
1-Propene(aq)	4.545e-227	1.912e-222	1.0000	-226.3424
NH4(CH3COO)2-	1.761e-230	2.397e-225	0.9320	-229.7848
2-Hydroxybutanoa	5.375e-231	5.540e-226	0.9320	-230.3002
Asparagine(aq)	1.569e-232	2.072e-227	1.0000	-231.8045
2-Hydroxybutanoi	1.074e-234	1.118e-229	1.0000	-233.9690
Cu(Gly)2(aq)	4.542e-235	9.610e-230	1.0000	-234.3428
Propane(aq)	4.325e-239	1.907e-234	1.0000	-238.3640
Diglycine(aq)	1.121e-241	1.481e-236	1.0000	-240.9503
Mg(Gly)2(aq)	8.881e-242	1.531e-236	1.0000	-241.0515
Butanoate	1.593e-242	1.387e-237	0.9320	-241.8285
Mn(Gly)2(aq)	3.950e-243	8.017e-238	1.0000	-242.4035
Diketopiperazine	3.188e-244	3.636e-239	1.0000	-243.4965
Butanoic_acid(aq	2.928e-245	2.579e-240	1.0000	-244.5334
Na(But)(aq)	2.338e-245	2.573e-240	1.0000	-244.6311
Ca(But)+	2.337e-245	2.971e-240	0.9320	-244.6620
Mg(But)+	1.164e-245	1.296e-240	0.9320	-244.9646
K(But)(aq)	8.208e-246	1.036e-240	1.0000	-245.0858
Ca(Gly)2(aq)	2.861e-246	5.383e-241	1.0000	-245.5435
Mn(But)+	2.038e-246	2.894e-241	0.9320	-245.7213
Cu(But)+	3.607e-247	5.432e-242	0.9320	-246.4734
Glutarate	7.032e-249	9.145e-244	0.7535	-248.2758
Ba(But)+	6.873e-249	1.542e-243	0.9320	-248.1935
Ba(Gly)2(aq)	4.661e-249	1.330e-243	1.0000	-248.3315
H-Glutarate	4.745e-251	6.219e-246	0.9320	-250.3543
Threonine(aq)	3.944e-253	4.696e-248	1.0000	-252.4041
Glutaric_acid(aq	3.208e-254	4.237e-249	1.0000	-253.4938
Ethylacetate(aq)	1.356e-254	1.194e-249	1.0000	-253.8678
S5O6--	8.226e-255	2.108e-249	0.7535	-254.2077
1-Propanamine(aq	3.024e-260	1.787e-255	1.0000	-259.5195
a-Aminobutyric_a	2.799e-262	2.886e-257	1.0000	-261.5530
Glutamic_acid(aq	4.211e-271	6.194e-266	1.0000	-270.3756
UO2(SCN)2(aq)	3.856e-276	1.489e-270	1.0000	-275.4139
Butanal(aq)	1.063e-277	7.663e-273	1.0000	-276.9734
S4--	7.332e-284	9.401e-279	0.7535	-283.2577
Cu(CH3COO)3-	5.804e-295	1.396e-289	0.9320	-294.2669
1-Butyne(aq)	2.738e-295	1.480e-290	1.0000	-294.5626
Mn(CH3COO)3-	5.437e-296	1.261e-290	0.9320	-295.2952
1-Butanol(aq)	1.786e-297	1.324e-292	1.0000	-296.7481
1-Butene(aq)	1.292e-299	7.246e-295	1.0000	-298.8888
2-Hydroxypentano	4.949e-303	5.795e-298	0.9320	-300.0000
Glutamine(aq)	8.314e-305	1.215e-299	1.0000	-300.0000
U(SCN)2++	6.744e-305	2.388e-299	0.7557	-300.0000

2-Hydroxypentano	5.747e-307	6.787e-302	1.0000	-300.0000
n-Butane(aq)	2.559e-311	1.487e-306	1.0000	-300.0000
Alanylglycine(aq	2.159e-312	3.154e-307	1.0000	-300.0000
Pentanoate	9.110e-315	9.210e-310	0.9320	-300.0000
Pentanoic_acid(a	1.816e-317	1.854e-312	1.0000	-300.0000
Na(Pent)(aq)	1.453e-317	1.802e-312	1.0000	-300.0000
Ca(Lac)2(aq)	1.452e-317	3.168e-312	1.0000	-300.0000
Ca(Pent)+	8.004e-318	1.130e-312	0.9320	-300.0000
K(Pent)(aq)	5.098e-318	7.147e-313	1.0000	-300.0000
Mg(Lac)2(aq)	4.271e-318	8.645e-313	1.0000	-300.0000
Mg(Pent)+	3.894e-318	4.883e-313	0.9320	-300.0000
Mn(Pent)+	9.183e-319	1.433e-313	0.9320	-300.0000
Cu(Lac)2(aq)	3.109e-319	7.511e-314	1.0000	-300.0000
Mn(Lac)2(aq)	2.583e-319	6.018e-314	1.0000	-300.0000
Cu(Pent)+	2.134e-319	3.512e-314	0.9320	-300.0000
Na(Lac)2-	1.635e-319	3.288e-314	0.9320	-300.0000
K(Lac)2-	4.695e-320	1.020e-314	0.9320	-300.0000
Ba(Pent)+	2.604e-321	6.207e-316	0.9320	-300.0000
Ba(Lac)2(aq)	4.298e-322	1.356e-316	1.0000	-300.0000
Adipate	9.387e-323	1.353e-317	0.7535	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.7535	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9320	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9320	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9320	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9320	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9320	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9320	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9320	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9320	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9320	-300.0000
HSb2S4-	0.0000	0.0000	0.9320	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9320	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000

Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7535	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7535	-300.0000
Sb2S4--	0.0000	0.0000	0.7535	-300.0000
H-Suberate	0.0000	0.0000	0.9320	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
H-Sebacate	0.0000	0.0000	0.9320	-300.0000
H-Pimelate	0.0000	0.0000	0.9320	-300.0000
S5--	0.0000	0.0000	0.7535	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9320	-300.0000
H-Adipate	0.0000	0.0000	0.9320	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7535	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9345	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9320	-300.0000
Octanoate	0.0000	0.0000	0.9320	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9320	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9320	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9320	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9320	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9320	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9320	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9320	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9320	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000

2-Hydroxyheptano	0.0000	0.0000	0.9320	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9320	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7535	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Fluorapatite	5.5120s/sat	Tremolite	-16.8320
Witherite	1.6380s/sat	Natrosilite	-16.9484
Quartz	0.7738s/sat	Ningyoite	-17.5644
Barite	0.6143s/sat	MnCl2:2H2O	-17.6389
Tridymite	0.5758s/sat	MgOHCl	-17.7819
Chalcedony	0.4822s/sat	Na2SiO3	-17.8039
Cristobalite(alp	0.1738s/sat	Ba2Si3O8	-18.0405
Ice	-0.0609	CuCl2	-19.2890
Coesite	-0.0935	MnCl2:H2O	-19.3889
Cristobalite(bet	-0.3322	UOFOH:.5H2O	-19.5740
Tenorite	-0.4876	MgCl2:4H2O	-19.7238
Rhodochrosite	-0.6399	Hillebrandite	-19.9457
SiO2(am)	-0.6928	UO2SO4	-19.9754
Calcite	-0.9079	UOFOH	-20.1087
Aragonite	-1.0535	Hydromagnesite	-20.3401
Dolomite-ord	-1.1900	Dicalcium_silica	-20.4838
Dolomite	-1.1901	UO2(NO3)2:6H2O	-21.5323
Malachite	-1.2442	Na2UO4(alpha)	-21.5660
Monohydrocalcite	-1.6978	Larnite	-21.9019
Magnesite	-2.0461	Akermanite	-22.0572
Dioptase	-2.0742	UOF2:H2O	-22.1338
Gypsum	-2.4023	UO2Cl	-22.2361
Anhydrite	-2.7884	UOF2	-22.8298
Fluorite	-2.8289	Scacchite	-22.8930
Dolomite-dis	-2.8962	UO2(NO3)2:3H2O	-23.3073
Bassanite	-3.4406	Lime	-23.5226
Sb2O3	-3.4598	Hydrophilite	-24.1812
CaSO4:0.5H2O(bet	-3.6363	Anthophyllite	-24.2980
UO3:2H2O	-3.9508	UO2(NO3)2:2H2O	-24.7401
Schoepite	-3.9528	U(HPO4)2:4H2O	-25.3725
Brochantite	-4.0416	UO2(PO3)2	-25.6159
UO2(OH)2(beta)	-4.1413	MgCl2:2H2O	-25.7602
Schoepite-dehy(.	-4.1971	UP2O7	-25.9364
UO3:.9H2O(alpha)	-4.2174	(UO2)3(PO4)2	-25.9630
Talc	-4.2460	K2UO4	-26.1869
Sellaite	-4.2528	(UO2)2P2O7	-26.2530
Schoepite-dehy(.	-4.3051	UO2Cl2:3H2O	-27.6399

Schoepite-dehy(1	-4.3271	Rankinite	-28.3833
Rhodonite	-4.4644	UO2(NO3)2:H2O	-28.7154
CaUO4	-4.5077	MgCl2:H2O	-29.4573
Cuprite	-4.6456	UO2Cl2:H2O	-30.7291
Enstatite	-4.9128	Tobermorite-14A	-30.8774
UO2CO3	-4.9201	UF4:2.5H2O	-31.3523
Rutherfordine	-4.9246	UO2(NO3)2	-32.5124
Whitlockite	-5.1600	UO2SO3	-32.5898
Nesquehonite	-5.2666	Tobermorite-11A	-33.3366
Nahcolite	-5.4040	Ba2SiO4	-33.8571
Hydroxylapatite	-5.4252	KMgCl3:2H2O	-34.0260
Schoepite-dehy(.	-5.5318	UO2Cl2	-34.9547
Niter	-5.6020	Foshagite	-35.2174
Schoepite-dehy(.	-6.0973	BaSiF6	-35.4029
Okenite	-6.3835	Merwinite	-35.5080
Brucite	-6.6056	Chloromagnesite	-35.7154
UO2HPO4:4H2O	-6.6237	UF4	-36.0769
Wollastonite	-6.8197	Afwillite	-36.7229
Mn(OH)2(am)	-6.8297	Tobermorite-9A	-37.3548
Bixbyite	-6.8546	U(SO4)2:8H2O	-40.6987
Atacamite	-6.9355	KMgCl3	-42.0283
Pseudowollastoni	-7.0980	U(SO4)2:4H2O	-42.1566
Pyrolusite	-7.1140	U(SO4)2	-42.5218
Mirabilite	-7.2149	BaO	-42.6063
UO3(gamma)	-7.2176	C	-42.8205
Diopside	-7.2734	Ba2U2O7	-44.1981
Azurite	-7.3849	UOCl2	-46.0105
Nantokite	-7.6155	U(CO3)2	-46.2182
Chalcanthite	-7.8064	UClF3	-47.6463
Chrysotile	-7.8339	U5O12Cl	-47.9193
Sylvite	-7.8510	Hatrurite	-47.9706
UO3(beta)	-7.8679	Xonotlite	-50.7442
Cu	-7.8882	UOF4	-54.2945
Arcanite	-7.8980	Na3UO4	-57.3586
UO3(alpha)	-8.2342	UF3	-58.0532
Halite	-8.4026	(UO2)2Cl3	-58.4343
UO2FOH:2H2O	-8.4315	Na	-58.5898
Sanbornite	-8.4429	UOCl3	-59.3634
Huntite	-8.7749	UF5(beta)	-60.0586
UO2FOH:H2O	-8.9248	Na4SiO4	-60.2508
Thenardite	-8.9945	UF5(alpha)	-60.4971
UO2.25	-9.0532	Mn	-61.3455
UO2.25(beta)	-9.1253	UCl2F2	-61.5295
Hausmannite	-9.2259	Covellite	-62.3370
Nitrobarite	-9.2503	K	-62.7230
Tephroite	-9.2980	Na2O	-62.8778
Artinite	-9.3921	UOCl	-63.8666
UO2FOH	-9.4892	Chalcocite	-63.9896
BaUO4	-9.6544	S	-64.3852
Manganosite	-9.7428	U2O3F6	-70.7747
Sepiolite	-9.8481	Ba3UO6	-74.0109
Natron	-10.1348	UCl3F	-75.2242
Saleeite	-10.4461	U(SO3)2	-79.1458
Na2CO3:7H2O	-10.8149	K2O	-81.2223
Mg1.25SO4(OH)0.5	-11.0515	Alabandite	-84.6651
UO2SO4:H2O	-11.4066	UCl4	-86.7629
(UO2)3(PO4)2:4H2	-11.6659	Na6Si2O7	-87.5980
Gyrolite	-11.7807	UCl3	-89.6568
UO2.6667	-11.8272	U2F9	-92.7604
Forsterite	-11.9031	UF6	-93.2455
Uraninite	-11.9462	U3O5F8	-94.5936
Uranocircite	-11.9937	Mg	-102.7848
Coffinite	-12.0279	BaS	-103.2570

Periclase	-12.1502	UN1.73(alpha)	-106.4319
MnSO4	-12.1956	U2O2Cl5	-106.7122
UPO5	-12.3439	UCl5	-108.9382
Thermonatrite	-12.4739	UN1.59(alpha)	-109.3512
Torbernite	-12.5522	Antigorite	-110.2060
Na2U2O7	-12.5604	P	-118.5649
Mg1.5SO4(OH)	-12.6324	Ca	-120.6693
Portlandite	-12.6474	UN	-123.3331
UO2ClOH:2H2O	-12.6918	Ba	-124.8449
BaU2O7	-12.6948	Si	-127.1337
Na2CO3	-12.8500	UCl6	-129.8696
MgUO4	-12.9075	U4F17	-163.9804
Monticellite	-13.0498	U	-172.9200
MgSO4	-13.3717	US	-176.8263
BaCl2:2H2O	-14.1988	UC	-197.1193
Chalcocyanite	-14.3398	US1.9	-199.2629
Autunite-H	-14.6971	UH3(beta)	-200.9508
BaCl2:H2O	-14.9889	US2	-203.8512
NaUO3	-15.4952	Stibnite	-239.5054
UO2SO4:3.5H2O	-15.8471	UC1.94(alpha)	-239.5509
UO2F2:3H2O	-15.9310	UP	-241.3346
UO2SO4:2.5H2O	-15.9408	US3	-264.8275
UO2SO4:3H2O	-16.0141	UP2	-354.4305
MnCl2:4H2O	-16.0978	U2S3	-373.2549
UO2F2	-16.3301	o-Phthalic_acid	-381.7928
Ba(OH)2:8H2O	-16.5668	U2C3	-438.7104
BaCl2	-16.6059	U3S5	-572.1616
UO2.3333(beta)	-16.6822	U3P4	-837.1014

Gases	fugacity	log fug.
N2(g)	0.1393	-0.856
H2O(g)	0.006731	-2.172
CO2(g)	0.002191	-2.659
NO2(g)	3.139e-011	-10.503
HF(g)	5.503e-015	-14.259
HCl(g)	1.723e-019	-18.764
H2(g)	5.370e-029	-28.270
NO(g)	2.062e-034	-33.686
O2(g)	7.522e-035	-34.124
CO(g)	4.063e-035	-34.391
SiF4(g)	6.486e-039	-38.188
NH3(g)	4.511e-040	-39.346
SO2(g)	1.004e-042	-41.998
Cl2(g)	8.270e-046	-45.083
UO2F2(g)	6.241e-063	-62.205
Cu(g)	3.174e-065	-64.498
Na(g)	3.178e-074	-73.498
UO2Cl2(g)	4.247e-075	-74.372
K(g)	3.174e-075	-74.498
UO3(g)	8.530e-077	-76.069
UOF4(g)	7.294e-077	-76.137
UF5(g)	1.257e-082	-81.901
UF4(g)	9.766e-085	-84.010
H2S(g)	3.129e-087	-86.505
CH4(g)	3.228e-090	-89.491
UF6(g)	1.891e-095	-94.723
F2(g)	1.097e-104	-103.960
UCl4(g)	1.456e-114	-113.837
UO2(g)	3.506e-117	-116.455
Mg(g)	3.578e-125	-124.446
UCl5(g)	5.956e-129	-128.225
UF3(g)	2.473e-131	-130.607

U2F10(g)	8.017e-137	-136.096
UCl6(g)	1.559e-137	-136.807
UCl3(g)	2.520e-140	-139.599
S2(g)	4.386e-145	-144.358
Ca(g)	5.557e-149	-148.255
C2H4(g)	1.546e-155	-154.811
C(g)	1.297e-170	-169.887
UF2(g)	1.853e-174	-173.732
UCl2(g)	1.394e-184	-183.856
UO(g)	1.939e-191	-190.712
Si(g)	7.475e-205	-204.126
UF(g)	1.392e-210	-209.856
U2Cl8(g)	1.649e-216	-215.783
UCl(g)	3.394e-226	-225.469
U2Cl10(g)	3.371e-228	-227.472
U(g)	3.001e-266	-265.523

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ba++	7.59e-007	7.59e-007	0.104			
Ca++	0.000559	0.000559	22.4			
Cl-	0.000110	0.000110	3.89			
Cu++	1.38e-007	1.38e-007	0.00876			
F-	1.54e-005	1.54e-005	0.292			
H+	0.000146	0.000146	0.147			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00166	0.00166	101.			
HPO4--	7.86e-007	7.86e-007	0.0754			
K+	0.000573	0.000573	22.4			
Mg++	0.000200	0.000200	4.87			
Mn++	8.28e-006	8.28e-006	0.455			
NH3(aq)	0.000268	0.000268	4.56			
NO3-	0.00101	0.00101	62.5			
Na+	0.00136	0.00136	31.2			
O2(aq)	0.000201	0.000201	6.43			
S2--	6.07e-007	6.07e-007	0.0389			
SO4--	0.000416	0.000416	39.9			
Sb(OH)3(aq)	2.32e-007	2.32e-007	0.0401			
SiO2(aq)	0.000185	0.000185	11.1			
UO2++	7.36e-009	7.36e-009	0.00199			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Antimony	2.320e-007	2.320e-007	0.02823		
Barium	7.588e-007	7.588e-007	0.1042		
Calcium	0.0005589	0.0005589	22.39		
Carbon	0.001660	0.001660	19.93		
Chlorine	0.0001099	0.0001099	3.894		
Copper	1.379e-007	1.379e-007	0.008762		
Fluorine	1.538e-005	1.538e-005	0.2921		
Hydrogen	111.0	111.0	1.119e+005		
Magnesium	0.0002003	0.0002003	4.868		
Manganese	8.278e-006	8.278e-006	0.4546		
Nitrogen	0.001276	0.001276	17.87		
Oxygen	55.52	55.52	8.880e+005		
Phosphorus	7.860e-007	7.860e-007	0.02434		
Potassium	0.0005729	0.0005729	22.39		
Silicon	0.0001848	0.0001848	5.188		
Sodium	0.001356	0.001356	31.15		
Sulfur	0.0004168	0.0004168	13.36		
Uranium	7.364e-009	7.364e-009	0.001752		

```
Temperature =  10.9 C    Pressure =  1.013 bars
pH =  7.300              log fO2 =  -29.990
Eh =   0.3980 volts      pe =   7.0633
Ionic strength      =    0.004293
Charge imbalance    =   -0.000046 eq/kg (-1.379% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000303 kg
Solution density    =    1.023    g/cm3
Chlorinity          =    0.000110 molal
Dissolved solids    =         303 mg/kg sol'n
Hardness            =       69.83 mg/kg sol'n as CaCO3
  carbonate         =       69.83 mg/kg sol'n as CaCO3
  non-carbonate     =        0.00 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=       72.13 mg/kg sol'n as CaCO3
Water type          =    Na-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3980	7.0633
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5981	10.6148
14*e- + 16*H+ + 2*SO4-- = 8*H2O + S2--	-0.2362	-4.1924

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.001428	87.13	0.9332	-2.8751
Na+	0.001358	31.22	0.9332	-2.8970
NO3-	0.001173	72.72	0.9319	-2.9612
K+	0.0005495	21.48	0.9319	-3.2907
Ca++	0.0005189	20.79	0.7657	-3.4009
SO4--	0.0002987	28.69	0.7576	-3.6453
CO2(aq)	0.0001932	8.499	1.0000	-3.7141
SiO2(aq)	0.0001788	10.74	1.0000	-3.7477
Mg++	0.0001541	3.744	0.7732	-3.9239
N2(aq)	0.0001416	3.966	1.0000	-3.8489
Cl-	0.0001103	3.910	0.9319	-3.9880
CaSO4(aq)	1.087e-005	1.479	1.0000	-4.9638
F-	1.025e-005	0.1947	0.9326	-5.0196
Mn++	7.834e-006	0.4302	0.7657	-5.2220
CaHCO3+	6.561e-006	0.6631	0.9332	-5.2131
MgSO4(aq)	4.851e-006	0.5837	1.0000	-5.3142
NaHCO3(aq)	3.187e-006	0.2677	1.0000	-5.4966
MgHCO3+	1.908e-006	0.1628	0.9332	-5.7494
HPO4--	1.322e-006	0.1268	0.7576	-5.9995
CO3--	1.155e-006	0.06930	0.7597	-6.0567
AlO2-	1.102e-006	0.06499	0.9332	-5.9877
Cu++	1.047e-006	0.06649	0.7657	-6.0962
Fe++	1.040e-006	0.05804	0.7657	-6.0991
H2PO4-	9.837e-007	0.09538	0.9332	-6.0371
KSO4-	9.332e-007	0.1261	0.9332	-6.0600
S2--	7.626e-007	0.04889	0.7576	-6.2383
Ba++	7.192e-007	0.09874	0.7617	-6.2614
CaCO3(aq)	5.617e-007	0.05620	1.0000	-6.2505
HAlO2(aq)	3.159e-007	0.01894	1.0000	-6.5005
HSiO3-	2.692e-007	0.02075	0.9332	-6.5999
MnSO4(aq)	2.662e-007	0.04019	1.0000	-6.5748
Sb(OH)3(aq)	2.571e-007	0.04440	1.0000	-6.5899
Zn++	1.457e-007	0.009522	0.7657	-6.9526
MgCO3(aq)	8.697e-008	0.007330	1.0000	-7.0606

OH-	6.694e-008	0.001138	0.9326	-7.2046
H+	5.337e-008	5.378e-005	0.9391	-7.3000
Al(OH)2+	2.960e-008	0.001805	0.9332	-7.5587
MgF+	2.806e-008	0.001215	0.9332	-7.5820
NaCl(aq)	2.020e-008	0.001180	1.0000	-7.6946
NaHSiO3(aq)	1.952e-008	0.001953	1.0000	-7.7095
CaF+	1.849e-008	0.001092	0.9332	-7.7630
FeCO3+	1.116e-008	0.001293	0.9332	-7.9824
MgCl+	1.045e-008	0.0006244	0.9332	-8.0108
CaCl+	8.897e-009	0.0006718	0.9332	-8.0808
Cd++	7.830e-009	0.0008799	0.7617	-8.2245
UO2(CO3)2--	6.046e-009	0.002358	0.7576	-8.3391
NaCO3-	5.792e-009	0.0004806	0.9332	-8.2672
Pb++	5.182e-009	0.001073	0.7597	-8.4049
ZnSO4(aq)	3.914e-009	0.0006317	1.0000	-8.4074
AlOH++	2.101e-009	9.240e-005	0.7597	-8.7969
UO2(CO3)3----	1.790e-009	0.0008052	0.3291	-9.2299
KCl(aq)	1.277e-009	9.521e-005	1.0000	-8.8936
NaF(aq)	1.086e-009	4.557e-005	1.0000	-8.9643
MnCl+	9.690e-010	8.756e-005	0.9332	-9.0437
HSO4-	8.167e-010	7.925e-005	0.9332	-9.1180
HF(aq)	5.519e-010	1.104e-005	1.0000	-9.2581
UO2CO3(aq)	3.774e-010	0.0001245	1.0000	-9.4232
NaAlO2(aq)	2.031e-010	1.664e-005	1.0000	-9.6923
BaCO3(aq)	1.579e-010	3.115e-005	1.0000	-9.8017
FeCl+	6.005e-011	5.481e-006	0.9332	-10.2515
Al+++	3.406e-011	9.188e-007	0.5662	-10.7148
Cu+	2.423e-011	1.539e-006	0.9332	-10.6456
BaCl+	1.595e-011	2.755e-006	0.9332	-10.8272
NaOH(aq)	1.387e-011	5.546e-007	1.0000	-10.8579
PO4---	1.269e-011	1.205e-006	0.5352	-11.1681
PbCl+	1.129e-011	2.738e-006	0.9332	-10.9774
ZnCl+	8.544e-012	8.613e-007	0.9332	-11.0984
H3PO4(aq)	5.932e-012	5.811e-007	1.0000	-11.2268
UO2OH+	5.185e-012	1.488e-006	0.9332	-11.3153
BaF+	3.208e-012	5.013e-007	0.9332	-11.5238
Sb(OH)2F(aq)	2.576e-012	4.501e-007	1.0000	-11.5891
Sb(OH)4-	2.205e-012	4.184e-007	0.9332	-11.6865
HNO3(aq)	2.006e-012	1.264e-007	1.0000	-11.6976
CdSO4(aq)	1.364e-012	2.842e-007	1.0000	-11.8653
CaCl2(aq)	1.172e-012	1.301e-007	1.0000	-11.9310
HCl(aq)	1.093e-012	3.983e-008	1.0000	-11.9614
Fe+++	9.710e-013	5.421e-008	0.5662	-12.2599
Sb(OH)2+	7.391e-013	1.151e-007	0.9332	-12.1613
MgP2O7--	2.268e-013	4.495e-008	0.7576	-12.7649
CdCl2(aq)	1.261e-013	2.310e-008	1.0000	-12.8994
UO2++	1.248e-013	3.368e-008	0.7597	-13.0233
UO2F+	1.079e-013	3.119e-008	0.9332	-12.9968
FeF++	7.570e-014	5.664e-009	0.7597	-13.2403
KHSO4(aq)	2.273e-014	3.094e-009	1.0000	-13.6434
HP2O7---	1.811e-014	3.168e-009	0.5352	-14.0134
UO2SO4(aq)	1.767e-014	6.468e-009	1.0000	-13.7527
FeF2+	8.119e-015	7.617e-010	0.9332	-14.1205
FeSO4+	7.202e-015	1.094e-009	0.9332	-14.1726
PbCl2(aq)	3.787e-015	1.053e-009	1.0000	-14.4217
UO2F2(aq)	3.027e-015	9.320e-010	1.0000	-14.5190
H2P2O7--	2.862e-015	5.034e-010	0.7576	-14.6639
ZnCl2(aq)	1.234e-015	1.682e-010	1.0000	-14.9086
HF2-	1.167e-015	4.549e-011	0.9332	-14.9630
P2O7----	3.292e-016	5.725e-011	0.3291	-15.9652
UO2(SO4)2--	3.275e-017	1.513e-011	0.7576	-16.6054
FeCl2(aq)	2.835e-017	3.592e-012	1.0000	-16.5474
KP2O7---	1.950e-017	4.152e-012	0.5352	-16.9815

UO2Cl+	1.308e-017	3.993e-012	0.9332	-16.9135
FeCl++	5.857e-018	5.346e-013	0.7597	-17.3517
UO2F3-	5.323e-018	1.740e-012	0.9332	-17.3038
(UO2)2(OH)2++	4.944e-018	2.838e-012	0.7597	-17.4253
CdCl3-	2.675e-018	5.850e-013	0.9332	-17.6027
PbCl3-	2.056e-019	6.446e-014	0.9332	-18.7169
UO2+	2.041e-019	5.510e-014	0.9332	-18.7202
ZnCl3-	1.074e-019	1.843e-014	0.9332	-18.9992
(UO2)3(OH)5+	9.726e-020	8.703e-014	0.9332	-19.0421
H3P2O7-	2.613e-020	4.623e-015	0.9332	-19.6128
(UO2)3(CO3)6(6-)	2.024e-020	2.367e-014	0.0820	-20.7802
UO2F4--	3.845e-022	1.330e-016	0.7576	-21.5357
ZnCl4--	1.253e-022	2.596e-017	0.7576	-22.0226
UO2Cl2(aq)	5.649e-023	1.925e-017	1.0000	-22.2480
U(OH)4(aq)	3.983e-023	1.219e-017	1.0000	-22.3998
PbCl4--	2.354e-023	8.212e-018	0.7576	-22.7488
FeCl4--	1.196e-024	2.363e-019	0.7576	-24.0429
Mn+++	1.119e-024	6.144e-020	0.5418	-24.2174
H4P2O7(aq)	3.221e-026	5.730e-021	1.0000	-25.4920
NO2-	9.318e-032	4.285e-027	0.9319	-31.0613
Formate	2.947e-032	1.326e-027	0.9326	-31.5609
H2(aq)	7.513e-033	1.514e-029	1.0000	-32.1242
O2(aq)	1.724e-033	5.515e-029	1.0000	-32.7635
Ca(For)+	3.493e-034	2.972e-029	0.9332	-33.4867
Mg(For)+	1.261e-034	8.738e-030	0.9332	-33.9293
Na(For)(aq)	4.129e-035	2.807e-030	1.0000	-34.3842
K(For)(aq)	1.453e-035	1.222e-030	1.0000	-34.8378
Mn(For)+	1.058e-035	1.057e-030	0.9332	-35.0056
HNO2(aq)	1.037e-035	4.873e-031	1.0000	-34.9843
Formic_acid(aq)	8.100e-036	3.727e-031	1.0000	-35.0915
Cu(For)+	2.916e-036	3.165e-031	0.9332	-35.5652
Fe(For)+	2.062e-036	2.079e-031	0.9332	-35.7157
SiF6--	1.142e-036	1.622e-031	0.7576	-36.0630
ClO-	9.214e-037	4.739e-032	0.9332	-36.0656
SO3--	7.715e-037	6.175e-032	0.7597	-36.2321
NH4+	6.829e-037	1.232e-032	0.9313	-36.1965
HSO3-	4.482e-037	3.633e-032	0.9332	-36.3785
Ba(For)+	3.674e-037	6.697e-032	0.9332	-36.4649
Zn(For)+	2.516e-037	2.777e-032	0.9332	-36.6292
Cd(For)+	1.474e-038	2.320e-033	0.9332	-37.8616
CO(aq)	1.339e-038	3.750e-034	1.0000	-37.8732
Pb(For)+	8.908e-039	2.246e-033	0.9332	-38.0802
HO2-	2.909e-039	9.599e-035	0.9332	-38.5662
NH3(aq)	2.563e-039	4.363e-035	1.0000	-38.5913
Oxalate	9.441e-040	8.308e-035	0.7576	-39.1455
UOH+++	1.721e-040	4.388e-035	0.5418	-40.0304
UF3+	1.300e-040	3.833e-035	0.9332	-39.9162
UF2++	8.261e-041	2.280e-035	0.7597	-40.2023
UF4(aq)	1.211e-041	3.803e-036	1.0000	-40.9168
U(CO3)5(6-)	4.432e-042	2.384e-036	0.0820	-42.4396
UF+++	1.517e-042	3.899e-037	0.5418	-42.0851
SO2(aq)	1.143e-042	7.319e-038	1.0000	-41.9420
H-Oxalate	6.356e-043	5.657e-038	0.9332	-42.2268
MnO4--	3.549e-043	4.220e-038	0.7576	-42.5704
USO4++	3.647e-044	1.218e-038	0.7597	-43.5574
U(SO4)2(aq)	2.763e-044	1.188e-038	1.0000	-43.5587
MnO4-	2.222e-046	2.642e-041	0.9326	-45.6835
HSO5-	1.642e-046	1.856e-041	0.9332	-45.8146
U++++	1.268e-046	3.018e-041	0.3398	-46.3656
UCl+++	6.269e-049	1.714e-043	0.5418	-48.4690
Oxalic_acid(aq)	5.399e-049	4.859e-044	1.0000	-48.2677
S2O6--	1.299e-060	2.079e-055	0.7576	-60.0070
ClO2-	1.444e-061	9.736e-057	0.9332	-60.8705

S2O8--	4.783e-063	9.187e-058	0.7576	-62.4408
U+++	2.615e-064	6.223e-059	0.5418	-63.8487
Ca(For)2(aq)	7.891e-065	1.026e-059	1.0000	-64.1029
Mg(For)2(aq)	3.517e-065	4.021e-060	1.0000	-64.4538
Mn(For)2(aq)	4.276e-066	6.197e-061	1.0000	-65.3690
Cu(For)2(aq)	2.175e-066	3.340e-061	1.0000	-65.6625
Fe(For)2(aq)	1.145e-066	1.671e-061	1.0000	-65.9410
Na(For)2-	8.677e-067	9.804e-062	0.9332	-66.0917
K(For)2-	2.569e-067	3.316e-062	0.9332	-66.6203
Zn(For)2(aq)	1.283e-067	1.994e-062	1.0000	-66.8918
Ba(For)2(aq)	6.307e-068	1.434e-062	1.0000	-67.2002
Cd(For)2(aq)	5.378e-068	1.088e-062	1.0000	-67.2694
Pb(For)2(aq)	4.142e-069	1.231e-063	1.0000	-68.3828
Formaldehyde(aq)	2.349e-069	7.050e-065	1.0000	-68.6292
ClO3-	7.899e-072	6.590e-067	0.9326	-71.1327
N3-	1.603e-072	6.735e-068	0.9332	-71.8250
HN3(aq)	5.267e-075	2.266e-070	1.0000	-74.2784
Cu(NH3)2++	4.775e-076	4.659e-071	0.7597	-75.4404
S2O5--	3.691e-078	5.319e-073	0.7576	-77.5534
Cd(NH3)2++	6.643e-081	9.728e-076	0.7597	-80.2970
Urea(aq)	4.064e-081	2.440e-076	1.0000	-80.3910
HCN(aq)	1.577e-082	4.261e-078	1.0000	-81.8021
UO2ClO3+	2.544e-084	8.988e-079	0.9332	-83.6246
CN-	7.610e-085	1.979e-080	0.9319	-84.1492
Methanol(aq)	7.320e-086	2.345e-081	1.0000	-85.1355
ClO4-	1.685e-086	1.675e-081	0.9326	-85.8037
HS-	5.389e-092	1.782e-087	0.9326	-91.2988
Glycolate	5.195e-092	3.897e-087	0.9332	-91.3145
H2S(aq)	4.105e-092	1.399e-087	1.0000	-91.3867
Ca(Glyc)+	1.071e-093	1.232e-088	0.9332	-93.0003
Mg(Glyc)+	1.491e-094	1.480e-089	0.9332	-93.8567
Na(Glyc)(aq)	7.436e-095	7.288e-090	1.0000	-94.1287
Cu(Glyc)+	4.746e-095	6.575e-090	0.9332	-94.3537
K(Glyc)(aq)	2.616e-095	2.985e-090	1.0000	-94.5823
Glycolic_acid(aq	1.733e-095	1.318e-090	1.0000	-94.7611
Mn(Glyc)+	1.432e-095	1.861e-090	0.9332	-94.8740
Fe(Glyc)+	8.649e-096	1.132e-090	0.9332	-95.0931
Zn(Glyc)+	1.980e-096	2.780e-091	0.9332	-95.7333
Methane(aq)	5.027e-097	8.063e-093	1.0000	-96.2987
Ba(Glyc)+	2.995e-097	6.358e-092	0.9332	-96.5536
S2O3--	6.041e-098	6.772e-093	0.7576	-97.3394
S--	5.701e-098	1.827e-093	0.7617	-97.3623
Pb(Glyc)+	4.328e-098	1.221e-092	0.9332	-97.3938
Cd(Glyc)+	2.855e-098	5.350e-093	0.9332	-97.5744
S2O4--	2.011e-098	2.576e-093	0.7617	-97.8148
Acetate	1.519e-102	8.964e-098	0.9339	-101.8483
CaCH3COO+	5.420e-105	5.371e-100	0.9332	-104.2960
MgCH3COO+	4.429e-105	3.690e-100	0.9332	-104.3837
Acetic_acid(aq)	4.130e-105	2.480e-100	1.0000	-104.3840
NaCH3COO(aq)	1.502e-105	1.232e-100	1.0000	-104.8233
KCH3COO(aq)	3.755e-106	3.684e-101	1.0000	-105.4254
CuCH3COO+	2.824e-106	3.461e-101	0.9332	-105.5792
MnCH3COO+	1.733e-106	1.975e-101	0.9332	-105.7912
FeCH3COO+	2.739e-107	3.145e-102	0.9332	-106.5925
BaCH3COO+	7.512e-108	1.475e-102	0.9332	-107.1543
ZnCH3COO+	6.127e-108	7.622e-103	0.9332	-107.2428
PbCH3COO+	1.600e-108	4.260e-103	0.9332	-107.8258
CdCH3COO+	9.597e-109	1.645e-103	0.9332	-108.0479
AlCH3COO++	6.755e-111	5.809e-106	0.7597	-110.2897
Malonate	2.029e-111	2.070e-106	0.7576	-110.8133
Cu(NH3)3++	1.246e-111	1.428e-106	0.7597	-111.0239
CuCH3COO(aq)	7.907e-113	9.691e-108	1.0000	-112.1020
H-Malonate	3.872e-113	3.989e-108	0.9332	-112.4420

Malonic_acid(aq)	1.330e-117	1.384e-112	1.0000	-116.8761
Methanamine(aq)	7.337e-122	2.278e-117	1.0000	-121.1345
Glycine(aq)	2.698e-124	2.025e-119	1.0000	-123.5689
Cu(Gly)+	2.037e-124	2.802e-119	0.9332	-123.7210
Mg(Gly)+	1.605e-127	1.578e-122	0.9332	-126.8246
Zn(Gly)+	1.404e-128	1.957e-123	0.9332	-127.8827
Mn(Gly)+	1.230e-128	1.586e-123	0.9332	-127.9400
Fe(Gly)+	7.443e-129	9.665e-124	0.9332	-128.1583
Ca(Gly)+	2.771e-129	3.162e-124	0.9332	-128.5873
S3O6--	1.147e-129	2.204e-124	0.7576	-129.0610
Pb(Gly)+	4.922e-130	1.384e-124	0.9332	-129.3378
Cd(Gly)+	1.411e-130	2.630e-125	0.9332	-129.8805
Ba(Gly)+	4.611e-132	9.743e-127	0.9332	-131.3662
Acetaldehyde(aq)	1.877e-137	8.266e-133	1.0000	-136.7266
SCN-	8.366e-138	4.858e-133	0.9326	-137.1078
NH4CH3COO(aq)	1.475e-138	1.137e-133	1.0000	-137.8311
Acetamide(aq)	1.226e-138	7.238e-134	1.0000	-137.9116
UO2SCN+	1.938e-149	6.358e-144	0.9332	-148.7426
Zn(NH3)4++	4.313e-153	5.756e-148	0.7597	-152.4846
Cd(NH3)4++	1.694e-155	3.056e-150	0.7597	-154.8906
Ethanol(aq)	1.297e-158	5.973e-154	1.0000	-157.8871
Ethyne(aq)	1.174e-159	3.056e-155	1.0000	-158.9303
Ethylene(aq)	2.137e-163	5.992e-159	1.0000	-162.6703
Lactate	1.004e-164	8.941e-160	0.9332	-164.0282
Ca(Lac)+	1.217e-166	1.571e-161	0.9332	-165.9447
Mg(Lac)+	2.908e-167	3.296e-162	0.9332	-166.5664
Na(Lac)(aq)	1.467e-167	1.643e-162	1.0000	-166.8337
K(Lac)(aq)	5.160e-168	6.612e-163	1.0000	-167.2873
Cu(Lac)+	4.209e-168	6.422e-163	0.9332	-167.4058
Lactic_acid(aq)	3.517e-168	3.167e-163	1.0000	-167.4539
Mn(Lac)+	1.958e-168	2.819e-163	0.9332	-167.7382
Fe(Lac)+	1.478e-168	2.141e-163	0.9332	-167.8604
Zn(Lac)+	1.862e-169	2.875e-164	0.9332	-168.7601
Ba(Lac)+	2.395e-170	5.420e-165	0.9332	-169.6507
Pb(Lac)+	8.123e-171	2.406e-165	0.9332	-170.1203
Cd(Lac)+	3.732e-171	7.518e-166	0.9332	-170.4580
Ethane(aq)	3.938e-174	1.184e-169	1.0000	-173.4048
Propanoate	1.877e-177	1.371e-172	0.9332	-176.7565
Propanoic_acid(a	6.864e-180	5.083e-175	1.0000	-179.1634
Ca(Prop)+	3.733e-180	4.223e-175	0.9332	-179.4579
Na(Prop)(aq)	2.704e-180	2.597e-175	1.0000	-179.5680
Mg(Prop)+	1.483e-180	1.444e-175	0.9332	-179.8589
USCN+++	1.038e-180	3.074e-175	0.5418	-180.2498
K(Prop)(aq)	9.514e-181	1.067e-175	1.0000	-180.0216
Cu(Prop)+	3.416e-181	4.666e-176	0.9332	-180.4965
Mn(Prop)+	2.510e-181	3.212e-176	0.9332	-180.6303
Fe(Prop)+	7.936e-182	1.023e-176	0.9332	-181.1304
S4O6--	2.736e-182	6.134e-177	0.7576	-181.6834
Zn(Prop)+	4.683e-183	6.482e-178	0.9332	-182.3595
Pb(Prop)+	1.732e-183	4.853e-178	0.9332	-182.7914
Ba(Prop)+	1.230e-183	2.587e-178	0.9332	-182.9402
Cd(Prop)+	1.089e-183	2.019e-178	0.9332	-182.9930
Ca(Glyc)2(aq)	1.049e-183	1.994e-178	1.0000	-182.9792
Cu(Glyc)2(aq)	1.860e-184	3.972e-179	1.0000	-183.7306
Succinate	1.026e-184	1.191e-179	0.7576	-184.1093
Mg(Glyc)2(aq)	8.891e-185	1.550e-179	1.0000	-184.0510
Fe(Glyc)2(aq)	2.723e-185	5.607e-180	1.0000	-184.5649
Zn(Glyc)2(aq)	9.723e-186	2.094e-180	1.0000	-185.0122
Mn(Glyc)2(aq)	5.718e-186	1.172e-180	1.0000	-185.2428
Na(Glyc)2-	4.300e-186	7.440e-181	0.9332	-185.3965
H-Succinate	1.856e-186	2.173e-181	0.9332	-185.7613
K(Glyc)2-	1.306e-186	2.469e-181	0.9332	-185.9142
Serine(aq)	4.799e-187	5.042e-182	1.0000	-186.3189

Pb(Glyc)2(aq)	1.281e-187	4.575e-182	1.0000	-186.8925
Ba(Glyc)2(aq)	6.926e-188	1.990e-182	1.0000	-187.1595
Cd(Glyc)2(aq)	4.536e-188	1.190e-182	1.0000	-187.3433
Succinic_acid(aq	1.529e-189	1.805e-184	1.0000	-188.8156
Ethanamine(aq)	1.458e-196	6.573e-192	1.0000	-195.8361
Alanine(aq)	7.099e-198	6.323e-193	1.0000	-197.1488
Cu(Ala)+	1.213e-198	1.839e-193	0.9332	-197.9461
Fe(Ala)+	2.351e-202	3.383e-197	0.9332	-201.6587
Zn(Ala)+	3.502e-203	5.374e-198	0.9332	-202.4856
Mg(Ala)+	2.878e-203	3.234e-198	0.9332	-202.5708
Mn(Ala)+	2.777e-203	3.970e-198	0.9332	-202.5865
Ca(Ala)+	1.399e-203	1.793e-198	0.9332	-202.8842
Cd(Ala)+	2.090e-204	4.189e-199	0.9332	-203.7099
Pb(Ala)+	1.041e-204	3.072e-199	0.9332	-204.0127
Ca(CH3COO)2(aq)	1.473e-205	2.329e-200	1.0000	-204.8319
Mg(CH3COO)2(aq)	5.092e-206	7.249e-201	1.0000	-205.2931
Cu(CH3COO)2(aq)	1.385e-206	2.514e-201	1.0000	-205.8587
Ba(Ala)+	8.629e-207	1.944e-201	0.9332	-206.0941
Acetone(aq)	2.105e-207	1.223e-202	1.0000	-206.6766
Mn(CH3COO)2(aq)	2.087e-207	3.610e-202	1.0000	-206.6805
Na(CH3COO)2-	1.301e-207	1.835e-202	0.9332	-206.9156
Zn(CH3COO)2(aq)	9.395e-208	1.723e-202	1.0000	-207.0271
Fe(CH3COO)2(aq)	8.662e-208	1.506e-202	1.0000	-207.0624
Aspartic_acid(aq	3.995e-208	5.316e-203	1.0000	-207.3984
K(CH3COO)2-	2.145e-208	3.370e-203	0.9332	-207.6986
Ba(CH3COO)2(aq)	3.253e-209	8.305e-204	1.0000	-208.4878
Cd(CH3COO)2(aq)	2.900e-209	6.683e-204	1.0000	-208.5375
Pb(CH3COO)2(aq)	1.875e-209	6.097e-204	1.0000	-208.7270
Al(CH3COO)2+	1.080e-210	1.566e-205	0.9332	-209.9966
Propanal(aq)	8.582e-212	4.983e-207	1.0000	-211.0664
Cu(CH3COO)2-	1.681e-214	3.053e-209	0.9332	-213.8044
1-Propyne(aq)	2.437e-230	9.760e-226	1.0000	-229.6132
S3--	6.341e-231	6.098e-226	0.7576	-230.3184
1-Propanol(aq)	1.831e-233	1.100e-228	1.0000	-232.7374
1-Propene(aq)	5.388e-236	2.266e-231	1.0000	-235.2686
2-Hydroxybutanoa	5.086e-240	5.242e-235	0.9332	-239.3236
NH4(CH3COO)2-	2.127e-240	2.895e-235	0.9332	-239.7022
Asparagine(aq)	1.414e-241	1.867e-236	1.0000	-240.8496
Cu(Gly)2(aq)	2.472e-243	5.230e-238	1.0000	-242.6070
2-Hydroxybutanoi	1.577e-243	1.642e-238	1.0000	-242.8021
Propane(aq)	2.227e-249	9.816e-245	1.0000	-248.6524
Zn(Gly)2(aq)	1.861e-250	3.973e-245	1.0000	-249.7302
Diglycine(aq)	1.631e-250	2.155e-245	1.0000	-249.7875
Mg(Gly)2(aq)	7.470e-251	1.288e-245	1.0000	-250.1267
Fe(Gly)2(aq)	5.147e-252	1.049e-246	1.0000	-251.2884
Mn(Gly)2(aq)	4.507e-252	9.150e-247	1.0000	-251.3461
Butanoate	7.508e-253	6.538e-248	0.9332	-252.1545
Diketopiperazine	6.447e-253	7.354e-248	1.0000	-252.1907
Pb(Gly)2(aq)	3.821e-253	1.357e-247	1.0000	-252.4178
Cd(Gly)2(aq)	3.225e-253	8.398e-248	1.0000	-252.4915
Ca(Gly)2(aq)	4.537e-255	8.536e-250	1.0000	-254.3432
Butanoic_acid(aq	2.199e-255	1.937e-250	1.0000	-254.6578
Na(But)(aq)	1.040e-255	1.145e-250	1.0000	-254.9829
Ca(But)+	1.024e-255	1.302e-250	0.9332	-255.0198
Mg(But)+	3.876e-256	4.317e-251	0.9332	-255.4416
K(But)(aq)	3.660e-256	4.618e-251	1.0000	-255.4365
Cu(But)+	1.081e-256	1.629e-251	0.9332	-255.9960
Mn(But)+	8.559e-257	1.215e-251	0.9332	-256.0976
Fe(But)+	3.283e-257	4.692e-252	0.9332	-256.5137
Ba(Gly)2(aq)	8.446e-258	2.410e-252	1.0000	-257.0733
Zn(But)+	3.066e-258	4.674e-253	0.9332	-257.5434
Glutarate	3.439e-259	4.472e-254	0.7576	-258.5842
Ba(But)+	3.289e-259	7.380e-254	0.9332	-258.5129

Pb(But)+	1.944e-259	5.720e-254	0.9332	-258.7413
Cd(But)+	1.844e-259	3.678e-254	0.9332	-258.7642
H-Glutarate	3.627e-261	4.754e-256	0.9332	-260.4704
Threonine(aq)	1.969e-262	2.345e-257	1.0000	-261.7057
Glutaric_acid(aq	3.797e-264	5.014e-259	1.0000	-263.4206
Ethylacetate(aq)	1.621e-264	1.428e-259	1.0000	-263.7902
S5O6--	1.046e-264	2.681e-259	0.7576	-264.1009
1-Propanamine(aq	6.937e-271	4.099e-266	1.0000	-270.1588
a-Aminobutyric_a	6.120e-273	6.309e-268	1.0000	-272.2133
Glutamic_acid(aq	1.552e-281	2.283e-276	1.0000	-280.8091
UO2(SCN)2(aq)	8.345e-287	3.222e-281	1.0000	-286.0786
Butanal(aq)	1.193e-288	8.601e-284	1.0000	-287.9233
S4--	1.179e-297	1.512e-292	0.7576	-297.0490
1-Butyne(aq)	9.175e-306	4.962e-301	1.0000	-300.0000
Cu(CH3COO)3-	7.411e-307	1.783e-301	0.9332	-300.0000
Zn(CH3COO)3-	1.592e-308	3.861e-303	0.9332	-300.0000
Mn(CH3COO)3-	1.129e-308	2.619e-303	0.9332	-300.0000
Pb(CH3COO)3-	3.226e-309	1.240e-303	0.9332	-300.0000
1-Butanol(aq)	1.386e-309	1.027e-304	1.0000	-300.0000
Cd(CH3COO)3-	1.316e-310	3.810e-305	0.9332	-300.0000
1-Butene(aq)	1.302e-311	7.306e-307	1.0000	-300.0000
2-Hydroxypentano	3.873e-315	4.535e-310	0.9332	-300.0000
U(SCN)2++	9.761e-317	3.456e-311	0.7597	-300.0000
Glutamine(aq)	6.305e-317	9.211e-312	1.0000	-300.0000
2-Hydroxypentano	7.074e-319	8.355e-314	1.0000	-300.0000
Zn(CN)4--	0.0000	0.0000	0.7576	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9332	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Alanylglycine(aq	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9332	-300.0000
H-Sebacate	0.0000	0.0000	0.9332	-300.0000
H-Pimelate	0.0000	0.0000	0.9332	-300.0000
H-Azelate	0.0000	0.0000	0.9332	-300.0000
H-Adipate	0.0000	0.0000	0.9332	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7576	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7576	-300.0000
Sb2S4--	0.0000	0.0000	0.7576	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9332	-300.0000
S5--	0.0000	0.0000	0.7576	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Pentanoate	0.0000	0.0000	0.9332	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000

Fe(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipate	0.0000	0.0000	0.7576	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Pent)+	0.0000	0.0000	0.9332	-300.0000
Pb(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Pent)+	0.0000	0.0000	0.9332	-300.0000
Pb(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7576	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Pb(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Fe(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9332	-300.0000
Fe(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9332	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9332	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9332	-300.0000
Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9332	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9332	-300.0000
Na(But)2-	0.0000	0.0000	0.9332	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9332	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9357	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Pent)+	0.0000	0.0000	0.9332	-300.0000
Mn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9332	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mn(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9332	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000

Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9332	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9332	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9332	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9332	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9332	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9332	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9332	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9332	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9332	-300.0000
Cd(Pent)+	0.0000	0.0000	0.9332	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9332	-300.0000
p-Toluate	0.0000	0.0000	0.9332	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9332	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9332	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9332	-300.0000
HSb2S4-	0.0000	0.0000	0.9332	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9332	-300.0000
Azelate	0.0000	0.0000	0.7576	-300.0000
Zn(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Zn(Pent)+	0.0000	0.0000	0.9332	-300.0000
Zn(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000

n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7576	-300.0000
o-Toluate	0.0000	0.0000	0.9332	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
(NH4)2Sb2S4(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Nontronite-Ca	22.5179s/sat	UO2SO4:H2O	-10.9589
Nontronite-Mg	22.4428s/sat	Mg1.25SO4(OH)0.5	-10.9763
Nontronite-K	22.3771s/sat	Na2CO3:7H2O	-11.1091
Nontronite-Na	22.1240s/sat	Cotunnite	-11.2863
Nontronite-H	21.6949s/sat	Sepiolite	-11.3114
Hematite	18.0566s/sat	Clinochlore-7A	-11.4276
Ferrite-Cu	15.6318s/sat	Periclase	-11.9744
Magnetite	15.4316s/sat	Forsterite	-12.0074
Cronstedtite-7A	14.2024s/sat	MnSO4	-12.0560
Ferrite-Zn	13.2270s/sat	UPO5	-12.1227
Delafossite	12.5533s/sat	Na2U2O7	-12.1524
Clinoptilolite-h	10.8820s/sat	UO2.6667	-12.1687
Clinoptilolite-C	10.8010s/sat	BaU2O7	-12.1915
Muscovite	10.7775s/sat	CdSO4	-12.1938
Clinoptilolite-K	10.4740s/sat	UO2ClOH:2H2O	-12.3153
Clinoptilolite-h	10.1509s/sat	Gyrolite	-12.3379
Stilbite	9.4227s/sat	Przhevalskite	-12.3873
Goethite	8.5681s/sat	Portlandite	-12.4866
Clinoptilolite-N	7.4472s/sat	MgUO4	-12.4978
Clinoptilolite-h	7.4455s/sat	Mg1.5SO4(OH)	-12.5531
Illite	7.3442s/sat	Thermonatrite	-12.5675
Beidellite-Ca	7.3407s/sat	Bassetite	-12.7820
Beidellite-Mg	7.2655s/sat	Na2CO3	-12.8916
Beidellite-K	7.2000s/sat	Autunite-H	-12.9484
Epidote-ord	7.0263s/sat	FeSO4	-13.0037
Epidote	7.0253s/sat	Uraninite	-13.0216
Paragonite	6.9505s/sat	Monticellite	-13.1205
Beidellite-Na	6.9467s/sat	MgSO4	-13.2049
Kaolinite	6.8452s/sat	PbF2	-13.2565
Ferrite-Ca	6.6568s/sat	Coffinite	-13.2700
Beidellite-H	6.5181s/sat	Chalcocyanite	-13.2740
Ferrite-Mg	6.4695s/sat	Mordenite-dehy	-14.0418
Mesolite	6.2770s/sat	FeF2	-14.1784
Pyrophyllite	6.2608s/sat	BaCl2:2H2O	-14.3104
Fluorapatite	6.1990s/sat	CdCl2:H2O	-14.5739
Montmor-Ca	5.8990s/sat	ZnSO4	-14.8177
Montmor-Mg	5.8987s/sat	BaCl2:H2O	-15.0422
Montmor-K	5.8331s/sat	UO2SO4:3.5H2O	-15.4251
Andradite	5.8325s/sat	UO2SO4:2.5H2O	-15.4856
Montmor-Na	5.5751s/sat	UO2SO4:3H2O	-15.5630
Scolecite	4.8121s/sat	CdCl2	-15.6928
Jarosite	4.1942s/sat	UO2F2:3H2O	-15.8035
Maximum_Microcli	4.1780s/sat	NaUO3	-15.8500
K-Feldspar	4.1761s/sat	MnCl2:4H2O	-16.0469
Laumontite	3.5056s/sat	Zn(NO3)2:6H2O	-16.0858
Fe(OH)3	3.2515s/sat	UO2F2	-16.1231
Smectite-low-Fe-	3.1200s/sat	Alum-K	-16.2500
Diaspore	3.0632s/sat	Pb4SO7	-16.3633
Celadonite	2.9747s/sat	BaCl2	-16.5905
Margarite	2.9303s/sat	Ba(OH)2:8H2O	-16.6849
Sanidine_high	2.8816s/sat	ZnF2	-17.0448

Boehmite	2.6348s/sat	Natrosilite	-17.1798
Gibbsite	2.5380s/sat	CaAl2O4	-17.1978
Mordenite	1.9827s/sat	MnCl2:2H2O	-17.4939
Smectite-high-Fe	1.8589s/sat	CdF2	-17.4979
Corundum	1.8347s/sat	MgOHCl	-17.5534
Lawsonite	1.8281s/sat	Ningyoite	-17.6631
Witherite	1.3148s/sat	Na2SiO3	-17.8619
Albite_low	1.2846s/sat	UO2.3333(beta)	-17.9614
Albite	1.2845s/sat	CuCl2	-18.2058
Kyanite	0.9900s/sat	Ba2Si3O8	-18.5712
Andalusite	0.6821s/sat	Tremolite	-18.5909
Analcime	0.6217s/sat	CaAl4O7	-18.9408
Quartz	0.5914s/sat	MnCl2:H2O	-19.1767
Dawsonite	0.4022s/sat	Ferrite-Dicalciu	-19.3015
Tridymite	0.3911s/sat	UO2SO4	-19.3347
Barite	0.3313s/sat	Gehlenite	-19.5063
Chalcedony	0.3066s/sat	MgCl2:4H2O	-19.6273
Sillimanite	0.2901s/sat	Hillebrandite	-19.9018
Tenorite	0.2825s/sat	Dicalcium_silica	-20.3788
Malachite	0.2344s/sat	UOFOH:.5H2O	-20.6806
Strengite	0.0976s/sat	Hydromagnesite	-20.7662
Cristobalite(alp	0.0080s/sat	UO2(NO3)2:6H2O	-21.0805
Natrolite	-0.0692	Na2UO4(alpha)	-21.1686
Ice	-0.0850	UOFOH	-21.1894
Albite_high	-0.1306	Larnite	-21.7553
Coesite	-0.2566	Akermanite	-22.1649
Kalsilite	-0.3438	UO2Cl	-22.3631
Chamosite-7A	-0.3466	Scacchite	-22.5904
Cristobalite(bet	-0.4768	ZnCl2	-22.6273
Alunite	-0.5227	UO2(NO3)2:3H2O	-22.7303
Cerussite	-0.6325	Lime	-23.0754
Rhodochrosite	-0.7784	UOF2:H2O	-23.3757
SiO2(am)	-0.8136	(UO2)3(PO4)2	-23.6964
Jadeite	-0.9287	UO2(PO3)2	-23.7870
Hercynite	-0.9929	Hydrophilite	-23.8525
Calcite	-1.0365	Lawrencite	-23.8812
Brochantite	-1.0919	UOF2	-24.0261
Aragonite	-1.1816	UO2(NO3)2:2H2O	-24.0952
Wairakite	-1.3658	(UO2)2P2O7	-24.2072
Dolomite-ord	-1.4869	U(HPO4)2:4H2O	-25.3050
Dolomite	-1.4869	MgCl2:2H2O	-25.4576
Dioptase	-1.5130	UP2O7	-25.6390
Siderite	-1.7518	KAl(SO4)2	-25.8045
Monohydrocalcite	-1.8371	K2UO4	-25.8108
Prehnite	-1.9717	Anthophyllite	-25.8709
Annite	-2.1285	UO2Cl2:3H2O	-27.0142
Magnesite	-2.1689	Pb	-27.0422
Amesite-14A	-2.3712	Clinoptilolite-d	-27.0498
Clinozoisite	-2.3838	Clinoptilolite-d	-27.4133
Zoisite	-2.4319	UO2(NO3)2:H2O	-27.9267
Gypsum	-2.5475	Rankinite	-28.3522
Anhydrite	-2.8643	Pargasite	-28.8060
Berlinite	-3.0094	MgCl2:H2O	-29.0362
Daphnite-14A	-3.0210	UO2Cl2:H2O	-29.9665
Anorthite	-3.0426	Clinoptilolite-d	-30.4168
Nepheline	-3.0869	Ettringite	-31.1412
Dolomite-dis	-3.1387	UO2(NO3)2	-31.6083
Ferrosilite	-3.1471	Tobermorite-14A	-32.0936
Smithsonite	-3.2451	UF4:2.5H2O	-32.8176
Fluorite	-3.2654	UO2SO3	-33.1911
Alamosite	-3.3328	Ba2SiO4	-33.6865
Zn2SiO4	-3.3337	KMgCl3:2H2O	-33.8030
Bassanite	-3.5136	UO2Cl2	-34.0727

Sb2O3	-3.6565	Tobermorite-11A	-34.3274
CaSO4:0.5H2O(bet	-3.7001	Zn3O(SO4)2	-34.8752
Schoepite	-3.7066	Chloromagnesite	-35.1216
UO3:2H2O	-3.7066	Foshagite	-35.3740
UO2(OH)2(beta)	-3.8716	Merwinite	-35.4006
Schoepite-dehy(.	-3.9327	Al2(SO4)3:6H2O	-35.7729
UO3:.9H2O(alpha)	-3.9390	BaSiF6	-36.2070
Atacamite	-4.0006	Afwillite	-36.6216
Phlogopite	-4.0197	Cd	-36.9583
Schoepite-dehy(.	-4.0244	UF4	-37.3562
Schoepite-dehy(1	-4.0407	Fe	-37.4012
Anglesite	-4.0568	Tobermorite-9A	-38.1626
Saponite-Ca	-4.1107	Molysite	-39.0486
Saponite-Mg	-4.1841	Fe2(SO4)3	-40.7282
Minnesotaite	-4.1842	U(SO4)2:8H2O	-41.4045
Saponite-K	-4.2514	KMgCl3	-41.5674
Hydroxylapatite	-4.3039	BaO	-41.8308
CaUO4	-4.3206	U(SO4)2:4H2O	-42.7254
Whitlockite	-4.3262	U(SO4)2	-42.9794
Zincite	-4.3390	Ba2U2O7	-44.7571
Saponite-Na	-4.5045	C	-44.9919
Cuprite	-4.5486	UOCl2	-46.4224
Rhodonite	-4.6163	U(CO3)2	-46.5293
UO2CO3	-4.6383	Hatrurite	-47.3155
Rutherfordine	-4.6523	UClF3	-48.5028
Sellaite	-4.6573	Zn	-48.5629
Zn(OH)2(epsilon)	-4.7375	U5O12Cl	-49.6996
Saponite-H	-4.9334	Xonotlite	-51.2462
Zn(OH)2(beta)	-5.0216	UOF4	-53.5437
Azurite	-5.0483	Al2(SO4)3	-54.4862
Enstatite	-5.0719	Na3UO4	-57.0495
Wustite	-5.1352	(UO2)2Cl3	-57.6348
Talc	-5.1993	Na	-58.1163
Schoepite-dehy(.	-5.2118	UOCl3	-58.7584
Paralaurionite	-5.2124	UF3	-59.4035
Nesquehonite	-5.2775	Na4SiO4	-59.6109
CdSiO3	-5.2914	UF5(beta)	-60.1853
Bixbyite	-5.3554	UF5(alpha)	-60.5887
Nahcolite	-5.5044	Mn	-61.5690
Pyrolusite	-5.5103	Na2O	-61.7075
Lanarkite	-5.5491	Pb2Cl5NH4	-61.9315
Ripidolite-14A	-5.6618	UCl2F2	-61.9638
Niter	-5.7204	K	-62.2170
Schoepite-dehy(.	-5.7618	Ca4Al2Fe2O10	-64.0088
UO2HPO4:4H2O	-5.8660	Ca3Al2O6	-64.3608
FeO	-5.9584	UOCl	-64.5648
Greenalite	-6.0107	Covellite	-66.3551
Analcime-dehy	-6.0967	S	-67.5649
Fe(OH)2	-6.2402	Chalcocite	-68.7373
Daphnite-7A	-6.5255	U2O3F6	-69.8148
Brucite	-6.5994	Ba3UO6	-72.7219
Okenite	-6.7647	UCl3F	-75.2408
Mn(OH)2(am)	-6.7894	CdS	-75.6954
UO3(gamma)	-6.8429	Galena	-76.8007
Wollastonite	-6.9288	Sphalerite	-79.1840
Litharge	-7.0191	K2O	-79.7627
Chalcanthite	-7.0641	Wurtzite	-81.5989
Fayalite	-7.1373	U(SO3)2	-81.8483
Pseudowollastoni	-7.1939	CdCl2(NH3)2	-84.0325
Massicot	-7.2161	ZnCl2(NH3)2	-84.8687
NaFeO2	-7.2720	Troilite	-86.3262
Melanterite	-7.2738	UCl4	-86.3566
UO3(beta)	-7.4768	Pyrrhotite	-86.4301

Nantokite	-7.4987	Na6Si2O7	-86.7443
Cordierite_hydr	-7.5218	PbSO4(NH3)2	-86.9491
Mirabilite	-7.6389	Alabandite	-89.0150
Diopside	-7.6543	UCl3	-89.8928
Hausmannite	-7.7845	UF6	-91.9793
UO3(alpha)	-7.8307	U3O5F8	-93.2646
PbCO3.PbO	-7.9306	U2F9	-94.2487
Clinochlore-14A	-7.9351	Mg	-102.0075
Sylvite	-7.9552	U2O2Cl5	-106.4670
Spinel	-8.0569	UCl5	-107.2916
PbFCl	-8.1152	BaS	-107.3176
Cd(OH)2	-8.1311	UN1.73(alpha)	-108.5115
FeF3	-8.1575	UN1.59(alpha)	-111.3506
Arcanite	-8.1808	P	-119.1270
UO2FOH:2H2O	-8.2810	Ca	-119.4719
Hedenbergite	-8.3890	Antigorite	-119.9565
Chrysotile	-8.4042	Al	-122.5509
Halite	-8.4240	Ba	-123.6820
Cu	-8.4943	UN	-124.8551
ZnSO4:7H2O	-8.6183	UCl6	-127.0148
Cd(OH)Cl	-8.7144	Si	-127.4112
UO2FOH:H2O	-8.7370	Pb(N3)2(orth)	-142.5498
Sanbornite	-8.7998	Pyrite	-142.9572
AlF3	-8.8116	Pb(N3)2(mono)	-143.0062
Saleeite	-8.8384	Chalcopyrite	-146.4809
ZnSO4:6H2O	-8.9230	ZnCl2(NH3)4	-162.1114
Thenardite	-9.1177	CdCl2(NH3)4	-163.0509
Ripidolite-7A	-9.1583	PbSO4(NH3)4	-167.6436
Huntite	-9.2192	U4F17	-168.0511
Ca-Al_Pyroxene	-9.2569	U	-173.3167
UO2FOH	-9.2619	US	-181.8316
Nitrobarite	-9.3433	Zn(ClO4)2:6H2O	-184.1124
Tephroite	-9.4263	UC	-200.1224
BaUO4	-9.4641	UH3(beta)	-203.0792
Manganosite	-9.6083	US1.9	-207.9627
Artinite	-9.6158	US2	-212.9154
Monteponite	-9.6278	Mayenite	-238.6686
UO2.25	-9.8039	ZnCl2(NH3)6	-241.0863
(UO2)3(PO4)2:4H2	-9.8150	CdCl2(NH3)6	-242.1634
UO2.25(beta)	-9.8724	UP	-243.4900
Torbernite	-10.0297	UC1.94(alpha)	-244.5394
Pb2SiO4	-10.0904	Stibnite	-252.9960
Cordierite_anhyd	-10.1525	US3	-277.1565
CdSO4:2.667H2O	-10.2190	Pb(SCN)2	-282.4818
Phosgenite	-10.2618	Bornite	-283.6417
ZnSO4:H2O	-10.4262	UP2	-357.3001
CdSO4:H2O	-10.4734	U2S3	-387.4864
Uranocircite	-10.4898	o-Phthalic_acid	-396.7500
Natron	-10.5542	U2C3	-446.8323
Grossular	-10.8156	U3S5	-595.5970
Pb3SO6	-10.9216	U3P4	-844.2789

Gases	fugacity	log fug.
N2(g)	0.1690	-0.772
H2O(g)	0.01061	-1.974
CO2(g)	0.003611	-2.442
NO2(g)	8.919e-012	-11.050
HF(g)	1.084e-014	-13.965
HCl(g)	5.792e-019	-18.237
H2(g)	8.575e-030	-29.067
O2(g)	1.023e-030	-29.990
NO(g)	5.533e-032	-31.257

CO(g)	1.032e-035	-34.986
SiF4(g)	9.321e-039	-38.031
NH3(g)	1.988e-041	-40.702
SO2(g)	4.360e-043	-42.361
Cl2(g)	3.874e-043	-42.412
Cd(g)	3.437e-052	-51.464
Pb(g)	6.741e-058	-57.171
UO2F2(g)	2.179e-061	-60.662
Cu(g)	2.537e-064	-63.596
Zn(g)	4.906e-067	-66.309
UO2Cl2(g)	5.216e-073	-72.283
Na(g)	2.919e-073	-72.535
K(g)	2.592e-074	-73.586
UO3(g)	1.551e-074	-73.809
UOF4(g)	2.123e-075	-74.673
UF5(g)	5.523e-082	-81.258
UF4(g)	1.258e-084	-83.900
H2S(g)	2.681e-091	-90.572
UF6(g)	5.799e-094	-93.237
CH4(g)	2.597e-094	-93.586
F2(g)	7.310e-101	-100.136
UCl4(g)	2.888e-113	-112.539
UO2(g)	1.454e-115	-114.838
Mg(g)	1.016e-123	-122.993
UCl5(g)	1.311e-126	-125.883
UF3(g)	1.065e-130	-129.972
UCl6(g)	2.512e-134	-133.600
U2F10(g)	1.984e-136	-135.703
UCl3(g)	4.118e-139	-138.385
Ca(g)	5.737e-147	-146.241
S2(g)	7.113e-151	-150.148
C2H4(g)	3.077e-161	-160.512
C(g)	1.387e-169	-168.858
UF2(g)	2.114e-173	-172.675
Al(g)	7.644e-177	-176.117
UCl2(g)	4.857e-183	-182.314
UO(g)	1.238e-189	-188.907
Si(g)	4.080e-203	-202.389
UF(g)	2.622e-209	-208.581
U2Cl8(g)	2.033e-214	-213.692
U2Cl10(g)	2.060e-224	-223.686
UCl(g)	1.993e-224	-223.700
U(g)	2.784e-264	-263.555

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Al+++	1.45e-006	1.45e-006	0.0391			
Ba++	7.19e-007	7.19e-007	0.0988			
Ca++	0.000537	0.000537	21.5			
Cd++	7.83e-009	7.83e-009	0.000880			
Cl-	0.000110	0.000110	3.91			
Cu++	1.05e-006	1.05e-006	0.0665			
F-	1.03e-005	1.03e-005	0.196			
Fe++	1.05e-006	1.05e-006	0.0587			
H+	0.000187	0.000187	0.188			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00164	0.00164	99.7			
HPO4--	2.31e-006	2.31e-006	0.221			
K+	0.000550	0.000550	21.5			
Mg++	0.000161	0.000161	3.91			
Mn++	8.10e-006	8.10e-006	0.445			
NH3(aq)	0.000283	0.000283	4.82			

NO3-	0.00117	0.00117	72.7
Na+	0.00136	0.00136	31.3
O2(aq)	0.000212	0.000212	6.80
Pb++	5.19e-009	5.19e-009	0.00108
S2--	7.63e-007	7.63e-007	0.0489
SO4--	0.000316	0.000316	30.3
Sb(OH)3(aq)	2.57e-007	2.57e-007	0.0444
SiO2(aq)	0.000179	0.000179	10.8
UO2++	8.22e-009	8.22e-009	0.00222
Zn++	1.50e-007	1.50e-007	0.00978

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Aluminum	1.450e-006	1.450e-006	0.03911		
Antimony	2.571e-007	2.571e-007	0.03129		
Barium	7.194e-007	7.194e-007	0.09876		
Cadmium	7.831e-009	7.831e-009	0.0008801		
Calcium	0.0005369	0.0005369	21.51		
Carbon	0.001635	0.001635	19.63		
Chlorine	0.0001104	0.0001104	3.911		
Copper	1.047e-006	1.047e-006	0.06649		
Fluorine	1.030e-005	1.030e-005	0.1956		
Hydrogen	111.0	111.0	1.119e+005		
Iron	1.051e-006	1.051e-006	0.05867		
Lead	5.193e-009	5.193e-009	0.001076		
Magnesium	0.0001610	0.0001610	3.911		
Manganese	8.101e-006	8.101e-006	0.4449		
Nitrogen	0.001456	0.001456	20.39		
Oxygen	55.52	55.52	8.880e+005		
Phosphorus	2.305e-006	2.305e-006	0.07138		
Potassium	0.0005504	0.0005504	21.51		
Silicon	0.0001791	0.0001791	5.028		
Sodium	0.001361	0.001361	31.29		
Sulfur	0.0003172	0.0003172	10.17		
Uranium	8.219e-009	8.219e-009	0.001956		
Zinc	1.496e-007	1.496e-007	0.009778		

```
Temperature =  10.3 C    Pressure =  1.013 bars
pH =  7.700              log fO2 =  -26.089
Eh =   0.4320 volts      pe =   7.6810
Ionic strength      =    0.007290
Charge imbalance    =    0.000189 eq/kg (3.77% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000427 kg
Solution density    =    1.023    g/cm3
Chlorinity          =    0.000110 molal
Dissolved solids    =         427 mg/kg sol'n
Hardness            =      198.19 mg/kg sol'n as CaCO3
  carbonate         =      128.90 mg/kg sol'n as CaCO3
  non-carbonate     =       69.30 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=      128.90 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.4320	7.6810

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.002517	153.5	0.9160	-2.6372
Ca++	0.001584	63.44	0.7146	-2.9463
NO3-	0.001543	95.63	0.9139	-2.8508
Na+	0.001101	25.31	0.9160	-2.9962
SO4--	0.0003711	35.64	0.7026	-3.5837
Mg++	0.0003047	7.401	0.7257	-3.6555
K+	0.0001997	7.804	0.9139	-3.7387
SiO2(aq)	0.0001897	11.39	1.0000	-3.7220
CO2(aq)	0.0001345	5.918	1.0000	-3.8712
Cl-	0.0001103	3.908	0.9139	-3.9966
CaSO4(aq)	3.560e-005	4.844	1.0000	-4.4486
CaHCO3+	3.300e-005	3.335	0.9160	-4.5196
MgSO4(aq)	1.023e-005	1.231	1.0000	-4.9900
CaCO3(aq)	6.785e-006	0.6788	1.0000	-5.1685
MgHCO3+	6.250e-006	0.5330	0.9160	-5.2422
CO3--	5.327e-006	0.3195	0.7057	-5.4249
F-	5.095e-006	0.09675	0.9150	-5.3315
NaHCO3(aq)	4.435e-006	0.3724	1.0000	-5.3531
Ba++	9.604e-007	0.1318	0.7087	-6.1670
HSiO3-	7.167e-007	0.05523	0.9160	-6.1828
MgCO3(aq)	6.879e-007	0.05798	1.0000	-6.1625
KSO4-	3.904e-007	0.05275	0.9160	-6.4466
OH-	1.637e-007	0.002782	0.9150	-6.8246
Cu++	1.077e-007	0.006842	0.7146	-7.1136
NaHSiO3(aq)	4.111e-008	0.004113	1.0000	-7.3860
CaF+	2.613e-008	0.001543	0.9160	-7.6209
MgF+	2.590e-008	0.001121	0.9160	-7.6248
CaCl+	2.533e-008	0.001913	0.9160	-7.6344
H+	2.157e-008	2.173e-005	0.9251	-7.7000
NaCO3-	2.041e-008	0.001693	0.9160	-7.7283
MgCl+	1.944e-008	0.001161	0.9160	-7.7494
NaCl(aq)	1.572e-008	0.0009184	1.0000	-7.8035
UO2(CO3)3----	1.278e-009	0.0005749	0.2433	-9.5074
BaCO3(aq)	8.312e-010	0.0001640	1.0000	-9.0803
UO2(CO3)2--	7.655e-010	0.0002985	0.7026	-9.2693
KCl(aq)	4.417e-010	3.291e-005	1.0000	-9.3549

NaF(aq)	4.196e-010	1.761e-005	1.0000	-9.3772
HSO4-	3.767e-010	3.655e-005	0.9160	-9.4621
HF(aq)	1.062e-010	2.124e-006	1.0000	-9.9739
NaOH(aq)	2.659e-011	1.063e-006	1.0000	-10.5752
BaCl+	1.966e-011	3.396e-006	0.9160	-10.7444
UO2CO3(aq)	1.042e-011	3.438e-006	1.0000	-10.9820
CaCl2(aq)	3.238e-012	3.592e-007	1.0000	-11.4897
BaF+	1.971e-012	3.080e-007	0.9160	-11.7434
HNO3(aq)	1.018e-012	6.414e-008	1.0000	-11.9921
Cu+	5.610e-013	3.563e-008	0.9160	-12.2892
HCl(aq)	4.273e-013	1.557e-008	1.0000	-12.3693
UO2OH+	8.267e-014	2.372e-008	0.9160	-13.1208
KHSO4(aq)	3.646e-015	4.963e-010	1.0000	-14.4382
UO2++	8.660e-016	2.337e-010	0.7057	-15.2138
UO2F+	3.459e-016	9.994e-011	0.9160	-15.4991
UO2SO4(aq)	1.296e-016	4.742e-011	1.0000	-15.8875
HF2-	1.108e-016	4.321e-012	0.9160	-15.9934
UO2F2(aq)	4.649e-018	1.431e-012	1.0000	-17.3327
UO2(SO4)2--	2.955e-019	1.365e-013	0.7026	-18.6826
UO2Cl+	8.382e-020	2.560e-014	0.9160	-19.1147
UO2F3-	4.058e-021	1.327e-015	0.9160	-20.4297
(UO2)2(OH)2++	1.353e-021	7.763e-016	0.7057	-21.0201
UO2+	3.202e-022	8.643e-017	0.9160	-21.5327
(UO2)3(CO3)6(6-)	7.126e-023	8.335e-017	0.0415	-23.5288
(UO2)3(OH)5+	2.451e-024	2.193e-018	0.9160	-23.6488
UO2Cl2(aq)	3.461e-025	1.180e-019	1.0000	-24.4607
UO2F4--	1.519e-025	5.252e-020	0.7026	-24.9719
U(OH)4(aq)	1.533e-026	4.689e-021	1.0000	-25.8145
O2(aq)	1.390e-029	4.446e-025	1.0000	-28.8570
Formate	4.727e-034	2.127e-029	0.9150	-33.3640
ClO-	7.832e-035	4.028e-030	0.9160	-34.1442
H2(aq)	6.751e-035	1.360e-031	1.0000	-34.1706
Ca(For)+	1.602e-035	1.363e-030	0.9160	-34.8334
Mg(For)+	3.793e-036	2.629e-031	0.9160	-35.4591
HO2-	6.008e-037	1.982e-032	0.9160	-36.2593
Na(For)(aq)	5.182e-037	3.522e-032	1.0000	-36.2855
K(For)(aq)	8.135e-038	6.840e-033	1.0000	-37.0897
Formic_acid(aq)	5.084e-038	2.339e-033	1.0000	-37.2938
SO3--	8.638e-039	6.913e-034	0.7057	-38.2150
Ba(For)+	7.305e-039	1.331e-033	0.9160	-38.1745
Cu(For)+	4.536e-039	4.923e-034	0.9160	-38.3814
HSO3-	1.883e-039	1.526e-034	0.9160	-38.7632
SiF6--	4.712e-040	6.692e-035	0.7026	-39.4800
CO(aq)	8.307e-041	2.326e-036	1.0000	-40.0806
Oxalate	2.757e-041	2.426e-036	0.7026	-40.7128
U(CO3)5(6-)	1.336e-043	7.183e-038	0.0415	-44.2560
H-Oxalate	6.963e-045	6.196e-040	0.9160	-44.1953
HSO5-	6.191e-045	6.997e-040	0.9160	-44.2464
UOH+++	5.017e-045	1.279e-039	0.4605	-44.6363
SO2(aq)	1.857e-045	1.189e-040	1.0000	-44.7312
UF2++	2.179e-046	6.013e-041	0.7057	-45.8130
UF3+	1.580e-046	4.660e-041	0.9160	-45.8394
UF+++	8.970e-048	2.305e-042	0.4605	-47.3839
UF4(aq)	7.106e-048	2.230e-042	1.0000	-47.1484
USO4++	4.622e-049	1.544e-043	0.7057	-48.4865
U(SO4)2(aq)	3.684e-049	1.584e-043	1.0000	-48.4337
Oxalic_acid(aq)	2.310e-051	2.079e-046	1.0000	-50.6364
U++++	1.724e-051	4.102e-046	0.2561	-51.3551
UCl+++	7.533e-054	2.059e-048	0.4605	-53.4598
ClO2-	1.062e-057	7.157e-053	0.9160	-57.0122
S2O8--	8.396e-062	1.612e-056	0.7026	-61.2292
S2O6--	2.493e-063	3.990e-058	0.7026	-62.7566
ClO3-	5.345e-066	4.459e-061	0.9150	-65.3106

Ca(For)2(aq)	5.627e-068	7.319e-063	1.0000	-67.2497
Mg(For)2(aq)	1.659e-068	1.896e-063	1.0000	-67.7801
U+++	6.909e-070	1.644e-064	0.4605	-69.4974
Na(For)2-	1.766e-070	1.996e-065	0.9160	-69.7910
Cu(For)2(aq)	5.294e-071	8.128e-066	1.0000	-70.2762
K(For)2-	2.322e-071	2.997e-066	0.9160	-70.6722
Ba(For)2(aq)	1.936e-071	4.400e-066	1.0000	-70.7130
Formaldehyde(aq)	1.324e-073	3.974e-069	1.0000	-72.8780
ClO4-	1.039e-078	1.032e-073	0.9150	-78.0222
UO2ClO3+	1.114e-080	3.935e-075	0.9160	-79.9914
S2O5--	6.781e-083	9.770e-078	0.7026	-82.3220
Methanol(aq)	3.999e-092	1.281e-087	1.0000	-91.3981
Glycolate	4.989e-098	3.742e-093	0.9160	-97.3401
Ca(Glyc)+	2.948e-099	3.393e-094	0.9160	-98.5685
Mg(Glyc)+	2.670e-100	2.651e-095	0.9160	-99.6117
HS-	1.970e-100	6.513e-096	0.9150	-99.7441
H2S(aq)	5.984e-101	2.039e-096	1.0000	-100.2230
Na(Glyc)(aq)	5.597e-101	5.484e-096	1.0000	-100.2521
K(Glyc)(aq)	8.787e-102	1.003e-096	1.0000	-101.0562
Glycolic_acid(aq	6.521e-102	4.957e-097	1.0000	-101.1857
Cu(Glyc)+	4.446e-102	6.159e-097	0.9160	-101.3902
Ba(Glyc)+	3.583e-103	7.606e-098	0.9160	-102.4839
S2O4--	3.477e-105	4.454e-100	0.7087	-104.6083
Methane(aq)	2.720e-105	4.362e-101	1.0000	-104.5654
S--	5.315e-106	1.704e-101	0.7087	-105.4240
S2O3--	1.084e-106	1.215e-101	0.7026	-106.1181
Acetate	1.439e-110	8.492e-106	0.9170	-109.8796
CaCH3COO+	1.467e-112	1.454e-107	0.9160	-111.8716
MgCH3COO+	7.869e-113	6.556e-108	0.9160	-112.1422
Acetic_acid(aq)	1.532e-113	9.195e-109	1.0000	-112.8148
NaCH3COO(aq)	1.115e-113	9.143e-109	1.0000	-112.9527
KCH3COO(aq)	1.243e-114	1.219e-109	1.0000	-113.9055
CuCH3COO+	2.603e-115	3.189e-110	0.9160	-114.6227
BaCH3COO+	8.825e-116	1.732e-110	0.9160	-115.0924
Malonate	3.471e-119	3.540e-114	0.7026	-118.6128
H-Malonate	2.489e-121	2.564e-116	0.9160	-120.6421
CuCH3COO(aq)	1.682e-122	2.061e-117	1.0000	-121.7743
Malonic_acid(aq)	3.348e-126	3.482e-121	1.0000	-125.4752
S3O6--	3.468e-139	6.662e-134	0.7026	-138.6132
Acetaldehyde(aq)	6.281e-148	2.766e-143	1.0000	-147.2020
Ethyne(aq)	3.534e-170	9.197e-166	1.0000	-169.4518
Ethanol(aq)	4.127e-171	1.900e-166	1.0000	-170.3844
Ethylene(aq)	6.606e-176	1.852e-171	1.0000	-175.1801
Lactate	5.606e-177	4.991e-172	0.9160	-176.2894
Ca(Lac)+	1.948e-178	2.514e-173	0.9160	-177.7486
Mg(Lac)+	3.018e-179	3.420e-174	0.9160	-178.5584
Na(Lac)(aq)	6.422e-180	7.193e-175	1.0000	-179.1924
K(Lac)(aq)	1.008e-180	1.292e-175	1.0000	-179.9964
Lactic_acid(aq)	7.685e-181	6.920e-176	1.0000	-180.1143
Cu(Lac)+	2.290e-181	3.494e-176	0.9160	-180.6782
Ba(Lac)+	1.662e-182	3.761e-177	0.9160	-181.8175
Ethane(aq)	1.216e-188	3.654e-184	1.0000	-187.9152
Propanoate	1.025e-191	7.486e-187	0.9160	-191.0274
Ca(Prop)+	5.821e-194	6.584e-189	0.9160	-193.2731
Mg(Prop)+	1.517e-194	1.477e-189	0.9160	-193.8571
Propanoic_acid(a	1.465e-194	1.085e-189	1.0000	-193.8340
Na(Prop)(aq)	1.158e-194	1.112e-189	1.0000	-193.9364
Ca(Glyc)2(aq)	2.697e-195	5.126e-190	1.0000	-194.5691
K(Prop)(aq)	1.818e-195	2.038e-190	1.0000	-194.7405
Cu(Prop)+	1.815e-196	2.478e-191	0.9160	-195.7792
Mg(Glyc)2(aq)	1.494e-196	2.605e-191	1.0000	-195.8256
Cu(Glyc)2(aq)	1.637e-197	3.496e-192	1.0000	-196.7859
Ba(Prop)+	8.296e-198	1.745e-192	0.9160	-197.1192

Na(Glyc)2-	3.148e-198	5.446e-193	0.9160	-197.5401
S4O6--	1.366e-198	3.063e-193	0.7026	-198.0178
Succinate	1.017e-198	1.180e-193	0.7026	-198.1460
K(Glyc)2-	4.247e-199	8.032e-194	0.9160	-198.4100
Ba(Glyc)2(aq)	7.677e-200	2.205e-194	1.0000	-199.1148
H-Succinate	6.938e-201	8.120e-196	0.9160	-200.1968
Succinic_acid(aq	2.242e-204	2.647e-199	1.0000	-203.6493
Ca(CH3COO)2(aq)	3.678e-221	5.815e-216	1.0000	-220.4344
Mg(CH3COO)2(aq)	8.398e-222	1.195e-216	1.0000	-221.0758
Cu(CH3COO)2(aq)	1.184e-223	2.149e-218	1.0000	-222.9267
Na(CH3COO)2-	9.273e-224	1.308e-218	0.9160	-223.0709
Acetone(aq)	4.123e-224	2.394e-219	1.0000	-223.3848
K(CH3COO)2-	6.785e-225	1.066e-219	0.9160	-224.2066
Ba(CH3COO)2(aq)	3.491e-225	8.914e-220	1.0000	-224.4570
Propanal(aq)	1.657e-228	9.617e-224	1.0000	-227.7808
Cu(CH3COO)2-	3.444e-232	6.252e-227	0.9160	-231.5011
1-Propyne(aq)	4.296e-247	1.721e-242	1.0000	-246.3669
1-Propanol(aq)	3.356e-252	2.016e-247	1.0000	-251.4741
S3--	1.482e-252	1.425e-247	0.7026	-251.9823
1-Propene(aq)	9.668e-255	4.067e-250	1.0000	-254.0146
2-Hydroxybutanoa	1.631e-258	1.681e-253	0.9160	-257.8256
2-Hydroxybutanoi	1.980e-262	2.060e-257	1.0000	-261.7034
Propane(aq)	3.950e-270	1.741e-265	1.0000	-269.4034
Butanoate	2.356e-273	2.051e-268	0.9160	-272.6660
Ca(But)+	9.173e-276	1.166e-270	0.9160	-275.0756
Butanoic_acid(aq	2.694e-276	2.373e-271	1.0000	-275.5695
Na(But)(aq)	2.561e-276	2.818e-271	1.0000	-275.5916
Mg(But)+	2.279e-276	2.538e-271	0.9160	-275.6804
K(But)(aq)	4.021e-277	5.072e-272	1.0000	-276.3957
Cu(But)+	3.302e-278	4.972e-273	0.9160	-277.5193
Glutarate	1.963e-279	2.553e-274	0.7026	-278.8603
Ba(But)+	1.275e-279	2.860e-274	0.9160	-278.9326
H-Glutarate	7.797e-282	1.022e-276	0.9160	-281.1462
Glutaric_acid(aq	3.194e-285	4.218e-280	1.0000	-284.4957
Ethylacetate(aq)	1.916e-285	1.687e-280	1.0000	-284.7176
S5O6--	7.947e-288	2.036e-282	0.7026	-287.2530
Butanal(aq)	1.314e-311	9.473e-307	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7026	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
Dodecanoate	0.0000	0.0000	0.9160	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9160	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9160	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)+	0.0000	0.0000	0.9160	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9160	-300.0000
Cu(Pent)+	0.0000	0.0000	0.9160	-300.0000
Ba(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9160	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9160	-300.0000

Na(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Lac)2-	0.0000	0.0000	0.9160	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9160	-300.0000
Cu(CH3COO)3-	0.0000	0.0000	0.9160	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9160	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9160	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)+	0.0000	0.0000	0.9160	-300.0000
Mg(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9160	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanoate	0.0000	0.0000	0.9160	-300.0000
Pentanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butanol(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.7026	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9160	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9160	-300.0000
K(Pent)(aq)	0.0000	0.0000	1.0000	-300.0000
K(Lac)2-	0.0000	0.0000	0.9160	-300.0000
Adipate	0.0000	0.0000	0.7026	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9160	-300.0000
Ca(Pent)+	0.0000	0.0000	0.9160	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9160	-300.0000
Ca(Lac)2(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9160	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9160	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9160	-300.0000
o-Phthalate	0.0000	0.0000	0.7026	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butyne(aq)	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000

n-Butane(aq)	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9160	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxypentano	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9160	-300.0000
H-Sebacate	0.0000	0.0000	0.9160	-300.0000
H-Pimelate	0.0000	0.0000	0.9160	-300.0000
2-Hydroxypentano	0.0000	0.0000	0.9160	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
H-Azelate	0.0000	0.0000	0.9160	-300.0000
H-Adipate	0.0000	0.0000	0.9160	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Suberate	0.0000	0.0000	0.7026	-300.0000
m-Toluate	0.0000	0.0000	0.9160	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9160	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7026	-300.0000
Benzoate	0.0000	0.0000	0.9199	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7026	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
S4--	0.0000	0.0000	0.7026	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9160	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butene(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Witherite	2.0534s/sat	UO2SO4:2.5H2O	-17.6267
Quartz	0.6298s/sat	UO2SO4:3H2O	-17.7038
Barite	0.4980s/sat	Dicalcium_silica	-17.9168
Dolomite-ord	0.4931s/sat	NaUO3	-17.9812
Dolomite	0.4930s/sat	Anthophyllite	-18.3401
Tridymite	0.4295s/sat	UO2F2:3H2O	-18.6222
Chalcedony	0.3445s/sat	Akermanite	-18.6315
Calcite	0.0480s/sat	UO2F2	-18.9482
Cristobalite(alp	0.0451s/sat	CuCl2	-19.2559
Tenorite	0.0429s/sat	Larnite	-19.2965
Ice	-0.0831	MgCl2:4H2O	-19.3904
Aragonite	-0.0971	UO2SO4	-21.4904
Coesite	-0.2197	Lime	-21.8870
Malachite	-0.3882	Na2UO4(alpha)	-22.0171
Cristobalite(bet	-0.4413	UO2(NO3)2:6H2O	-23.0428
Monohydrocalcite	-0.7516	Hydrophilite	-23.4414
SiO2(am)	-0.7799	UO2.3333(beta)	-23.4549
Dolomite-dis	-1.1629	Rankinite	-24.6372
Magnesite	-1.2770	UO2(NO3)2:3H2O	-24.7023
Dioptase	-1.7122	UOFOH:.5H2O	-24.8044
Talc	-1.9364	UO2Cl	-25.1909
Gypsum	-2.0304	MgCl2:2H2O	-25.2366

Anhydrite	-2.3526	UOFOH	-25.3152
Brochantite	-2.7568	Tobermorite-14A	-25.7389
Bassanite	-3.0021	UO2(NO3)2:2H2O	-26.0724
CaSO4:0.5H2O(bet	-3.1893	K2UO4	-27.3583
Fluorite	-3.4288	Tobermorite-11A	-27.9904
Enstatite	-4.0046	UOF2:H2O	-28.1991
Nesquehonite	-4.3929	MgCl2:H2O	-28.8244
CaUO4	-4.5015	UOF2	-28.8530
Sellaite	-5.0154	UO2Cl2:3H2O	-29.2379
UO3:2H2O	-5.1147	UO2(NO3)2:H2O	-29.9148
Schoepite	-5.1148	Foshagite	-30.3973
Chrysotile	-5.2194	Merwinite	-30.6608
UO2(OH)2(beta)	-5.2817	Tobermorite-9A	-31.8398
Diopside	-5.3227	Ba2SiO4	-31.9514
Schoepite-dehy(.	-5.3424	UO2Cl2:H2O	-32.2008
UO3:.9H2O(alpha)	-5.3496	Afwillite	-32.9119
Nahcolite	-5.3592	UO2(NO3)2	-33.6054
Schoepite-dehy(.	-5.4351	KMgCl3:2H2O	-34.0336
Schoepite-dehy(1	-5.4519	Chloromagnesite	-34.9231
Huntite	-5.4630	UO2Cl2	-36.3164
Okenite	-5.4635	UO2SO3	-37.3609
Brucite	-5.5692	UF4:2.5H2O	-39.0437
Wollastonite	-5.6731	BaSiF6	-39.5187
Atacamite	-5.7339	BaO	-41.0286
Pseudowollastoni	-5.9393	KMgCl3	-41.8165
Niter	-6.0451	UF4	-43.5967
Azurite	-6.0656	Hatrurite	-43.6729
UO2CO3	-6.1975	Xonotlite	-43.7243
Rutherfordine	-6.2109	U(SO4)2:8H2O	-46.2827
Schoepite-dehy(.	-6.6256	U(SO4)2:4H2O	-47.6144
Sepiolite	-6.9297	U(SO4)2	-47.8773
Cuprite	-7.0265	Ba2U2O7	-47.8784
Schoepite-dehy(.	-7.1768	C	-49.1926
Artinite	-7.6853	U(CO3)2	-50.3008
Mirabilite	-7.7511	UOCl2	-50.6764
Sanbornite	-7.8617	UClF3	-54.4591
Chalcanthite	-8.0182	UOF4	-57.8305
UO3(gamma)	-8.2611	Na4SiO4	-58.4929
Sylvite	-8.4051	Na3UO4	-58.6604
Halite	-8.5299	Na	-58.9220
UO3(beta)	-8.8963	Na2O	-61.2262
Arcanite	-9.0054	U5O12Cl	-62.1767
Nitrobarite	-9.0125	UOCl3	-62.4290
Nantokite	-9.1361	(UO2)2Cl3	-62.7097
UO3(alpha)	-9.2512	K	-63.3755
Thenardite	-9.2538	UF3	-65.9835
Gyrolite	-9.7760	UF5(beta)	-66.1695
Forsterite	-9.9137	UF5(alpha)	-66.5756
BaUO4	-10.0062	UCl2F2	-67.6359
Natron	-10.0984	Antigorite	-68.9036
UO2FOH:2H2O	-10.3916	UOCl	-69.4584
Mg1.25SO4(OH)0.5	-10.4107	Ba3UO6	-71.6243
Tremolite	-10.6614	S	-74.3666
Na2CO3:7H2O	-10.6626	Covellite	-75.3824
Cu	-10.7378	U2O3F6	-76.9268
Monticellite	-10.8371	Chalcocite	-79.9986
UO2FOH:H2O	-10.8505	K2O	-80.0044
Periclase	-10.9572	UCl3F	-80.6284
Portlandite	-11.2761	Na6Si2O7	-85.0470
UO2FOH	-11.3786	U(SO3)2	-90.7931
Mg1.5SO4(OH)	-11.7302	UCl4	-91.4600
Thermonatrite	-12.1371	UCl3	-95.6084
Na2CO3	-12.4651	UF6	-97.7257

UO2.25	-12.7179	Mg	-103.1465
UO2.25(beta)	-12.7866	U3O5F8	-103.2144
MgUO4	-12.8880	U2F9	-106.4670
MgSO4	-12.9041	UCl5	-111.8288
UO2SO4:H2O	-13.0997	U2O2Cl5	-114.3955
UO2ClOH:2H2O	-14.1266	BaS	-115.2994
BaU2O7	-14.1467	Ca	-120.4510
BaCl2:2H2O	-14.2263	Ba	-125.0194
Chalcocyanite	-14.2533	UCl6	-130.9834
Na2U2O7	-14.3911	Si	-131.5851
BaCl2:H2O	-14.9627	U	-181.0049
Ba(OH)2:8H2O	-15.8132	U4F17	-192.7485
Hydromagnesite	-16.1727	US	-196.2116
UO2.6667	-16.3275	UC	-211.9779
Uraninite	-16.4380	UH3(beta)	-213.7985
BaCl2	-16.5162	US1.9	-228.4001
Natrosilite	-16.5418	US2	-234.0294
Coffinite	-16.6493	UC1.94(alpha)	-260.3479
Ba2Si3O8	-16.7335	US3	-305.0657
MgOHCl	-16.9336	U2S3	-422.9679
Na2SiO3	-17.2617	o-Phthalic_acid	-428.4317
Hillebrandite	-17.4350	U2C3	-474.7483
UO2SO4:3.5H2O	-17.5636	U3S5	-652.1820

Gases	fugacity	log fug.
H2O(g)	0.01025	-1.989
CO2(g)	0.002470	-2.607
NO2(g)	4.631e-013	-12.334
HF(g)	2.007e-015	-14.697
HCl(g)	2.134e-019	-18.671
O2(g)	8.152e-027	-26.089
H2(g)	7.670e-032	-31.115
CO(g)	6.332e-038	-37.198
SiF4(g)	1.386e-041	-40.858
Cl2(g)	5.082e-042	-41.294
SO2(g)	6.926e-046	-45.159
UO2F2(g)	2.572e-064	-63.590
Cu(g)	1.109e-066	-65.955
Na(g)	4.189e-074	-73.378
UO2Cl2(g)	2.403e-075	-74.619
K(g)	1.675e-075	-74.776
UO3(g)	4.240e-076	-75.373
UOF4(g)	9.665e-080	-79.015
UF5(g)	4.998e-088	-87.301
UF4(g)	5.652e-091	-90.248
UF6(g)	9.998e-100	-99.000
H2S(g)	3.847e-100	-99.415
F2(g)	1.819e-100	-99.740
CH4(g)	1.387e-102	-101.858
UCl4(g)	1.943e-118	-117.711
UO2(g)	3.458e-119	-118.461
Mg(g)	6.551e-125	-124.184
UCl5(g)	3.363e-131	-130.473
UF3(g)	1.972e-137	-136.705
UCl6(g)	2.538e-138	-137.596
UCl3(g)	6.131e-145	-144.212
Ca(g)	5.213e-148	-147.283
U2F10(g)	1.902e-148	-147.721
S2(g)	1.603e-164	-163.795
C2H4(g)	9.370e-174	-173.028
C(g)	4.957e-174	-173.305
UF2(g)	1.640e-180	-179.785

UCl2(g)	1.487e-189	-188.828
UO(g)	2.213e-195	-194.655
Si(g)	1.914e-207	-206.718
UF(g)	8.846e-217	-216.053
U2Cl8(g)	1.007e-224	-223.997
UCl(g)	1.277e-231	-230.894
U2Cl10(g)	1.590e-233	-232.799
U(g)	3.754e-272	-271.426

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ba++	9.61e-007	9.61e-007	0.132			
Ca++	0.00166	0.00166	66.5			
Cl-	0.000110	0.000110	3.91			
Cu++	1.08e-007	1.08e-007	0.00684			
F-	5.15e-006	5.15e-006	0.0977			
H+	0.000121	0.000121	0.122			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00271	0.00271	165.			
K+	0.000200	0.000200	7.82			
Mg++	0.000322	0.000322	7.82			
NO3-	0.00154	0.00154	95.6			
Na+	0.00111	0.00111	25.4			
O2(aq)	-5.21e-009	-5.21e-009	-0.000167			
SO4--	0.000417	0.000417	40.1			
SiO2(aq)	0.000190	0.000190	11.4			
UO2++	2.05e-009	2.05e-009	0.000554			

		In fluid		Sorbed	
Elemental composition	total moles	moles	mg/kg	moles	mg/kg
Barium	9.613e-007	9.613e-007	0.1320		
Calcium	0.001659	0.001659	66.47		
Carbon	0.002708	0.002708	32.52		
Chlorine	0.0001103	0.0001103	3.910		
Copper	1.077e-007	1.077e-007	0.006842		
Fluorine	5.147e-006	5.147e-006	0.09775		
Hydrogen	111.0	111.0	1.118e+005		
Magnesium	0.0003219	0.0003219	7.820		
Nitrogen	0.001543	0.001543	21.60		
Oxygen	55.52	55.52	8.880e+005		
Potassium	0.0002001	0.0002001	7.820		
Silicon	0.0001904	0.0001904	5.346		
Sodium	0.001106	0.001106	25.41		
Sulfur	0.0004174	0.0004174	13.38		
Uranium	2.054e-009	2.054e-009	0.0004887		

```
Temperature =  10.2 C    Pressure =  1.013 bars
pH =  7.600              log fO2 =  -32.704
Eh =   0.3450 volts      pe =   6.1367
Ionic strength      =    0.007230
Charge imbalance    =    0.000233 eq/kg (4.652% error)
Activity of water   =    0.999996
Solvent mass        =    1.000000 kg
Solution mass       =    1.000427 kg
Solution density    =    1.023    g/cm3
Chlorinity          =    0.000110 molal
Dissolved solids    =         427 mg/kg sol'n
Hardness            =      198.18 mg/kg sol'n as CaCO3
  carbonate         =      122.62 mg/kg sol'n as CaCO3
  non-carbonate     =       75.55 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=      122.62 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

Nernst redox couples	Eh (volts)	pe
e- + .25*O2(aq) + H+ = .5*H2O	0.3450	6.1367
8*e- + 9*H+ + NO3- = 3*H2O + NH3(aq)	0.5698	10.1349

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.002399	146.3	0.9163	-2.6580
NO3-	0.001711	106.0	0.9142	-2.8057
Ca++	0.001591	63.73	0.7155	-2.9438
Na+	0.001059	24.34	0.9163	-3.0130
SO4--	0.0003256	31.26	0.7036	-3.6400
Mg++	0.0003063	7.440	0.7265	-3.6527
K+	0.0002247	8.781	0.9142	-3.6874
SiO2(aq)	0.0001801	10.81	1.0000	-3.7446
CO2(aq)	0.0001618	7.120	1.0000	-3.7909
Cl-	0.0001103	3.907	0.9142	-3.9965
CaHCO3+	3.164e-005	3.197	0.9163	-4.5377
CaSO4(aq)	3.144e-005	4.278	1.0000	-4.5026
N2(aq)	2.846e-005	0.7971	1.0000	-4.5457
MgSO4(aq)	9.020e-006	1.085	1.0000	-5.0448
MgHCO3+	5.996e-006	0.5114	0.9163	-5.2601
CaCO3(aq)	5.138e-006	0.5140	1.0000	-5.2892
F-	5.094e-006	0.09673	0.9153	-5.3314
NaHCO3(aq)	4.077e-006	0.3423	1.0000	-5.3897
CO3--	4.015e-006	0.2408	0.7067	-5.5471
Ba++	1.060e-006	0.1455	0.7097	-6.1236
HSiO3-	5.379e-007	0.04145	0.9163	-6.3073
MgCO3(aq)	5.220e-007	0.04399	1.0000	-6.2824
KSO4-	3.859e-007	0.05214	0.9163	-6.4514
Cu++	1.692e-007	0.01075	0.7155	-6.9169
OH-	1.286e-007	0.002186	0.9153	-6.9292
NaHSiO3(aq)	2.978e-008	0.002979	1.0000	-7.5261
H+	2.715e-008	2.735e-005	0.9253	-7.6000
CaF+	2.627e-008	0.001551	0.9163	-7.6185
MgF+	2.607e-008	0.001128	0.9163	-7.6218
Cd++	2.574e-008	0.002893	0.7097	-7.7383
CaCl+	2.548e-008	0.001924	0.9163	-7.6317
MgCl+	1.958e-008	0.001170	0.9163	-7.7461
NaCl(aq)	1.512e-008	0.0008832	1.0000	-7.8205
NaCO3-	1.486e-008	0.001233	0.9163	-7.8660
UO2(CO3)3----	1.139e-009	0.0005126	0.2446	-9.5549

UO2(CO3)2--	8.981e-010	0.0003502	0.7036	-9.1993
BaCO3(aq)	6.917e-010	0.0001364	1.0000	-9.1601
KCl(aq)	4.961e-010	3.697e-005	1.0000	-9.3044
HSO4-	4.152e-010	4.029e-005	0.9163	-9.4197
NaF(aq)	4.033e-010	1.693e-005	1.0000	-9.3944
HF(aq)	1.334e-010	2.668e-006	1.0000	-9.8747
Cu+	3.075e-011	1.953e-006	0.9163	-10.5500
BaCl+	2.170e-011	3.748e-006	0.9163	-10.7015
NaOH(aq)	2.013e-011	8.048e-007	1.0000	-10.6962
UO2CO3(aq)	1.625e-011	5.361e-006	1.0000	-10.7891
CdSO4(aq)	4.228e-012	8.811e-007	1.0000	-11.3738
CaCl2(aq)	3.265e-012	3.622e-007	1.0000	-11.4861
BaF+	2.176e-012	3.400e-007	0.9163	-11.7003
HNO3(aq)	1.418e-012	8.934e-008	1.0000	-11.8482
HCl(aq)	5.383e-013	1.962e-008	1.0000	-12.2689
CdCl2(aq)	3.700e-013	6.779e-008	1.0000	-12.4318
UO2OH+	1.346e-013	3.861e-008	0.9163	-12.9090
KHSO4(aq)	4.519e-015	6.151e-010	1.0000	-14.3449
UO2++	1.787e-015	4.823e-010	0.7067	-14.8987
UO2F+	7.147e-016	2.065e-010	0.9163	-15.1838
UO2SO4(aq)	2.345e-016	8.580e-011	1.0000	-15.6299
HF2-	1.391e-016	5.422e-012	0.9163	-15.8948
UO2F2(aq)	9.611e-018	2.959e-012	1.0000	-17.0172
CdCl3-	7.772e-018	1.700e-012	0.9163	-17.1474
UO2(SO4)2--	4.682e-019	2.163e-013	0.7036	-18.4822
UO2Cl+	1.730e-019	5.282e-014	0.9163	-18.7999
UO2+	2.311e-020	6.237e-015	0.9163	-19.6742
UO2F3-	8.388e-021	2.742e-015	0.9163	-20.1143
(UO2)2(OH)2++	3.613e-021	2.073e-015	0.7067	-20.5929
(UO2)3(CO3)6(6-)	1.167e-022	1.365e-016	0.0420	-23.3094
U(OH)4(aq)	3.906e-023	1.195e-017	1.0000	-22.4082
(UO2)3(OH)5+	6.709e-024	6.003e-018	0.9163	-23.2113
UO2Cl2(aq)	7.137e-025	2.432e-019	1.0000	-24.1465
UO2F4--	3.139e-025	1.086e-019	0.7036	-24.6559
Formate	8.728e-031	3.927e-026	0.9153	-30.0975
H2(aq)	1.304e-031	2.628e-028	1.0000	-30.8846
Ca(For)+	2.978e-032	2.533e-027	0.9163	-31.5641
Mg(For)+	7.067e-033	4.897e-028	0.9163	-32.1887
Na(For)(aq)	9.210e-034	6.261e-029	1.0000	-33.0357
NO2-	7.481e-034	3.440e-029	0.9142	-33.1650
K(For)(aq)	1.691e-034	1.421e-029	1.0000	-33.7720
Formic_acid(aq)	1.183e-034	5.441e-030	1.0000	-33.9271
Ba(For)+	1.490e-035	2.716e-030	0.9163	-34.8647
SO3--	1.466e-035	1.173e-030	0.7067	-34.9847
Cu(For)+	1.320e-035	1.433e-030	0.9163	-34.9172
NH4+	1.269e-035	2.287e-031	0.9132	-34.9361
HSO3-	4.024e-036	3.261e-031	0.9163	-35.4333
O2(aq)	3.378e-036	1.080e-031	1.0000	-35.4713
Cd(For)+	1.349e-036	2.123e-031	0.9163	-35.9080
CO(aq)	1.927e-037	5.396e-033	1.0000	-36.7151
NH3(aq)	8.861e-038	1.509e-033	1.0000	-37.0525
Oxalate	4.842e-038	4.260e-033	0.7036	-37.4676
HNO2(aq)	4.147e-038	1.949e-033	1.0000	-37.3822
ClO-	3.814e-038	1.962e-033	0.9163	-37.4566
SiF6--	1.141e-039	1.620e-034	0.7036	-39.0956
HO2-	2.296e-040	7.574e-036	0.9163	-39.6771
U(CO3)5(6-)	2.111e-040	1.135e-034	0.0420	-41.0519
UOH+++	2.555e-041	6.514e-036	0.4619	-40.9281
H-Oxalate	1.540e-041	1.370e-036	0.9163	-40.8505
SO2(aq)	4.985e-042	3.192e-037	1.0000	-41.3024
UF2++	1.414e-042	3.902e-037	0.7067	-42.0003
UF3+	1.026e-042	3.026e-037	0.9163	-42.0267
UF+++	5.810e-044	1.493e-038	0.4619	-43.5713

UF4(aq)	4.625e-044	1.452e-038	1.0000	-43.3349
USO4++	2.629e-045	8.778e-040	0.7067	-44.7311
U(SO4)2(aq)	1.836e-045	7.893e-040	1.0000	-44.7362
U++++	1.112e-047	2.647e-042	0.2574	-47.5431
Oxalic_acid(aq)	6.434e-048	5.790e-043	1.0000	-47.1915
HSO5-	3.293e-048	3.722e-043	0.9163	-47.5204
UCl+++	4.892e-050	1.337e-044	0.4619	-49.6460
S2O6--	5.803e-060	9.288e-055	0.7036	-59.3890
Ca(For)2(aq)	1.935e-061	2.517e-056	1.0000	-60.7132
Mg(For)2(aq)	5.730e-062	6.549e-057	1.0000	-61.2418
Na(For)2-	5.813e-064	6.567e-059	0.9163	-63.2736
Cu(For)2(aq)	2.856e-064	4.384e-059	1.0000	-63.5443
ClO2-	2.527e-064	1.704e-059	0.9163	-63.6354
U+++	1.531e-064	3.642e-059	0.4619	-64.1505
Cd(For)2(aq)	1.429e-064	2.891e-059	1.0000	-63.8451
K(For)2-	8.924e-065	1.152e-059	0.9163	-64.0874
Ba(For)2(aq)	7.297e-065	1.658e-059	1.0000	-64.1369
S2O8--	4.888e-065	9.387e-060	0.7036	-64.4636
Formaldehyde(aq)	5.951e-067	1.786e-062	1.0000	-66.2254
N3-	9.159e-073	3.847e-068	0.9163	-72.0761
Cu(NH3)2++	9.655e-074	9.420e-069	0.7067	-73.1660
HN3(aq)	1.500e-075	6.453e-071	1.0000	-74.8238
ClO3-	6.307e-076	5.261e-071	0.9153	-75.2386
S2O5--	3.094e-076	4.458e-071	0.7036	-75.6621
Cd(NH3)2++	2.678e-077	3.921e-072	0.7067	-76.7230
Urea(aq)	4.169e-078	2.503e-073	1.0000	-77.3799
HCN(aq)	7.657e-080	2.068e-075	1.0000	-79.1160
CN-	7.176e-082	1.866e-077	0.9142	-81.1831
Methanol(aq)	3.532e-082	1.131e-077	1.0000	-81.4519
HS-	3.163e-087	1.046e-082	0.9153	-86.5383
H2S(aq)	1.216e-087	4.142e-083	1.0000	-86.9151
Glycolate	4.197e-088	3.148e-083	0.9163	-87.4150
Ca(Glyc)+	2.498e-089	2.875e-084	0.9163	-88.6403
UO2ClO3+	2.717e-090	9.599e-085	0.9163	-89.6039
Mg(Glyc)+	2.263e-090	2.247e-085	0.9163	-89.6833
Na(Glyc)(aq)	4.534e-091	4.443e-086	1.0000	-90.3435
K(Glyc)(aq)	8.323e-092	9.496e-087	1.0000	-91.0797
Glycolic_acid(aq	6.913e-092	5.255e-087	1.0000	-91.1604
ClO4-	6.060e-092	6.024e-087	0.9153	-91.2560
Cu(Glyc)+	5.904e-092	8.178e-087	0.9163	-91.2668
Methane(aq)	4.747e-092	7.612e-088	1.0000	-91.3236
S--	6.716e-093	2.153e-088	0.7097	-92.3218
Ba(Glyc)+	3.334e-093	7.077e-088	0.9163	-92.5150
S2O3--	1.929e-093	2.162e-088	0.7036	-92.8673
Cd(Glyc)+	7.144e-094	1.339e-088	0.9163	-93.1840
S2O4--	3.101e-095	3.971e-090	0.7097	-94.6575
Acetate	2.389e-097	1.410e-092	0.9173	-96.6592
CaCH3COO+	2.452e-099	2.429e-094	0.9163	-98.6485
MgCH3COO+	1.318e-099	1.098e-094	0.9163	-98.9180
Acetic_acid(aq)	3.204e-100	1.923e-095	1.0000	-99.4943
NaCH3COO(aq)	1.783e-100	1.462e-095	1.0000	-99.7489
KCH3COO(aq)	2.323e-101	2.279e-096	1.0000	-100.6339
CuCH3COO+	6.817e-102	8.354e-097	0.9163	-101.2043
BaCH3COO+	1.619e-102	3.177e-097	0.9163	-101.8288
CdCH3COO+	4.679e-103	8.019e-098	0.9163	-102.3678
Malonate	5.470e-106	5.580e-101	0.7036	-105.4147
CuCH3COO(aq)	1.534e-107	1.880e-102	1.0000	-106.8142
Cu(NH3)3++	8.886e-108	1.018e-102	0.7067	-107.2021
H-Malonate	4.943e-108	5.092e-103	0.9163	-107.3440
Malonic_acid(aq)	8.376e-113	8.712e-108	1.0000	-112.0770
Methanamine(aq)	1.256e-116	3.901e-112	1.0000	-115.9009
Glycine(aq)	3.974e-119	2.982e-114	1.0000	-118.4007
Cu(Gly)+	9.063e-120	1.247e-114	0.9163	-119.0807

Mg(Gly)+	8.674e-122	8.529e-117	0.9163	-121.0997
Ca(Gly)+	2.252e-123	2.569e-118	0.9163	-122.6854
Cd(Gly)+	1.252e-124	2.333e-119	0.9163	-123.9404
S3O6--	8.433e-126	1.620e-120	0.7036	-125.2267
Ba(Gly)+	1.785e-126	3.771e-121	0.9163	-125.7864
Acetaldehyde(aq)	2.541e-131	1.119e-126	1.0000	-130.5950
SCN-	1.397e-131	8.112e-127	0.9153	-130.8932
NH4CH3COO(aq)	4.155e-132	3.202e-127	1.0000	-131.3814
Acetamide(aq)	3.424e-132	2.021e-127	1.0000	-131.4655
UO2SCN+	4.306e-145	1.412e-139	0.9163	-144.4039
Cd(NH3)4++	8.306e-149	1.499e-143	0.7067	-148.2314
Ethanol(aq)	3.267e-151	1.505e-146	1.0000	-150.4858
Ethyne(aq)	1.395e-153	3.632e-149	1.0000	-152.8553
Ethylene(aq)	5.197e-156	1.457e-151	1.0000	-155.2843
Lactate	4.225e-157	3.762e-152	0.9163	-156.4121
Ca(Lac)+	1.478e-158	1.908e-153	0.9163	-157.8682
Mg(Lac)+	2.290e-159	2.595e-154	0.9163	-158.6781
Na(Lac)(aq)	4.662e-160	5.222e-155	1.0000	-159.3315
K(Lac)(aq)	8.558e-161	1.096e-155	1.0000	-160.0676
Lactic_acid(aq)	7.297e-161	6.571e-156	1.0000	-160.1368
Cu(Lac)+	2.724e-161	4.156e-156	0.9163	-160.6027
Ba(Lac)+	1.385e-162	3.133e-157	0.9163	-161.8966
Cd(Lac)+	4.864e-163	9.796e-158	0.9163	-162.3510
Ethane(aq)	1.892e-165	5.688e-161	1.0000	-164.7230
Propanoate	1.521e-168	1.111e-163	0.9163	-167.8557
Ca(Prop)+	8.697e-171	9.836e-166	0.9163	-170.0986
Propanoic_acid(a	2.740e-171	2.029e-166	1.0000	-170.5622
Mg(Prop)+	2.272e-171	2.211e-166	0.9163	-170.6816
Na(Prop)(aq)	1.655e-171	1.590e-166	1.0000	-170.7811
K(Prop)(aq)	3.039e-172	3.407e-167	1.0000	-171.5173
Cu(Prop)+	4.251e-173	5.805e-168	0.9163	-172.4095
Cd(Prop)+	2.736e-174	5.073e-169	0.9163	-173.6008
Ba(Prop)+	1.360e-174	2.859e-169	0.9163	-173.9046
S4O6--	3.508e-175	7.863e-170	0.7036	-174.6076
Ca(Glyc)2(aq)	1.928e-175	3.664e-170	1.0000	-174.7150
Succinate	1.435e-175	1.665e-170	0.7036	-174.9959
USCN+++	1.365e-175	4.039e-170	0.4619	-175.2004
Mg(Glyc)2(aq)	1.070e-176	1.865e-171	1.0000	-175.9708
Cu(Glyc)2(aq)	1.837e-177	3.922e-172	1.0000	-176.7359
H-Succinate	1.234e-177	1.445e-172	0.9163	-176.9465
Na(Glyc)2-	2.152e-178	3.722e-173	0.9163	-177.7052
K(Glyc)2-	3.391e-179	6.413e-174	0.9163	-178.5076
Serine(aq)	1.890e-179	1.985e-174	1.0000	-178.7236
Cd(Glyc)2(aq)	8.971e-180	2.354e-174	1.0000	-179.0472
Ba(Glyc)2(aq)	6.015e-180	1.728e-174	1.0000	-179.2208
Succinic_acid(aq	5.028e-181	5.935e-176	1.0000	-180.2986
Ethanamine(aq)	1.291e-187	5.818e-183	1.0000	-186.8891
Alanine(aq)	5.444e-189	4.848e-184	1.0000	-188.2641
Cu(Ala)+	2.810e-190	4.260e-185	0.9163	-189.5892
Mg(Ala)+	8.022e-194	9.012e-189	0.9163	-193.1337
Ca(Ala)+	5.906e-194	7.566e-189	0.9163	-193.2667
Ca(CH3COO)2(aq)	1.024e-194	1.618e-189	1.0000	-193.9899
Cd(Ala)+	9.651e-195	1.934e-189	0.9163	-194.0534
Mg(CH3COO)2(aq)	2.346e-195	3.339e-190	1.0000	-194.6296
Cu(CH3COO)2(aq)	5.171e-197	9.388e-192	1.0000	-196.2864
Na(CH3COO)2-	2.469e-197	3.481e-192	0.9163	-196.6455
Ba(Ala)+	1.731e-197	3.901e-192	0.9163	-196.7996
Acetone(aq)	1.497e-197	8.689e-193	1.0000	-196.8249
Cd(CH3COO)2(aq)	2.179e-198	5.021e-193	1.0000	-197.6617
K(CH3COO)2-	2.109e-198	3.314e-193	0.9163	-197.7138
Ba(CH3COO)2(aq)	1.064e-198	2.717e-193	1.0000	-197.9729
Aspartic_acid(aq	2.511e-199	3.341e-194	1.0000	-198.6001
Propanal(aq)	5.993e-202	3.479e-197	1.0000	-201.2223

Cu(CH3COO)2-	5.235e-204	9.505e-199	0.9163	-203.3190
S3--	2.047e-219	1.968e-214	0.7036	-218.8417
1-Propyne(aq)	1.523e-220	6.098e-216	1.0000	-219.8174
1-Propanol(aq)	2.376e-222	1.427e-217	1.0000	-221.6242
1-Propene(aq)	6.811e-225	2.865e-220	1.0000	-224.1668
2-Hydroxybutanoa	1.099e-228	1.132e-223	0.9163	-227.9971
NH4(CH3COO)2-	9.550e-229	1.299e-223	0.9163	-228.0580
Asparagine(aq)	3.189e-231	4.211e-226	1.0000	-230.4964
2-Hydroxybutanoi	1.679e-232	1.748e-227	1.0000	-231.7749
Cu(Gly)2(aq)	3.139e-233	6.642e-228	1.0000	-232.5031
Propane(aq)	5.495e-237	2.422e-232	1.0000	-236.2601
Mg(Gly)2(aq)	1.132e-239	1.951e-234	1.0000	-238.9462
Diglycine(aq)	3.516e-240	4.643e-235	1.0000	-239.4540
Butanoate	3.125e-240	2.721e-235	0.9163	-239.5431
Cd(Gly)2(aq)	8.012e-242	2.086e-236	1.0000	-241.0963
Diketopiperazine	1.347e-242	1.536e-237	1.0000	-241.8707
Ca(But)+	1.224e-242	1.557e-237	0.9163	-241.9500
Butanoic_acid(aq	4.501e-243	3.964e-238	1.0000	-242.3467
Na(But)(aq)	3.272e-243	3.601e-238	1.0000	-242.4852
Mg(But)+	3.049e-243	3.395e-238	0.9163	-242.5538
Ca(Gly)2(aq)	1.011e-243	1.901e-238	1.0000	-242.9954
K(But)(aq)	6.007e-244	7.577e-239	1.0000	-243.2214
Cu(But)+	6.911e-245	1.041e-239	0.9163	-244.1984
Glutarate	2.477e-246	3.221e-241	0.7036	-245.7588
Cd(But)+	2.376e-246	4.739e-241	0.9163	-245.6620
Ba(But)+	1.867e-246	4.188e-241	0.9163	-245.7668
Ba(Gly)2(aq)	8.891e-247	2.537e-241	1.0000	-246.0510
H-Glutarate	1.240e-248	1.625e-243	0.9163	-247.9447
Threonine(aq)	3.979e-251	4.737e-246	1.0000	-250.4003
Glutaric_acid(aq	6.397e-252	8.448e-247	1.0000	-251.1940
Ethylacetate(aq)	3.175e-252	2.796e-247	1.0000	-251.4983
S5O6--	2.115e-254	5.418e-249	0.7036	-253.8274
1-Propanamine(aq	3.166e-258	1.871e-253	1.0000	-257.4995
a-Aminobutyric_a	2.412e-260	2.486e-255	1.0000	-259.6177
Glutamic_acid(aq	5.003e-269	7.359e-264	1.0000	-268.3007
Butanal(aq)	4.242e-275	3.057e-270	1.0000	-274.3724
UO2(SCN)2(aq)	2.967e-276	1.145e-270	1.0000	-275.5277
S4--	6.298e-283	8.075e-278	0.7036	-282.3535
Cu(CH3COO)3-	4.498e-292	1.082e-286	0.9163	-291.3850
1-Butyne(aq)	2.941e-292	1.590e-287	1.0000	-291.5315
Cd(CH3COO)3-	1.594e-294	4.614e-289	0.9163	-293.8354
1-Butanol(aq)	9.202e-295	6.818e-290	1.0000	-294.0361
1-Butene(aq)	8.438e-297	4.732e-292	1.0000	-296.0738
2-Hydroxypentano	4.298e-300	5.032e-295	0.9163	-299.4047
Glutamine(aq)	7.293e-303	1.065e-297	1.0000	-300.0000
2-Hydroxypentano	3.865e-304	4.564e-299	1.0000	-300.0000
U(SCN)2++	1.914e-305	6.776e-300	0.7067	-300.0000
n-Butane(aq)	1.392e-308	8.090e-304	1.0000	-300.0000
Alanylglycine(aq	2.416e-310	3.530e-305	1.0000	-300.0000
Pentanoate	7.636e-312	7.718e-307	0.9163	-300.0000
Ca(Lac)2(aq)	7.350e-314	1.603e-308	1.0000	-300.0000
Ca(Pent)+	1.775e-314	2.505e-309	0.9163	-300.0000
Pentanoic_acid(a	1.196e-314	1.221e-309	1.0000	-300.0000
Mg(Lac)2(aq)	1.174e-314	2.377e-309	1.0000	-300.0000
Na(Pent)(aq)	8.492e-315	1.054e-309	1.0000	-300.0000
Mg(Pent)+	4.318e-315	5.414e-310	0.9163	-300.0000
K(Pent)(aq)	1.559e-315	2.185e-310	1.0000	-300.0000
Cu(Lac)2(aq)	5.471e-316	1.322e-310	1.0000	-300.0000
Na(Lac)2-	2.276e-316	4.576e-311	0.9163	-300.0000
Cu(Pent)+	1.710e-316	2.814e-311	0.9163	-300.0000
K(Lac)2-	3.587e-317	7.789e-312	0.9163	-300.0000
Cd(Pent)+	7.484e-318	1.597e-312	0.9163	-300.0000
Cd(Lac)2(aq)	4.441e-318	1.290e-312	1.0000	-300.0000

Ba(Pent)+	2.983e-318	7.110e-313	0.9163	-300.0000
Ba(Lac)2(aq)	1.218e-318	3.840e-313	1.0000	-300.0000
Adipate	1.539e-319	2.217e-314	0.7036	-300.0000
H-Adipate	7.559e-322	1.097e-316	0.9163	-300.0000
Leucylglycine(aq	0.0000	0.0000	1.0000	-300.0000
Leucine(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
K(Prop)2-	0.0000	0.0000	0.9163	-300.0000
Ba(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
1-Octanamine(aq)	0.0000	0.0000	1.0000	-300.0000
K(Pent)2-	0.0000	0.0000	0.9163	-300.0000
Cd(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Azelate	0.0000	0.0000	0.7036	-300.0000
2-Hexanone(aq)	0.0000	0.0000	1.0000	-300.0000
K(But)2-	0.0000	0.0000	0.9163	-300.0000
Isoleucine(aq)	0.0000	0.0000	1.0000	-300.0000
Azelaic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Hexanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Hexanoate	0.0000	0.0000	0.9163	-300.0000
Hexanal(aq)	0.0000	0.0000	1.0000	-300.0000
Heptanoic_acid(a	0.0000	0.0000	1.0000	-300.0000
2-Heptanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexyne(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanamine(aq	0.0000	0.0000	1.0000	-300.0000
Heptanoate	0.0000	0.0000	0.9163	-300.0000
Heptanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Butanone(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Adipic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexene(aq)	0.0000	0.0000	1.0000	-300.0000
p-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
p-Toluate	0.0000	0.0000	0.9163	-300.0000
o-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
o-Phthalate	0.0000	0.0000	0.7036	-300.0000
n-Propylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Pentylbenzene(	0.0000	0.0000	1.0000	-300.0000
H-Suberate	0.0000	0.0000	0.9163	-300.0000
H-Sebacate	0.0000	0.0000	0.9163	-300.0000
n-Hexylbenzene(a	0.0000	0.0000	1.0000	-300.0000
H-Pimelate	0.0000	0.0000	0.9163	-300.0000
n-Hexane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Heptylbenzene(	0.0000	0.0000	1.0000	-300.0000
n-Heptane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Butylbenzene(a	0.0000	0.0000	1.0000	-300.0000
m-Toluic_acid(aq	0.0000	0.0000	1.0000	-300.0000
m-Toluate	0.0000	0.0000	0.9163	-300.0000
H-Azelate	0.0000	0.0000	0.9163	-300.0000
Valine(aq)	0.0000	0.0000	1.0000	-300.0000
Undecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Undecanoate	0.0000	0.0000	0.9163	-300.0000
1-Hexanol(aq)	0.0000	0.0000	1.0000	-300.0000
1-Butanamine(aq)	0.0000	0.0000	1.0000	-300.0000
Ca(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
UO2(SCN)3-	0.0000	0.0000	0.9163	-300.0000
Ca(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ethylbenzene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Pentanone(aq)	0.0000	0.0000	1.0000	-300.0000
Tryptophan(aq)	0.0000	0.0000	1.0000	-300.0000
Toluene(aq)	0.0000	0.0000	1.0000	-300.0000
Dodecanoic_acid(	0.0000	0.0000	1.0000	-300.0000
Suberic_acid(aq)	0.0000	0.0000	1.0000	-300.0000

Suberate	0.0000	0.0000	0.7036	-300.0000
Dodecanoate	0.0000	0.0000	0.9163	-300.0000
2-Octanone(aq)	0.0000	0.0000	1.0000	-300.0000
1-Pentyne(aq)	0.0000	0.0000	1.0000	-300.0000
1-Hexanamine(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Sebacate	0.0000	0.0000	0.7036	-300.0000
Decanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Tyrosine(aq)	0.0000	0.0000	1.0000	-300.0000
Decanoate	0.0000	0.0000	0.9163	-300.0000
Decanal(aq)	0.0000	0.0000	1.0000	-300.0000
S5--	0.0000	0.0000	0.7036	-300.0000
1-Pentene(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Cu(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Benzoate	0.0000	0.0000	0.9202	-300.0000
2-Hydroxyoctanoi	0.0000	0.0000	1.0000	-300.0000
Pimelic_acid(aq)	0.0000	0.0000	1.0000	-300.0000
Pimelate	0.0000	0.0000	0.7036	-300.0000
Phenylalanine(aq	0.0000	0.0000	1.0000	-300.0000
Benzene(aq)	0.0000	0.0000	1.0000	-300.0000
Phenol(aq)	0.0000	0.0000	1.0000	-300.0000
Pentanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyoctanoa	0.0000	0.0000	0.9163	-300.0000
1-Pentanol(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptyne(aq)	0.0000	0.0000	1.0000	-300.0000
Octanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
Octanoate	0.0000	0.0000	0.9163	-300.0000
Octanal(aq)	0.0000	0.0000	1.0000	-300.0000
Nonanoic_acid(aq	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoi	0.0000	0.0000	1.0000	-300.0000
Nonanoate	0.0000	0.0000	0.9163	-300.0000
Nonanal(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxynonanoa	0.0000	0.0000	0.9163	-300.0000
1-Pentanamine(aq	0.0000	0.0000	1.0000	-300.0000
Na(Prop)2-	0.0000	0.0000	0.9163	-300.0000
Ba(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(Pent)2-	0.0000	0.0000	0.9163	-300.0000
Cu(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyhexanoi	0.0000	0.0000	1.0000	-300.0000
Cu(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
Ba(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Na(But)2-	0.0000	0.0000	0.9163	-300.0000
2-Hydroxyhexanoa	0.0000	0.0000	0.9163	-300.0000
1-Octyne(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptene(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	1.0000	-300.0000
Mg(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxyheptano	0.0000	0.0000	0.9163	-300.0000
1-Octene(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Prop)2(aq)	0.0000	0.0000	1.0000	-300.0000
Cd(Pent)2(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octane(aq)	0.0000	0.0000	1.0000	-300.0000
n-Octylbenzene(a	0.0000	0.0000	1.0000	-300.0000
n-Pentane(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoi	0.0000	0.0000	1.0000	-300.0000
Mg(But)2(aq)	0.0000	0.0000	1.0000	-300.0000
Mg(Ala)2(aq)	0.0000	0.0000	1.0000	-300.0000
o-Toluate	0.0000	0.0000	0.9163	-300.0000
Methionine(aq)	0.0000	0.0000	1.0000	-300.0000
2-Hydroxydecanoa	0.0000	0.0000	0.9163	-300.0000

1-Octanol(aq)	0.0000	0.0000	1.0000	-300.0000
1-Heptanol(aq)	0.0000	0.0000	1.0000	-300.0000

Mineral saturation states

	log Q/K		log Q/K
Witherite	1.9775s/sat	UO2SO4:3H2O	-17.4476
Quartz	0.6102s/sat	Na2SiO3	-17.5240
Barite	0.4876s/sat	CdF2	-17.6531
Tridymite	0.4099s/sat	Hillebrandite	-17.8680
Chalcedony	0.3248s/sat	UO2F2:3H2O	-18.3079
Dolomite-ord	0.2524s/sat	Dicalcium_silica	-18.3509
Dolomite	0.2523s/sat	UO2F2	-18.6354
Tenorite	0.0346s/sat	UO2.3333(beta)	-18.8393
Cristobalite(alp	0.0252s/sat	CuCl2	-19.0624
Calcite	-0.0722	Akermanite	-19.2905
Ice	-0.0827	MgCl2:4H2O	-19.3906
Aragonite	-0.2173	Larnite	-19.7313
Coesite	-0.2397	Anthophyllite	-19.9357
Malachite	-0.3214	UO2SO4	-21.2376
Cristobalite(bet	-0.4615	UOFOH:.5H2O	-21.2975
SiO2(am)	-0.8006	UOFOH	-21.8087
Monohydrocalcite	-0.8715	Lime	-22.0995
Magnesite	-1.3983	Na2UO4(alpha)	-22.1492
Dolomite-dis	-1.4046	UO2(NO3)2:6H2O	-22.6359
Dioptase	-1.7397	UO2Cl	-23.3338
Gypsum	-2.0840	Hydrophilite	-23.4446
Anhydrite	-2.4074	UO2(NO3)2:3H2O	-24.2975
Talc	-2.6284	UOF2:H2O	-24.5892
Brochantite	-2.6390	MgCl2:2H2O	-25.2404
Bassanite	-3.0570	UOF2	-25.2440
CaSO4:0.5H2O(bet	-3.2443	Rankinite	-25.2976
Fluorite	-3.4249	UO2(NO3)2:2H2O	-25.6689
Cuprite	-3.7462	Tobermorite-14A	-26.8782
CdSiO3	-4.2212	K2UO4	-27.3542
Enstatite	-4.2305	MgCl2:H2O	-28.8303
Nesquehonite	-4.5159	UO2Cl2:3H2O	-28.9261
CaUO4	-4.5941	Tobermorite-11A	-29.1336
UO3:2H2O	-5.0035	UO2(NO3)2:H2O	-29.5137
Schoepite	-5.0037	Foshagite	-31.2820
Sellaite	-5.0130	Merwinite	-31.5283
UO2(OH)2(beta)	-5.1710	UO2Cl2:H2O	-31.8914
Schoepite-dehy(.	-5.2316	Ba2SiO4	-32.3050
UO3:.9H2O(alpha)	-5.2390	Tobermorite-9A	-32.9862
Schoepite-dehy(.	-5.3246	UO2(NO3)2	-33.2063
Schoepite-dehy(1	-5.3414	Afwillite	-33.5735
Nahcolite	-5.3954	UO2SO3	-33.8147
Atacamite	-5.5572	KMgCl3:2H2O	-33.9848
Okenite	-5.7072	Cd	-34.6667
Diopside	-5.7722	Chloromagnesite	-34.9320
Brucite	-5.7751	UF4:2.5H2O	-35.2289
Chrysotile	-5.8724	UO2Cl2	-36.0092
Wollastonite	-5.8988	BaSiF6	-39.0882
Azurite	-5.9263	UF4	-39.7851
Niter	-5.9458	BaO	-41.2060
Huntite	-5.9480	KMgCl3	-41.7718
UO2CO3	-6.0046	C	-42.5290
Rutherfordine	-6.0179	U(SO4)2:8H2O	-42.5860
Pseudowollastoni	-6.1651	U(SO4)2:4H2O	-43.9201
Schoepite-dehy(.	-6.5158	U(SO4)2	-44.1850
Schoepite-dehy(.	-7.0672	Hatrurite	-44.3213
Cd(OH)2	-7.0824	Ba2U2O7	-44.6938
Nantokite	-7.3936	Xonotlite	-45.0809

Cu	-7.4503	U(CO3)2	-46.7436
Mirabilite	-7.8355	UOCl2	-47.0748
Sepiolite	-7.8642	UClF3	-50.6519
Chalcanthite	-7.8773	U5O12Cl	-53.2856
Cd(OH)Cl	-7.9491	Na3UO4	-57.2754
Artinite	-8.0106	UOF4	-57.3260
Sanbornite	-8.0650	Na	-57.4147
UO3(gamma)	-8.1522	Na4SiO4	-59.0080
Sylvite	-8.3521	UOCl3	-60.3774
Halite	-8.5462	(UO2)2Cl3	-60.5461
Monteponite	-8.5856	UF3	-60.6354
UO3(beta)	-8.7877	Na2O	-61.4872
Nitrobarite	-8.8753	K	-61.8009
Arcanite	-8.9567	Covellite	-62.0718
UO3(alpha)	-9.1428	Chalcocite	-63.3984
Thenardite	-9.3436	UCl2F2	-63.8329
CdSO4:2.667H2O	-9.7347	UF5(beta)	-63.9134
CdSO4:H2O	-9.9938	UOCl	-64.3196
BaUO4	-10.0580	UF5(alpha)	-64.3202
UO2.25	-10.1356	S	-64.3475
UO2FOH:2H2O	-10.1782	CdS	-70.1181
UO2.25(beta)	-10.2044	Ba3UO6	-72.0229
Gyrolite	-10.2442	U2O3F6	-76.1096
Natron	-10.2492	UCl3F	-76.8296
Forsterite	-10.3463	Antigorite	-79.3871
Mg1.25SO4(OH)0.5	-10.5207	K2O	-80.1347
UO2FOH:H2O	-10.6378	CdCl2(NH3)2	-80.4583
Na2CO3:7H2O	-10.8156	U(SO3)2	-80.5183
Periclase	-11.1661	Na6Si2O7	-85.8292
UO2FOH	-11.1666	UCl4	-87.6655
Monticellite	-11.2692	UCl3	-90.2705
Portlandite	-11.4836	UF6	-97.0293
CdSO4	-11.7224	Mg	-100.0942
Mg1.5SO4(OH)	-11.8916	U2F9	-100.3980
Tremolite	-12.2517	U3O5F8	-102.0872
Thermonatrite	-12.2937	BaS	-102.1571
Na2CO3	-12.6226	UN1.73(alpha)	-106.7039
UO2SO4:H2O	-12.8435	U2O2Cl5	-108.7434
MgSO4	-12.9642	UN1.59(alpha)	-109.5019
MgUO4	-12.9855	UCl5	-109.5882
Uraninite	-13.0321	Ca	-117.4049
Coffinite	-13.2634	Ba	-121.9319
UO2.6667	-13.9099	UN	-122.8450
UO2ClOH:2H2O	-13.9140	Si	-125.0598
BaU2O7	-14.0885	UCl6	-130.2961
CdCl2:H2O	-14.1067	CdCl2(NH3)4	-156.3925
Chalcocyanite	-14.1182	U	-171.0676
BaCl2:2H2O	-14.1810	US	-176.2301
Na2U2O7	-14.4080	U4F17	-179.0560
BaCl2:H2O	-14.9183	UC	-195.3693
CdCl2	-15.2298	UH3(beta)	-198.9233
Ba(OH)2:8H2O	-15.9748	US1.9	-199.3869
NaUO3	-16.3441	US2	-204.0135
BaCl2	-16.4731	CdCl2(NH3)6	-232.4220
Natrosilite	-16.8240	UC1.94(alpha)	-237.4766
Hydromagnesite	-16.8649	US3	-265.0291
MgOHCl	-17.0397	U2S3	-372.9677
Ba2Si3O8	-17.1204	o-Phthalic_acid	-378.4368
UO2SO4:3.5H2O	-17.3069	U2C3	-434.8687
UO2SO4:2.5H2O	-17.3706	U3S5	-572.1633

Gases	fugacity	log fug.

N2(g)	0.03354	-1.474
H2O(g)	0.01017	-1.993
CO2(g)	0.002960	-2.529
NO2(g)	2.886e-011	-10.540
HF(g)	2.500e-015	-14.602
HCl(g)	2.652e-019	-18.576
H2(g)	1.480e-028	-27.830
O2(g)	1.976e-033	-32.704
NO(g)	1.008e-033	-32.997
CO(g)	1.465e-034	-33.834
NH3(g)	6.640e-040	-39.178
SiF4(g)	3.298e-041	-40.482
SO2(g)	1.850e-042	-41.733
Cl2(g)	3.935e-045	-44.405
Cd(g)	6.028e-050	-49.220
Cu(g)	2.023e-063	-62.694
UO2F2(g)	5.009e-064	-63.300
Na(g)	1.321e-072	-71.879
K(g)	6.189e-074	-73.208
UO2Cl2(g)	4.644e-075	-74.333
UO3(g)	5.051e-076	-75.297
UOF4(g)	3.000e-079	-78.523
UF5(g)	8.738e-086	-85.059
H2S(g)	7.787e-087	-86.109
UF4(g)	3.463e-087	-86.461
CH4(g)	2.414e-089	-88.617
UF6(g)	4.926e-099	-98.307
F2(g)	1.326e-103	-102.878
UCl4(g)	1.168e-114	-113.933
UO2(g)	7.899e-116	-115.102
Mg(g)	7.193e-122	-121.143
UCl5(g)	5.691e-129	-128.245
UF3(g)	4.057e-132	-131.392
UCl6(g)	1.218e-137	-136.914
UCl3(g)	1.259e-139	-138.900
U2F10(g)	6.028e-144	-143.220
S2(g)	1.711e-144	-143.767
Ca(g)	5.610e-145	-144.251
C2H4(g)	7.345e-154	-153.134
C(g)	2.009e-167	-166.697
UF2(g)	1.138e-173	-172.944
UCl2(g)	1.026e-182	-181.989
UO(g)	9.378e-189	-188.028
Si(g)	5.918e-201	-200.228
UF(g)	2.087e-208	-207.680
U2Cl8(g)	3.711e-217	-216.430
UCl(g)	2.976e-223	-222.526
U2Cl10(g)	4.722e-229	-228.326
U(g)	2.955e-262	-261.529

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ba++	1.06e-006	1.06e-006	0.146			
Ca++	0.00166	0.00166	66.5			
Cd++	2.57e-008	2.57e-008	0.00289			
Cl-	0.000110	0.000110	3.91			
Cu++	1.69e-007	1.69e-007	0.0108			
F-	5.15e-006	5.15e-006	0.0977			
H+	0.000151	0.000151	0.152			
H2O	55.5	55.5	1.00e+006			
HCO3-	0.00261	0.00261	159.			
K+	0.000225	0.000225	8.80			

Mg++	0.000322	0.000322	7.82
NH3(aq)	5.69e-005	5.69e-005	0.969
NO3-	0.00171	0.00171	106.
Na+	0.00106	0.00106	24.4
O2(aq)	4.25e-005	4.25e-005	1.36
SO4--	0.000366	0.000366	35.2
SiO2(aq)	0.000181	0.000181	10.8
UO2++	2.05e-009	2.05e-009	0.000554

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Barium	1.061e-006	1.061e-006	0.1456		
Cadmium	2.575e-008	2.575e-008	0.002893		
Calcium	0.001659	0.001659	66.46		
Carbon	0.002612	0.002612	31.36		
Chlorine	0.0001103	0.0001103	3.909		
Copper	1.693e-007	1.693e-007	0.01075		
Fluorine	5.147e-006	5.147e-006	0.09774		
Hydrogen	111.0	111.0	1.118e+005		
Magnesium	0.0003218	0.0003218	7.819		
Nitrogen	0.001768	0.001768	24.75		
Oxygen	55.52	55.52	8.880e+005		
Potassium	0.0002251	0.0002251	8.796		
Silicon	0.0001806	0.0001806	5.071		
Sodium	0.001063	0.001063	24.43		
Sulfur	0.0003664	0.0003664	11.74		
Uranium	2.054e-009	2.054e-009	0.0004887		

Draft Environmental Impact Statement

Troy Mine Revised Reclamation Plan

May 2011

Montana Department of Environmental Quality

Kootenai National Forest
Three Rivers Ranger District

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Draft Environmental Impact Statement
Troy Mine Revised Reclamation Plan

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Abstract: This Draft Environmental Impact Statement for the Troy Mine Revised Reclamation Plan describes the land, people, and resources potentially affected by the proposed revised reclamation activities. The purpose of the proposed revision is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. Alternatives considered in detail include a No Action Alternative (the previously approved 1978 reclamation plan), the Proposed Action (Troy Mine, Inc.'s Revised Reclamation Plan), and an Agency-Mitigated Alternative (the Agencies preferred alternative). This Draft EIS analyzes Troy Mine, Inc.'s revised plan as well as agency-proposed modifications (*e.g.* adit closure, mine water management, water treatment and monitoring, reclamation cover requirements, subsidence monitoring, debris disposal, and road closures). The major state and federal actions include approval of a reclamation plan and any necessary permits to implement the reclamation activities including construction and long-term monitoring.

Reviewers should provide their comments to either KNF or DEQ during the review period of the Draft EIS. The KNF and the DEQ will analyze and respond to the comments jointly and will use the information acquired in the preparation of the final environmental impact statement (Final EIS). Reviewers have an obligation to structure their participation in the National Environmental Policy Act (NEPA) and Montana Environmental Policy Act (MEPA) process so that it is meaningful and alerts the agencies to the reviewers' position and contentions [Vermont Yankee Nuclear Power Corp. v. Natural Resource Defense Council, 435 U.S. 519, 553 (1978)]. Environmental objections that could have been raised at the Draft EIS stage may be waived if not raised until after completion of the Final EIS. [City of Angoon v. Hodel (9th Circuit, 1986) and Wisconsin Heritages, Inc. v. Harris, 490 F. Supp. 1334, 1338 (E.D. Wis. 1980)]. Comments on the Draft EIS should be specific and should address the adequacy of the statement and the merits of the alternatives discussed (40 Code of Federal Regulations (CFR) 1503.3).

Send Comments To: Bobbie Lacklen (Kootenai National Forest) email: TroyMineReclamation@fs.fed.us or Emily Corsi (MT DEQ) email: deqTroyMine@mt.gov or postal addresses listed above.

Comments Due: 45 days after the Notice of Availability is published in the *Federal Register,* which will be on or about May 20, 2011.

Table of Contents

Executive Summary ES-1
ES.1 Introduction ES-1
ES.1.1 Project Area Description ES-1
ES.2 Purpose and Need ES-3
ES.3 Scope of Decisions To Be Made ES-3
ES.3.1 Kootenai National Forest ES-3
ES.3.2 Montana Department of Environmental Quality ES-4
ES.4 Public Involvement ES-4
ES.5 Issue Identification and Alternative Development ES-5
ES.6 Alternatives ES-5
ES.6.1 No Action Alternative ES-6
ES.6.2 Proposed Action ES-8
ES.6.3 Agency-Mitigated Alternative ES-12
ES.7 Environmental Consequences ES-16
ES.7.1 Fish ES-16
ES.7.2 Geology ES-17
ES.7.3 Hydrology ES-17
ES.7.4 Reclamation Materials ES-18
ES.7.5 Transportation ES-19
ES.7.6 Vegetation ES-19
ES.7.7 Wildlife ES-20
Chapter 1 Purpose of and Need for Action 1-1
1.1 Introduction 1-1
1.2 Document Structure 1-1
1.3 Project Area Description 1-2
1.4 Background 1-3
1.4.1 Exploration and Operations 1-3
1.4.2 Operating Permit History 1-3
1.4.3 Revised Reclamation Plan and Bond Review 1-6
1.4.4 Other Changes to the Operating Permit 1-6
1.5 Proposed Action 1-7
1.6 Purpose of and Need for Action 1-7
1.6.1 Kootenai National Forest 1-8
1.6.2 Montana Department of Environmental Quality 1-8
1.6.3 Troy Mine, Incorporated 1-8
1.7 Agency Roles and Responsibilities 1-9
1.7.1 Federal Agencies 1-9
1.7.2 State or County Agencies 1-10
1.8 Decision Framework 1-11
1.8.1 Federal Agencies with Permit or Plan Approval 1-11
1.8.2 State Agencies with Permit or Plan Approval 1-12
Chapter 2 Alternatives 2-1
2.1 Existing Mine Facilities 2-1
2.1.1 Land Ownership 2-1
2.1.2 Tailings Impoundment Area 2-2

2.1.3 Office/Shop and Mill Areas 2-3
2.1.4 Other Mine Components 2-6
2.2 Public Involvement 2-9
2.3 Issue Identification 2-10
2.3.1 Major Issues 2-11
2.3.2 Issues Considered and Not Evaluated Further 2-14
2.4 Comparison of Alternatives 2-17
2.4.1 No Action Alternative 2-35
2.4.2 Proposed Action 2-42
2.4.3 Agency-Mitigated Alternative 2-51
2.5 Mitigation and Monitoring Measures Common to All Alternatives 2-59
2.6 Alternatives Considered but Eliminated from Detailed Study 2-59
Chapter 3 Affected Environment and Environmental Consequences 3-1
3.1 Introduction 3-1
3.2 Past and Current Actions 3-1
3.2.1 KNF Management Activities 3-2
3.2.2 Private and State Land Actions 3-3
3.3 Reasonably Foreseeable Future Actions 3-3
3.3.1 Kootenai National Forest 3-4
3.3.2 Private and State Lands 3-5
3.4 Air Quality 3-5
3.4.1 Introduction 3-5
3.4.2 Regulatory Framework 3-5
3.4.3 Analysis Area 3-6
3.4.4 Affected Environment 3-6
3.4.5 Environmental Consequences 3-7
3.4.6 Resource Impact Summary 3-10
3.4.7 Effectiveness of Mitigation Measures 3-10
3.4.8 Cumulative Effects 3-10
3.4.9 Regulatory Compliance 3-10
3.5 American Indian Consultation 3-11
3.5.1 Introduction 3-11
3.5.2 Regulatory Framework 3-11
3.5.3 Analysis Area 3-12
3.5.4 Affected Environment 3-12
3.5.5 Environmental Consequences 3-12
3.6 Cultural Resources 3-13
3.6.1 Introduction 3-13
3.6.2 Regulatory Framework 3-13
3.6.3 Analysis Area 3-14
3.6.4 Affected Environment 3-14
3.6.5 Environmental Consequences 3-15
3.6.6 Regulatory Compliance 3-15
3.7 Fish Habitat 3-15
3.7.1 Introduction 3-15
3.7.2 Regulatory Framework 3-15
3.7.3 Analysis Area 3-17
3.7.4 Affected Environment 3-18

3.7.5 Environmental Consequences 3-19
3.7.6 Resource Impact Summary 3-24
3.7.7 Effectiveness of Mitigation Measures 3-25
3.7.8 Cumulative Effects 3-25
3.7.9 Regulatory Compliance 3-25
3.7.10 Statement of Findings 3-25
3.8 Geology 3-26
3.8.1 Introduction 3-26
3.8.2 Regulatory Framework 3-26
3.8.3 Analysis Area 3-26
3.8.4 Affected Environment 3-27
3.8.5 Environmental Consequences 3-36
3.8.6 Resource Impact Summary 3-41
3.8.7 Effectiveness of Mitigation Measures 3-42
3.8.8 Cumulative Effects 3-42
3.8.9 Regulatory Compliance 3-42
3.9 Hydrology 3-42
3.9.1 Introduction 3-42
3.9.2 Regulatory Framework 3-42
3.9.3 Analysis Area 3-44
3.9.4 Affected Environment 3-45
3.9.5 Environmental Consequences 3-62
3.10 Land Use 3-91
3.10.1 Introduction 3-91
3.10.2 Regulatory Framework 3-91
3.10.3 Analysis Area 3-92
3.10.4 Affected Environment 3-92
3.10.5 Environmental Consequences 3-99
3.11 Recreation 3-102
3.11.1 Introduction 3-102
3.11.2 Regulatory Framework 3-102
3.11.3 Analysis Area 3-102
3.11.4 Affected Environment 3-102
3.11.5 Environmental Consequences 3-106
3.12 Socioeconomics 3-108
3.12.1 Introduction 3-108
3.12.2 Regulatory Framework 3-108
3.12.3 Analysis Area 3-108
3.12.4 Affected Environment 3-108
3.12.5 Environmental Consequences 3-111
3.13 Reclamation Materials 3-112
3.13.1 Introduction 3-112
3.13.2 Regulatory Framework 3-112
3.13.3 Analysis Area 3-113
3.13.4 Affected Environment 3-113
3.13.5 Environmental Consequences 3-115
3.14 Sound 3-122
3.14.1 Introduction 3-122

3.14.2 Regulatory Framework 3-122
3.14.3 Analysis Area 3-122
3.14.4 Affected Environment 3-122
3.14.5 Environmental Consequences 3-123
3.15 Transportation 3-125
3.15.1 Introduction 3-125
3.15.2 Regulatory Framework 3-125
3.15.3 Analysis Area 3-126
3.15.4 Affected Environment 3-126
3.15.5 Environmental Consequences 3-130
3.16 Vegetation 3-135
3.16.1 Introduction 3-135
3.16.2 Native Plant Species and Noxious Weeds 3-135
3.16.3 Proposed, Threatened, Endangered, and Sensitive Plants 3-151
3.16.4 Old Growth Forest 3-157
3.17 Visual/Scenery 3-160
3.17.1 Introduction 3-160
3.17.2 Regulatory Framework 3-160
3.17.3 Analysis Area 3-160
3.17.4 Affected Environment 3-160
3.17.5 Environmental Consequences 3-165
3.18 Wildlife 3-167
3.18.1 Introduction 3-167
3.18.2 Regulatory Framework 3-168
3.18.3 Analysis Area 3-170
3.18.4 Threatened and Endangered Wildlife Species 3-171
3.18.5 Sensitive Wildlife Species 3-192
3.18.6 Management Indicator Species (MIS) 3-219
3.18.7 Migratory Birds 3-230
3.19 Other Required Disclosures 3-231
3.19.1 Environmental Justice 3-231
3.19.2 Important Farmland, Rangeland, and Forest Lands 3-231
3.19.3 Energy Requirements and Conservation Potential 3-232
3.19.4 Urban Quality and the Design of the Built Environment 3-232
3.19.5 Irreversible and Irretrievable Commitment of Resources 3-232
Chapter 4 Consultation and Coordination 4-1
4.1 Preparers and Contributors 4-1
4.1.1 Forest Service 4-1
4.1.2 Department of Environmental Quality 4-1
4.1.3 EIS Consultant Team 4-2
4.2 Consultation and Coordination with Agencies, Organizations, and Individuals 4-3
4.2.1 Federal, State, Tribal, or Local Agencies 4-3
4.2.2 Organizations and Businesses 4-4
4.2.3 Individuals 4-5
Chapter 5 Index 5-1
Chapter 6 List of Acronyms 6-1
Chapter 7 Glossary 7-1
Chapter 8 References 8-1

Tables

Table ES-1 Potentially Substantial Effects by Alternative ES-21
Table 2-1. Comparison of Alternatives 2-19
Table 2-2. No Action Alternative Groundwater Monitoring Sites and Schedule 2-36
Table 2-3. No Action Alternative Surface Water Monitoring Sites and Schedule 2-38
Table 2-4. Proposed Action Road Reclamation 2-49
Table 3-1. Recent Timber Sales within Lake Creek Watershed 3-3
Table 3-2. RHCA Categories and Standard Widths. 3-17
Table 3-3. Interim Riparian Management Objective Standards by Stream Width. 3-17
Table 3-4. Potential Copper Concentrations in Lake Creek Under the No Action Alternative 3-21
Table 3-5. Comparison of Troy and Rock Creek Deposits 3-30
Table 3-6. Water Quality Impaired Streams (2008 Water Quality Integrated Report, DEQ) 3-50
Table 3-7. Water Quality Data for Mine Discharge Water 3-51
Table 3-8. Recent Surface Water Quality Data for Stanley Creek, 2005 – 2009. 3-52
Table 3-9. Surface Water Quality Data for Lake Creek, 2005 – 2009. 3-53
Table 3-10. Surface Water Quality Data in Mine Workings Vicinity, 2000 – 2010. 3-57
Table 3-11. Groundwater Quality Data for Monitoring Wells at Tailings Impoundment, 2000 – 2009 3-59
Table 3-12. Estimated Monthly Mine Water Discharges (cubic feet per second) 3-64
Table 3-13. Land Ownership within Lake Creek Watershed 3-93
Table 3-14. KNF Management Areas within Lake Creek Watershed 3-96
Table 3-15. USFS Management Areas (MA) within Troy Mine Permit Area 3-98
Table 3-16. Selected Demographics, Income, and Employment 3-109
Table 3-17. Montana and Lincoln County Age Classifications and Minority Populations 3-110
Table 3-18. Threatened and Sensitive Species 3-153
Table 3-19. Old Growth Forest Acres Under 5,500 feet Elevation on NFSL in the Analysis Area and Forest-wide 3-158
Table 3-20. Forest Plan VQOs for Analysis Area Management Areas (MA) 3-164
Table 3-21. Forest Plan VQOs for Management Areas (MA) within the Permit Area 3-164
Table 3-22. Threatened and Endangered Wildlife Species Found within the Analysis Area 3-171
Table 3-23. Habitat Component Status for BMU 3 3-175
Table 3-24. Linear Open Road Densities in BMU 3 3-176
Table 3-25. Sensitive Wildlife Species 3-193
Table 3-26. KNF Management Indicator Species 3-220

Figures

Figure ES-1. Project Area ES-2
Figure 1-1. Project Area 1-4
Figure 1-2. Troy Mine Permit Area and Ownership 1-5
Figure 2-1. Tailings Impoundment Area 2-4
Figure 2-2. Office/Shop and Mill Areas 2-5
Figure 2-3. Underground Facilities 2-7
Figure 2-4. Libby Loadout Facility Location 2-8
Figure 2-5. Proposed Surface and Groundwater Monitoring Sites 2-40
Figure 3-1. Regional Geology 3-29
Figure 3-2. Surface Water 3-46
Figure 3-3. Mill Site Drainage Channel Alternatives 3-54
Figure 3-4. Seeps, Springs, and Surface Water Monitoring Sites in the Mine Workings Vicinity 3-56

Figure 3-5. Typical Section of Expected Groundwater Surfaces 3-66
Figure 3-6. Land Ownership within Analysis Area for Land Use 3-94
Figure 3-7. NFSL Management Areas 3-95
Figure 3-8. Recreation 3-104
Figure 3-9. Road System in Analysis Area 3-128
Figure 3-10. Road System Under No Action and Agency-Mitigated Alternatives 3-132
Figure 3-11. Road System Under the Proposed Action 3-133
Figure 3-12. Lake Creek Watershed and Planning Subunits 3-172
Figure 3-13. Bear Management Units 3-174
Figure 3-14. Lynx Analysis Units 3-184

Appendices

Appendix A Scoping Report
Appendix B Mine Water Balance Analysis - Troy Mine
Appendix C Mine Water Management Analysis - Troy Mine
Appendix D Troy Mine Copper Attenuation Study-Secondary Processes
Appendix E Troy Mine Mill Site Conceptual Channel Design
Appendix F Troy Mine Area Surface Water Evaluation
Appendix G Troy Mine Conceptual Design of New Water Line for Transport of Mine Water after Mine Closure
Appendix H Mine Water Plume Location and Identification Phase I Results and Phase 2 & 3 Work Plan
Appendix I Assessment of Natural Attenuation of Metals in a Decant Pond Disposal System

Executive Summary

This Executive Summary provides an overview of the contents of the Draft Environmental Impact Statement (EIS) for the Troy Mine Revised Reclamation Plan. The Draft EIS describes the land, people, and resources potentially affected by the proposed revised reclamation activities. This summary does not provide all of the information contained in the Draft EIS. If more detailed information is desired, please refer to the Draft EIS, its appendices, or referenced reports.

ES.1 Introduction

The United States Department of Agriculture (USDA) Forest Service (USFS) Kootenai National Forest (KNF) and the Montana Department of Environmental Quality (DEQ) have prepared this EIS in compliance with the National Environmental Policy Act (NEPA), the Montana Environmental Policy Act (MEPA), the Metal Mine Reclamation Act (MMRA), and with other relevant federal and state laws and regulations.

In 1978, the Montana Department of State Lands (DSL) and KNF issued a Draft and Final EIS that addressed potential impacts from both the operation and reclamation of the Troy Mine, which is operated by Troy Mine, Incorporated (Troy Mine, Inc.). Troy Mine, Inc. was formerly known as Genesis, Incorporated, and documents prepared under the earlier name referenced in this Draft EIS are attributed to Genesis.

In the fall of 1999, DEQ and KNF (the Agencies) initiated a review of the Troy Mine reclamation bond. DEQ and KNF notified the mining company that the approved 1978 reclamation plan needed to be revised and a substantial bond increase would be required. The mining company prepared a revised reclamation plan and the final draft was submitted to the Agencies in March of 2006 (Genesis 2006). The 2006 Revised Reclamation Plan is the subject of this Draft EIS and is referred to as the Proposed Action.

ES.1.1 Project Area Description

The Troy Mine is located about 15 miles south of Troy, Montana, in Lincoln County (Figure ES-1). The nearest towns to Troy are Libby, Montana, located 18 miles to the east and Bonners Ferry, Idaho (ID), located 33 miles to the west. The project area lies within the KNF immediately west and north of Bull Lake and is within the Stanley, Lake, and Ross creek drainages.

The Troy Mine is accessible from Montana Highway 56 (MT 56) and National Forest System Road (NFSR) 4626. The mine permit area covers 2,782 acres of public, private, and patented land. Approximately 57 percent of the project area is on private and patented land, and the other 43 percent is on the KNF.

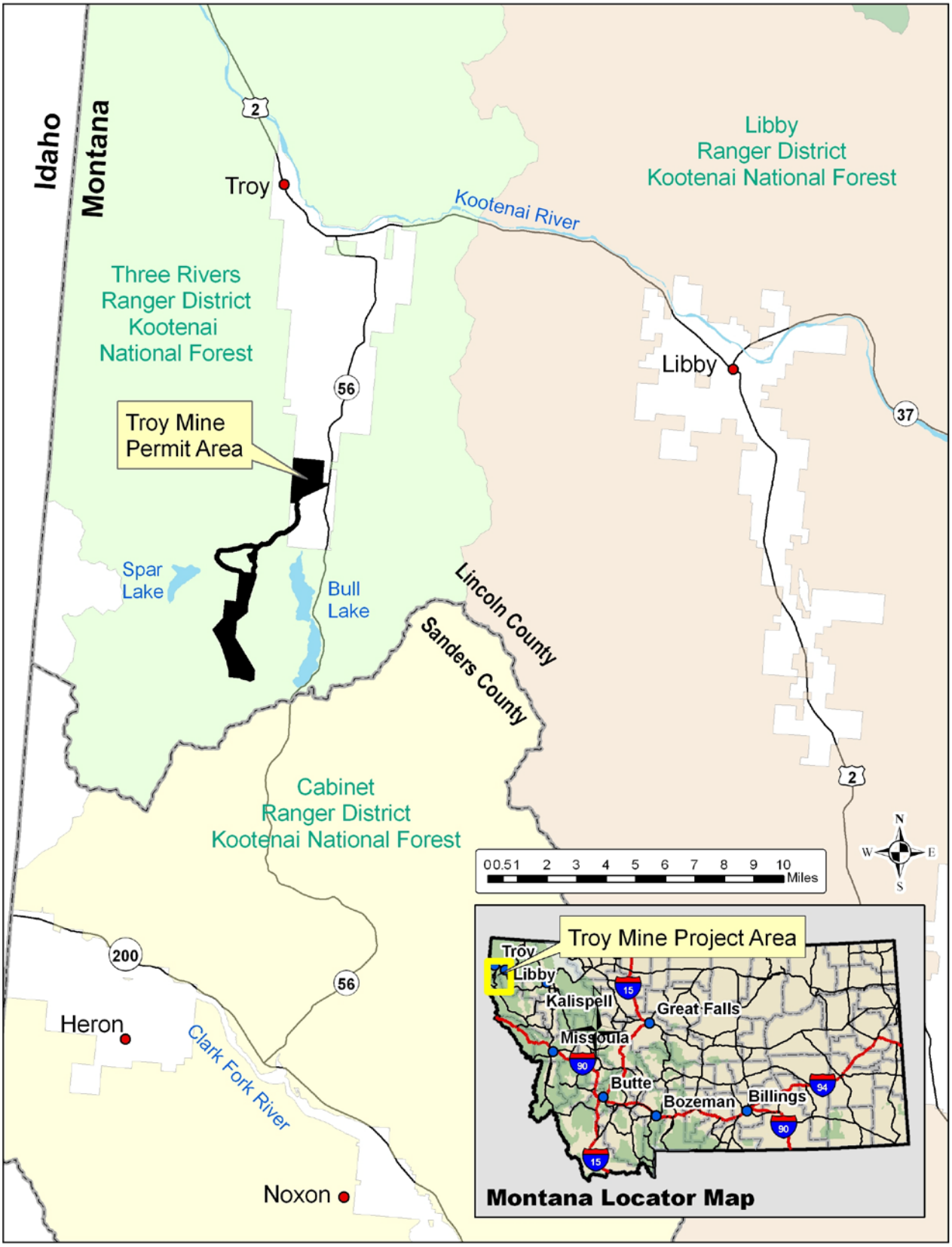

Figure ES-1. Project Area

The mine facilities consist of an underground mine, the mill, and various office facilities; the tailings and reclaim water pipelines; a power line; a tailings impoundment; and associated support facilities. The tailings facility and associated disturbances are on approximately 430 acres of disturbed area on private land owned by Troy Mine, Inc. Both the tailings and reclaim water pipelines and the power line are on National Forest System Lands (NFSL), private, and patented land. The South Adit portal is located on patented land, while the North Adit portal and the mill and office/shop facilities are located on unpatented claims on NFSL. There are approximately 15.6 acres of disturbed land at the portal patios and 34 acres of disturbed lands at the mill site. Associated roads, pipelines and other small disturbed areas exist throughout the project area.

ES.2 Purpose and Need

The purpose of the proposed reclamation plan is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. The approved 1978 reclamation plan does not meet state or federal requirements for mine water discharge. The need for the revised reclamation plan stems from several objectives that need to be met after mine closure:

- Reclamation plans must meet state and federal requirements;
- Protection of surface and groundwater quality;
- Protection of public health and safety;
- Minimization of environmental risk; and
- Restoration of productive land use.

ES.3 Scope of Decisions To Be Made

The major state and federal actions include approval of a reclamation plan and any necessary permits to implement the reclamation activities including construction and long-term monitoring.

ES.3.1 Kootenai National Forest

KNF's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for the Troy Mine. To satisfy this request, KNF must:

- Select an alternative that meets the requirements of 36 Code of Federal Regulations (CFR) 228.8 which directs that all mining operations shall be conducted to minimize adverse environmental impacts on National Forest surface resources where feasible;
- Ensure implementation of the selected alternative would assist in preserving and maintaining forest resources to meet the long-term management goals of the 1987 Land and Resource Management Plan (Forest Plan), as amended; and
- Ensure compliance with other applicable federal laws.

KNF also has responsibility jointly with DEQ to review, analyze, and calculate the reclamation bond amount.

The KNF Forest Supervisor will use the EIS process to develop the information necessary to make an informed decision as required by 36 CFR 228, Subpart A. Based on the information presented and alternatives developed in this EIS, the KNF Forest Supervisor will issue a Record of Decision (ROD) on Troy Mine, Inc.'s proposal.

The ROD would document the Forest Supervisor decision on one of the following:

- No Action Alternative
- Approval of the Revised Reclamation Plan as submitted (the Proposed Action) as an amendment to the existing Plan of Operations for the Troy Mine, or
- Approval of a Revised Reclamation Plan (Agency-Mitigated Alternative), as an amendment to the existing Plan of Operations for the Troy Mine. The amendment would incorporate mitigations and stipulations to meet the mandates of applicable laws, regulations, and policies.

ES.3.2 Montana Department of Environmental Quality

DEQ's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for Troy Mine. To satisfy this request, DEQ must determine whether the Revised Reclamation Plan satisfies the requirements of the MMRA, Title 82, Chapter 4, Part 3, Montana Code Annotated (MCA).

The DEQ Director will use the EIS process to develop the information necessary to determine whether the Proposed Action meets the performance standards of the MMRA, including but not limited to:

- The removal of buildings and other structures at closure consistent with the post-mine land uses;
- Post-closure environmental monitoring programs and contingency plans;
- Compliance with state air and water quality standards.

The DEQ Director would issue a ROD documenting the decision on the reclamation proposal.

ES.4 Public Involvement

At the beginning of the NEPA/MEPA process, the Agencies conducted scoping to solicit public input on the purpose and need and the Proposed Action. A public scoping meeting was held in October 2007. The scoping process is described in a Scoping Report for the project. Based on the comments received during agency and public scoping, a number of major issues were identified that drove the development of alternatives to the Proposed Action.

At the time of the scoping, the project team determined that an environmental assessment (EA) would be produced to document the analysis. During the course of preparing the EA, several potential water quality issues were identified that are of sufficient significance to warrant the preparation of an EIS. These issues include the potential for mine water discharge to impact surface water and potentially

exceed aquatic life standards; the potential for the tailings pipeline to fail potentially resulting in erosion and discharge of contaminants into Stanley or Lake creeks; and issues related to the long-term maintenance of the pipeline. Given these potential issues, the Agencies issued a Notice of Intent to prepare an EIS in the Federal Register on April 14, 2011.

ES.5 Issue Identification and Alternative Development

Issues were identified through the agency and public scoping process, through the Agencies' review of the *2006 Revised Reclamation Plan*, and through interagency discussions on the development of alternatives. Issues were evaluated to determine whether the proposed action or an alternative would result in significant impacts. The Council on Environmental Quality (CEQ) regulations define significant impacts in terms of both context and intensity (40 CFR 1508.27). MEPA also provides direction on determining the significance of impacts similar to the definitions used under NEPA (ARM 17.4.608(1), MCA 75.1.201).

Major issues are those for which:

- there may be potentially significant impacts;
- there is a concern about potential effects directly or indirectly resulting from implementation of the Proposed Action; or
- there is a concern about the effectiveness of proposed mitigation measures.

The major issues identified include:

Water Management

- Adit closure and mine water distribution;
- Water treatment and disposal;
- Groundwater quality;
- Surface water quality; and
- Long-term monitoring of water quality

Reclamation

- Reclamation materials;
- Subsidence;
- Revegetation;
- Infrastructure (buildings and other structural materials and how they will be removed or reclaimed); and
- Topography (disturbed areas)

ES.6 Alternatives

Three alternatives were developed and evaluated in this EIS. The No Action Alternative consists of the 1978 Reclamation Plan that was previously approved and the reclamation work that has been

completed through August of 2010 by Genesis (now Troy Mine, Inc.). The Proposed Action describes the Revised Reclamation Plan submitted by Genesis to the Agencies in March of 2006. The Agency-Mitigated Alternative was developed by the Agencies and is based on issues derived from interagency and public scoping comments on the Proposed Action.

ES.6.1 No Action Alternative

The original reclamation plan was first analyzed in the *1978 Draft Environmental Impact Statement* (DSL and KNF 1978) and later approved by the Agencies. It does not directly address many of the issues identified through scoping.

ES.6.1.1 Water Management

Adit closure and mine water distribution

The No Action Alternative proposes to close the adits by plugging them with concrete. After mine closure, surface and groundwater would be expected to accumulate in the mine, eventually discharge onto the portal patios and infiltrate into groundwater, and ultimately enter Stanley Creek.

Water treatment and disposal

The No Action Alternative does not address water treatment.

Toe ponds at the base of the tailings impoundment capture seepage and embankment runoff which is then pumped to the impoundment. This pumping would not continue long-term after reclamation. Surface drainage would be from the low point of the impoundment surface to an appropriate natural drainage.

Groundwater quality

The No Action Alternative does not address groundwater quality beyond operational monitoring. Groundwater would enter the mine, flood the workings, and eventually exit the mine and discharge into the groundwater system and Stanley Creek.

Surface water quality

Under the No Action Alternative, seven existing water quality monitoring stations on Stanley, Fairway, and Lake creeks would continue to be sampled post-reclamation for flow and water quality three times per year until the Agencies agree that monitoring is no longer necessary.

Other than monitoring, management of water quality is not addressed under the No Action Alternative. Precipitation would enter the mine through fractures, the workings would flood, and the water would eventually exit the mine and discharge into Stanley Creek.

Long-term monitoring of water quality

Monitoring includes periodic water level and water quality sampling of monitoring wells, springs, and areas of groundwater expression in the vicinity of the mine.

As part of the baseline sampling program, two test wells were drilled in July of 1976. Surface water quality has been monitored at seven sites on Stanley, Fairway, and Lake creeks since 1986. Five

additional surface water sites are sampled and represent the farthest upgradient expressions of groundwater in drainages around the mine. These sites were chosen to monitor changes in the quality of groundwater discharging to surface drainages. These monitoring wells and sites would continue to be evaluated to determine potential mine water influence on surface and groundwater under the No Action Alternative.

Surface water quality monitoring as described above would continue post-reclamation three times per year until the Agencies agree that monitoring is no longer necessary.

ES.6.1.2 Reclamation

Reclamation materials

Soil salvaged from the west side of the tailings impoundment would be used to provide an average 12-inch cover over the portal patio at the mine and at those areas where buildings and facilities would be removed.

The surface of the tailings impoundment and the embankment would be covered with 18 inches of stockpiled soil and revegetated. The No Action Alternative does not specifically identify the source of these stockpiled soils. The soil needed to complete reclamation would likely come from the soil stockpiled from the construction of the tailings facility.

Subsidence

Subsidence was not addressed as part of the original 1978 reclamation plan. However, during operations, two surface subsidence features developed along the East Fault and a permit revision was issued to address these subsidence issues. Although the Agencies currently hold a bond for reclamation of possible future surface subsidence, it may not be sufficient to cover mitigation for surface subsidence on steep slopes.

Revegetation

The No Action Alternative proposes a mixture of introduced grasses and legumes, native shrubs, and trees to cover all disturbed areas upon reclamation. Soils would be seeded during the first appropriate growing season after necessary surface grading and preparation has been completed. Areas would be fertilized at 200 lb/acre and mulched on south-facing slopes.

Slopes and benches of the tailings embankment would be capped with an average of 18 inches of reclamation material. The tailings impoundment surface would have 18 inches of stockpiled lacustrine and volcanic ash-derived soil materials spread on the surface.

Ponderosa pine, Douglas-fir, western larch, and shrubs would be planted on embankment benches and the tailings impoundment. A grass and legume seed mix would be applied to provide complete vegetative cover. Container-grown tree seedlings would be planted (680 trees/acre density) with container-grown shrubs interspersed among the trees. In 1997 and 1999, 3,750 trees were planted on the northeast face of the slope below the North Adit.

The No Action Alternative calls for stockpile sites to be revegetated and planted with trees and shrubs after the soil has been used for reclamation.

Fertilization and irrigation would depend on reclamation progress. The operational irrigation system includes large irrigation sprinklers and aluminum sprinkler pipe.

Noxious weeds have invaded disturbed sites at the mill site, the tailings line corridor on road cuts and fills, and along the periphery of the tailings facility. There is a current noxious weed control plan approved by Lincoln County and KNF in place. The No Action Alternative would continue the current noxious weed control plan which includes chemical weed control.

Under the No Action Alternative, there is no provision to monitor dust or to minimize the potential for blowing dust through irrigation or revegetation.

Infrastructure

Buildings and all materials would be removed from the project area under the No Action Alternative including removal of the tailings pipelines, the reclaim water line, and the 115 kV transmission line. Disposition of underground equipment is not addressed in the No Action Alternative.

The No Action Alternative would leave the main mine access road (NFSR 4626) open for public recreation access to Spar Lake and Mt. Vernon although the gate would remain at the mill site limiting motorized access. All other roads would be removed and reclaimed, pending approval of KNF.

Topography

Under the No Action Alternative, the surface of the tailings impoundment would be graded and reworked to provide areas suitable for revegetation, but no changes in the configuration of the tailings embankment are proposed.

The benches at the mill site would be left flat or nearly flat. The cut and fill slopes would be regraded and re-established at 1.5 horizontal to 1 vertical (1.5H:1V) slopes. The northeast face of the slope below the North Adit has already been recontoured and revegetated.

At the mine itself, the slopes of the development rock fill patio would remain at their existing angle-of-repose. The surface and edges of the patios would be graded to both distribute surface water runoff and to prevent erosion.

Regrading of the borrow sites once excavations are complete is not addressed in the No Action Alternative.

ES.6.2 Proposed Action

The Revised Reclamation Plan, which is the Proposed Action under this EIS, was submitted to DEQ and KNF in March of 2006. The Proposed Action would reclaim the land to allow current or historic activities to continue or resume once reclamation has been completed.

Under the Proposed Action, the proposed reclamation would be accomplished in three phases: pre-closure, closure, and post-closure. Pre-closure tasks include on-going monitoring, testing, and evaluations necessary to complete design of reclamation elements. Closure tasks would take place two years after final cessation of mining and would include facility removal, regrading, revegetation, and maintenance of short-term components of the water management plan. Adit plugs would be installed during the closure period. Post-closure tasks would include management of mine water flowing through pipelines, maintenance of pipelines, and monitoring of water quality (mine water and surface/groundwater). Under the Proposed Action, the post-closure phase is estimated to last two to five years after mining ends.

ES.6.2.1 Water Management

Adit closure and mine water distribution

The Proposed Action would seal all mine openings against entry by backfilling with mine development rock or with material obtained during regrading of the portal areas. Backfill would be placed from the adit opening back 30 feet into the adits and tight to the roof. Rock remaining after adit plugging would be graded against the side of the slope to form a wedge. Two concrete non-hydraulic plugs would be constructed in the Service and Conveyor adits to funnel water into the collection pipe for conveyance to the decant ponds. No access to this pipe intake would be provided. No concrete plugs are proposed for the remaining adits.

Under the Proposed Action, the two tailings pipelines would be retained to convey water from the mine site to the decant ponds. Once the mine water is of sufficient quality for direct discharge to Stanley Creek, the portions of the tailings pipelines that are buried less than three feet deep would be removed. In the event that the pipeline in use needs repair, water would be diverted through the other pipeline until the first pipeline is repaired or replaced.

Two separate stream channels would be constructed across the mill pad and down the fill slope. Channels would be armored with coarse rock sides to provide stability in 100-year, 24 hour storms. An energy dissipation basin would be created at the toe of the fill slope.

Drainage from the tailings impoundment would continue to the decant ponds and would not be directed to a natural drainage.

Water treatment and disposal

The Proposed Action would route mine pool water through the tailings pipelines to the decant ponds until natural attenuation processes remove nitrogen and copper compounds to an acceptable background quality. The Proposed Action would also continue to use the toe ponds to capture seepage and embankment runoff. After reclamation, snowmelt and runoff from the toe ponds would be pumped to the impoundment to supply irrigation water for the newly-reclaimed surface, if needed, or directly to the decant ponds.

Groundwater quality

The Proposed Action includes continued use of the decant water disposal system to passively and effectively achieve metal attenuation in the mine water. The monitoring plan would include groundwater monitoring to evaluate potential sources of groundwater seepage from the mine as it floods.

Surface water quality

The Proposed Action water quality monitoring plan includes both annual macroinvertebrate monitoring and water quality and flow monitoring three times per year. This water quality monitoring program would continue under the Proposed Action until such time as the Agencies agree that monitoring is no longer necessary. The surface water quality monitoring sites that would be sampled are the same sites as those identified under the No Action Alternative.

The Proposed Action would also retain the toe ponds as permanent features to provide wildlife and wetlands habitat. After operations have ceased, the toe ponds would be connected by inter-pond channels. Although no discharge from the toe ponds is expected, an armored outfall would nonetheless be installed to protect against erosion. No channel to Lake Creek would be constructed.

Storm water runoff would continue to be directed to the decant ponds and the tailings would be contoured to maintain the general flow direction toward the decant ponds.

Long-term monitoring of water quality

The Proposed Action long-term surface and groundwater quality monitoring plan is the same as the No Action Alternative plan.

ES.6.2.2 Reclamation

Reclamation materials

As necessary, all reclamation materials would have chemical fertilizers added to promote successful revegetation. The Proposed Action would not add organic matter to any reclamation materials.

The Proposed Action would leave the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to provide wildlife and wetlands habitat where they would act as a berm to maintain the toe ponds and to minimize the potential for sediment to reach Lake Creek. Reclamation materials for the tailings impoundment surface would be obtained from the borrow sites which are located east of the impoundment. The tailings facility surface would be covered with an average of 18 inches of growth medium.

The Proposed Action would cover development rock at the portal patios with a 12-inch layer of a finer-grained growth medium from local borrow sources to promote revegetation. However, the Proposed Action does not directly identify potential local borrow source locations.

Under the Proposed Action, the tailings embankment would be inspected annually. This geotechnical monitoring would continue until Troy Mine, Inc. and the Agencies agree to discontinue it.

Subsidence

Subsidence was not addressed as part of the Proposed Action.

Revegetation

Several different plant species mixes would be developed and vegetation types would be applied based on pre-mine occurrence, establishment potential, growth characteristics, soil stabilization qualities, commercial availability, experience from on-site tests, and post-mine land use objectives. Native species would be emphasized and noxious weed-free seed would be used. A wetland mix would be provided for designated areas. Annual ryegrass would be added to forest mixes to provide initial rapid stabilization.

A lower elevation forest mix would be seeded over the majority of the tailings surface, with the addition of some grassland and wetland mix. An upper elevation forest mix would be applied to the portal patios and the mill site office and shop area. Smaller disturbed areas would be planted with a grassland mix and would rely on natural establishment of woody species.

Under the Proposed Action, the borrow sites would be reclaimed after completion of all excavation activities. Impoundment-area borrow sites would be planted with the lower elevation forest species mix and the USFS borrow site would be revegetated with plant species typical of upper elevation forest types.

Fertilizer would be applied except within 200 feet of a perennial stream; mulching would be applied to slopes steeper than 20% with less than 50% coarse fragments. Irrigation may be used during the first season to ensure initial stand development (except for slopes steeper than 10% or upper elevation sites). The operational irrigation system would be used under gravity pressure to irrigate during the first growing season so that pumps would not be needed.

Under the Proposed Action, monitoring of revegetation would occur during the pre-closure and closure phases of mine operation. If poor vegetation growth is noted, additional site remediation would occur.

Similar to the No Action Alternative, the approved noxious weed control plan would continue to be implemented and chemical weed control may continue as needed.

Best Management Practices (BMPs) and irrigation would be used as needed to suppress dust until vegetation is established.

Infrastructure

The Proposed Action would rip asphalt from parking areas and bury it on site with a minimum of three feet of cover material. The buildings would be demolished and materials such as concrete, metal, glass, plastic, and wood would be buried on-site with a minimum of three feet of cover material. Fuel, water, and other tanks would be removed from the site.

Under the Proposed Action, underground equipment would be salvaged if possible. If a salvage market cannot be found, this equipment would be cleaned, all fluids would be removed, and the equipment would be abandoned in place.

The Revised Reclamation Plan states that any existing USFS roads would remain in place per USFS requirements. The Agencies interpret this requirement to mean that no roads are proposed for reclamation under the Proposed Action. The gate would remain in place at the mill site limiting access to non-motorized modes.

The existing storm water collection system would remain in place during the entire building demolition phase, with additional BMPs employed (such as silt fences to control erosion and protect surface water from runoff). The final grading plan would use diversion ditches, culverts, velocity control structures, and riprap in high runoff areas to reduce the potential for sedimentation in Stanley Creek.

All surface pipelines would eventually be removed and salvaged. The two operational 8-inch steel tailings pipelines would be used in succession to pipe mine water to the tailings facility until they wear out or until water quality improves enough to permit discharge into Stanley Creek. Once the pipelines are no longer needed, any sections that are buried less than three feet deep would be removed.

The main power line is the property of Northern Lights Inc. which would have the final decision on removal or preservation of all or portions of the 115-kV power line.

Topography

Slopes of the portal patios would be regraded by pulling the edges up and filling against the cut slope/roadway. Flat areas would be covered with 12 inches of growth medium. The mill site and office and shop areas would be regraded similar to the No Action Alternative except that some demolition debris would be buried on site.

The tailings embankment would be treated in the same manner as under the No Action Alternative. The toe ponds would be connected by inter-pond channels with an armored outfall. Once ore milling has ceased, the tailings impoundment surface is expected to slope to the east in a manner that allows surface water to flow to the eastern edge of the impoundment and into the decant ponds, where it would infiltrate and recharge groundwater. Therefore, no surface regrading would occur under the Proposed Action.

Impoundment-area borrow sites would be graded to reduce slopes to 2H:1V and to establish upper slope diversion ditches. The USFS borrow site would be regraded to blend in with the surrounding topography.

When mine water is no longer routed to the tailings facility, the decant ponds would be regraded to form one shallow depression which would be able to capture runoff from the tailings facility surface and to prevent surface water runoff from leaving the impoundment.

ES.6.3 Agency-Mitigated Alternative

The Agency-Mitigated Alternative is based upon the Proposed Action, but includes additional mitigation measures and monitoring requirements that address major issues identified during the earlier scoping and Interdisciplinary Team (IDT) review process.

ES.6.3.1 Water Management

Adit closure and mine water distribution

The Agency-Mitigated Alternative would plug the South Adit with development rock for approximately 130 feet into the adit (100 feet farther than the Proposed Action). Concrete intake structures would be installed in both the Service and Conveyor adits to capture mine water and to funnel it to the collection pipelines. Closure devices would be installed to prevent unauthorized public access to the Service and Conveyor adits and to allow for periodic cleanout of the intake structures.

A new, buried, mine water pipeline with an automatic leak detection system would replace the two existing 8-inch surface tailings pipelines. The original 10-inch reclaim water line would remain in place for use as an emergency water conveyance line and it also would be retrofitted with a leak detection system. The new pipeline would be buried or double-lined at stream crossings to minimize risk to surface and groundwater systems. In the unlikely event that the pipeline capacity of both lines is exceeded, mine water would flow over the concrete intake structures in the Service and Conveyor adits and would pass through the rock backfill.

A channel would be constructed from the Service and Conveyor adits to the mill site stream channels for emergency overflow from the adits in case the design capacities are ever exceeded. At the mill site and office and shop areas, only one stream channel would be constructed (rather than two under the Proposed Action). The channel would be lined with an impervious liner and rock used in the channel would be sized for the 100-year flow and would not include development rock.

Should mine water be of sufficient quality for direct discharge to surface water without treatment, it would be rerouted to a designed channel to discharge to Stanley Creek. At that time, both the new mine water and the old reclaim pipelines buried less than three feet deep would be removed, and the pipeline corridor and decant pond would be reclaimed.

Water treatment and disposal

Under the Agency-Mitigated Alternative, the ponds would be maintained as deep ponds in order to maintain geochemical functions that facilitate metals attenuation. A berm would be created to prevent storm water runoff from the tailings impoundment surface from draining directly to the decant ponds.

Groundwater quality

The Agency-Mitigated Alternative would be the same as the Proposed Action and continue the seepage pumping activities at the toe ponds until water quality standards are met. Any monitoring wells would be plugged and abandoned per ARM 36.21.810.

Surface water quality

There would be additional monitoring of seeps and springs at the mine during closure to verify whether state water quality standards have been met.

Long-term monitoring of water quality

In addition to the water quality monitoring described for the Proposed Action, the Agency-Mitigated Alternative would include post-closure water quality monitoring for a minimum of five years after mine water discharge actually commences. One additional surface water monitoring site would be added on upper Stanley Creek and four additional monitoring wells in the vicinity of the decant ponds would be added to verify that geochemical conditions in the area of mine water discharge are maintained.

ES.6.3.2 Reclamation

Reclamation materials

The Agency-Mitigated Alternative would use the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to cover the tailings facility. The lowest portion of the vegetated outer slopes of the stockpile would be maintained to minimize water runoff and to prevent sediment from leaving the majority of the disturbed stockpile surface. A field review of existing reclamation would be conducted to determine if additional soil would need to be spread on the embankment face and benches where soil is thin and revegetation is not adequate.

At the mill site, the Agency-Mitigated Alternative growth medium soil would be the same as in the Proposed Action, but the USFS borrow area material would not be used because of the presence of rush skeletonweed. Both the North and South portal patios would be covered with growth medium from the mine and mill areas.

Growth material would be amended with an agency-approved, wood-based, organic amendment to raise the organic matter content to achieve 1,100 lbs of nitrogen per acre. At the tailings impoundment, this organic amendment would be tilled in to a depth of six inches and at the mine and mill site it would be tilled into the top 12 inches of reclamation material.

Growth medium would be placed on the tailings impoundment in one lift to prevent compaction. All growth media placed for reclamation would be ripped to loosen soil before seeding takes place.

Geotechnical monitoring of the tailings embankment would be conducted by a qualified professional engineer for a minimum of five years after reclamation is completed.

Subsidence

The existing surface subsidence feature that has not achieved a level of stability and utility comparable to the pre-disturbance condition would be reclaimed prior to mine closure. The reclamation bond would be increased to address the possibility of future subsidence on steep terrain. Annual inspections would be conducted to identify new surface subsidence features.

Revegetation

Species mixes would be adjusted to account for site-specific conditions as proposed under the Proposed Action. However, a wetland mix would not be used on the tailings impoundment and trees would be planted there as described in the No Action Alternative. Seed sources for native plant species would be

from northwestern Montana to the extent that these species are commercially available at the time of reclamation. Chemical fertilizers would not be used under the Agency-Mitigated Alternative.

The Agencies would perform a field review of previously reclaimed areas to determine if areas need additional cover materials, revegetation, or reseeding.

Noxious weeds would be controlled in conformance with the approved weed control plan.

Revegetated areas would be monitored until the requirements for bond release are met. Monitoring would also continue until vegetation is sufficiently established to maintain air quality.

Infrastructure

Asphalt from the parking lots and other paved areas would be crushed and used for road gravel on NFSR 4626 or hauled to an approved landfill off NFSL. All demolition materials, whether originating above or below ground, would be disposed of off NFSL in appropriate disposal areas to comply with the Montana Solid Waste Act. Underground equipment would be removed or abandoned in place as under the Proposed Action except that any equipment on NFSL would be removed.

Roads would either be maintained to minimize sediment delivery to surface waters or they would be treated per KNF specifications. Specific road treatments by road segment are described in the Draft EIS.

Water diversion culverts at the mill site would have both ends plugged with concrete, and culverts under roads would be left in place.

Topography

Portal patios would be regraded similar to the Proposed Action, but all growth medium for the mine and mill area would be salvaged from the mill site fill or from the borrow area east of the impoundment. All demolition debris would be disposed of off NFSL in appropriate disposal areas.

All drainage channels would be constructed from imported non-mineralized rock rather than from mine development rock to minimize the potential for metal leaching. Alignment of the larger drainage channel would be down the angle-of-repose mill fill slope. A third channel would be designed from the Service and Conveyor adits to connect with the mill site drainage channels for overflow from the adits if the design capacities are ever exceeded.

A qualified engineer would annually monitor and verify the stability of the embankment for a minimum of five years after reclamation is completed. All eroded or bare areas on the embankment would be repaired by spreading 12 inches of the stockpiled growth medium. The toe ponds would be treated as under the Proposed Action except that non-native fish species may be removed.

Grading of borrow sites and decant ponds would be as described in the Proposed Alternative.

ES.7 Environmental Consequences

The following sections provide a summary of the effects of implementing each alternative. Information is focused on activities and effects where different levels of effects can be distinguished between alternatives. Detailed effects analyses for each alternative are found in Chapter 3 of the Draft EIS.

Reclamation activities were found to have minimal to no effect on several of the resource areas analyzed and there were minimal differences between the potential effects of each alternative. These resource areas include air quality, cultural resources affiliated with tribal groups, traditional cultural properties, historic resources, land use, recreation, socioeconomics, sound, and visual scenery. Many of these same resource areas would experience a net positive benefit from reclamation over the long-term, including air quality, land use, recreation, socioeconomics, sound, and visual scenery. These resource areas are not discussed further in this summary and a more detailed description of potential effects is found in Chapter 3 of the Draft EIS.

Resource areas where there could be potentially substantial impacts under one or more alternatives include fish, geology, hydrology, reclamation materials, transportation, vegetation, and wildlife. The differences in potential effects between alternatives for these resource areas are described in the sections below. Potentially substantial impacts are summarized in Table ES-1.

ES.7.1 Fish

Potential impacts on fish could occur from sediment delivery to creeks and from water quality impacts.

The No Action Alternative and the Agency-Mitigated Alternative would temporarily increase sediment delivery to Stanley, Ross, and Lake creeks during reclamation activities but would reduce sediment loads and improve fish habitat over the long-term through road treatment. Sediment increases in Ross and Lake creeks would be small relative to existing sediment loads and would not result in measurable effects to cutthroat or bull trout habitat or populations**.** The Agency-Mitigated Alternative would introduce the smallest amount of sediment to stream channels due to design features and mitigation measures such as timing restrictions within Riparian Habitat Conservation Area (RHCAs).

The Proposed Action would deliver the greatest amount of sediment to streams because roads would not receive treatment under this alternative. Any additional sediment from these sources would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact water quality for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment.

The No Action Alternative would discharge mine water directly to Stanley Creek that could exceed current surface water quality standards and could potentially impact macroinvertebrate, tailed frog, and brook trout abundance. Both the Proposed Action and the Agency-Mitigated Alternative would route mine water discharge to the decant ponds where natural attenuation mechanisms would provide long-term water quality treatment. The Proposed Action would use the existing tailings pipelines which are 30 years old. These pipelines have the potential to break allowing a large volume of adit water and sediment to reach Stanley Creek and/or Lake Creek until the pipeline could be shut off and repaired.

The Agency-Mitigated Alternative would mitigate this potential effect by constructing a new pipeline with an automatic leak detection system and would retain the existing buried line as a backup system. The Agency-Mitigated Alternative would include long-term maintenance of the water treatment/management system and monitoring of seeps and springs to detect potential water quality issues in a timely manner. The Agency-Mitigated Alternative would avoid potential surface water impacts by using only rock with little or no potential for near-neutral metal leaching in reconstructed stream channels.

ES.7.2 Geology

Geology effects include consideration of how the geochemical composition of the geologic materials would affect revegetation success, mitigation for potential subsidence events, and effects of reclamation on topography.

In all three reclamation alternatives, the geology and geochemical composition would have minimal impact on revegetation success. There are some differences between alternatives in the selection of materials for reclamation in different parts of the project area. Under the Agency-Mitigated Alternative, no additional measures would be required to mitigate geochemical impacts to reclamation success. The use of the rocky glacial and the lacustrine and volcanic ash-derived soils as growth media would minimize root contact with mined materials. This would effectively minimize the potential effects of plant uptake of metals from the development rock and tailings.

After mine closure, another subsidence event could occur regardless of the alternative selected. However, only the Agency-Mitigated Alternative includes an adequate range of practicable mitigation measures to address potential subsidence events.

Similarly, all three alternatives would provide a net positive effect to local topography through increased soil stability, erosion resistance, and storm water control. Regrading would not return the mine area or the tailings impoundment area to pre-mine conditions, but revegetation would soften the man-made appearance. The portal patio slopes would resemble talus slopes, and the tailings impoundment would resemble a terrace above Lake Creek. The Agency-Mitigated Alternative would use the most appropriate technology currently available including engineering and reclamation practices that have been proven effective to stabilize soils, minimize erosion, and to limit infiltration into mined materials containing metals.

ES.7.3 Hydrology

The No Action Alternative would not comply with the Federal Clean Water Act, Montana Water Quality Act, USFS policy, or with the Kootenai National Forest Plan because untreated mine water that would exceed water quality standards would be discharged to surface water. Moreover, moderate to high sediment delivery is likely from the mill site, mine portals, and from the tailings impoundment following the proposed reclamation.

In contrast, mine water disposal under either the Proposed Action or the Agency-Mitigated Alternative would reduce potential water quality impacts to Stanley Creek and to upper Lake Creek. Under both the

Proposed Action and the Agency-Mitigated Alternative, the mine discharge would be routed to the decant ponds for treatment. At the decant ponds, the water would infiltrate and be treated by natural attenuation mechanisms along the groundwater flow path to reduce concentrations of constituents of concern to levels that would meet water quality standards. There is a greater risk of short-term water quality violations under the Proposed Action because of the higher risk of accidental discharge of mine water from failure of the tailings pipeline to Stanley or Lake creeks. The likelihood of surface water quality impacts would be further reduced under the Agency-Mitigated Alternative by installing a new buried mine water pipeline with a leak detection and backup system for mine water transport.

Stanley and Lake creeks have been listed on the TMDL 303d list as impaired streams. Probable causes of impairment of Stanley Creek are copper and nutrients. Probable causes of impairment of Lake Creek are nutrients, sediment, and physical substrate habitat alterations. Because nitrate concentrations would decrease after blasting ceases, closure and reclamation of the mine would reduce nutrient loading to surface water under all alternatives. After mine closure, there would be reduced risk of spills of mine tailings into surface water under all alternatives. The No Action Alternative would result in increased copper loading from mine water discharge to Stanley Creek and would not accomplish the goals of the TMDL program. Both the Proposed Action and the Agency-Mitigated Alternative would reduce the potential for loading of copper to Stanley Creek.

Reclamation of mine roads on NFSL under the No Action and Agency-Mitigated alternatives would reduce sedimentation and siltation in Lake Creek over the long-term. The Proposed Action would not reduce sedimentation and siltation in Lake Creek over the long-term because it would not treat unneeded roads. Under the Proposed Action, sediment would also originate from stream erosion across the mill site. Any additional sediment from untreated roads and stream erosion across the mill site would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact beneficial uses for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment.

ES.7.4 Reclamation Materials

All three alternatives would provide reclamation of disturbed sites. The growth medium replacement plans for the tailings impoundment under the No Action and Agency-Mitigated alternatives would produce the best long-term results in terms of soil quality and plant productivity. The necessary volume of soil already exists in the soil stockpiles, and the glacial outwash borrow materials would not be needed under either of these alternatives. No additional disturbance would occur in the glacial outwash borrow areas under these two alternatives. The Agency-Mitigated Alternative would use BMPs not included in the No Action Alternative to minimize potential impacts of erosion to Lake Creek and to the toe ponds that could possibly result from use of stockpiled materials. Under the No Action Alternative there may still be issues with erosion of fine-grained soils that would not be stable on slopes over eight percent in the mine and mill area.

The No Action Alternative and the Proposed Action would use chemical fertilizers as needed to improve productivity. The Agency-Mitigated Alternative would use organic, wood-based amendments to improve the nitrogen content of the growth media. The Agency-Mitigated Alternative would also

require appropriate soil testing to identify other amendments, such as organic fertilizer, that may be needed to increase soil quality and revegetation success.

The MMRA requires the reclamation of all disturbed lands to comparable stability and utility as that of adjacent lands. The No Action and Agency-Mitigated alternatives would reclaim all mining lands to comparable stability and utility; however, the Agency-Mitigated Alternative would achieve these goals more effectively and would use the soil materials that were stockpiled prior to construction of the tailings impoundment. The Proposed Action would not produce comparable utility on the reclaimed tailings impoundment.

ES.7.5 Transportation

Under all three alternatives there would be a substantial reduction in traffic after reclamation activities are completed. This reduction in traffic would reduce road maintenance costs on local road networks.

The Proposed Action maintains the existing road system and related road maintenance costs. The No Action and Agency-Mitigated alternatives implement BMPs on 19.2 miles of road needed for long-term access (includes stabilization for intermittent stored service) and decommission 6.5 miles of unneeded road, thereby reducing long-term road maintenance costs as compared to the Proposed Action. The Agency-Mitigated Alternative further reduces long-term road maintenance costs by replacing the 6 miles of paved surface on NFSR 4626 with gravel.

ES.7.6 Vegetation

There would be little new disturbance from implementing any of the reclamation alternatives. In general, all three alternatives would revegetate areas that have been disturbed for over 30 years. Disturbed lands would be covered with a growth medium to promote vegetation and would be reseeded or planted, thereby returning the land to a more natural, mostly vegetated state. Under all three alternatives, most of the site would eventually become reforested, but the diverse native plant communities that were originally present would never fully re-establish. The loss of many native species would limit wildlife habitat on public and private lands for some species, and it would take several decades for a forest-dominated habitat to develop on reclaimed lands.

Potential issues and differences between alternatives with respect to vegetation include the seed and plant mixes proposed, the use of soil amendments to promote plant growth, the use of various borrow materials that have differing amounts of noxious weed seed, and the treatment of invasive, noxious weeds.

The No Action Alternative proposes one seed and plant mix that would be used on all disturbed sites regardless of elevation. This mix includes non-native grasses and legumes and because the No Action Alternative includes planting of non-native species, it would not comply with the Forest Service Northern Region Native Plant Policy. The No Action Alternative would not meet current standards for public lands, and thus would be considered not feasible as far as revegetation is concerned.

The Proposed Action includes five different seed/planting mixtures of native grasses, legumes, shrubs, and trees proposed for site-specific use on the basis of pre-mine species occurrence, establishment potential, growth characteristics, borrow stabilization qualities, commercial availability, experience gained from previously completed reclamation activities, and post-mine land use objectives. Seed and plant mixes would be used with consideration for differences in plant communities based on elevation. Under the Agency-Mitigated Alternative, these seed and plant mixes would be required to use seed sources native to northwestern Montana.

Both the No Action Alternative and the Proposed Action would use chemical fertilizers to promote plant growth. The Agency-Mitigated Alternative adds an agency-approved, wood-based, organic amendment in the top six inches of reclamation materials at the tailings impoundment, and in the top 12 inches of reclamation materials at the mine portals, and mill site. Approximately 1,100 lbs/acre of organic nitrogen would be added to the growth medium in this fashion.

Use of the USFS borrow source (which contains rush skeletonweed, a new invader weed species) under both the No Action Alternative and the Proposed Action would not comply with the KNF noxious weed MOU with Lincoln County. The No Action Alternative would use the lacustrine and volcanic ash-derived soil materials from near the tailings impoundment to reclaim the mine and mill areas. However, another new invader species, meadow knapweed, is found in those materials. Use of these reclamation materials on NFSL under the No Action Alternative would not comply with the KNF noxious weed MOU with Lincoln County.

The Agency-Mitigated Alternative would better comply with the regulatory framework because it would not use the USFS borrow area containing rush skeletonweed and would limit the use of lacustrine and volcanic ash-derived soil material containing meadow knapweed to private lands.

ES.7.7 Wildlife

There are no differences between the three alternatives and no substantial impacts for the following wildlife species:

- Threatened or Endangered Species: Canada lynx, gray wolf
- Sensitive Species: bald eagle, black-backed woodpecker, Coeur d'Alene salamander, common loon, fisher, flammulated owl, harlequin duck, peregrine falcon, Townsend's big-eared bat, wolverine
- Management Indicator Species: elk, mountain goat, pileated woodpecker
- Migratory birds

There are substantial differences between the alternatives with respect to grizzly bear and western toad.

The No Action and Agency-Mitigated Alternatives would reclaim most roads, which would improve habitat conditions for grizzly bear. The Agency-Mitigated Alternative includes seasonal restrictions on road reclamation work that could further minimize effects on grizzly bear. The Proposed Action does

not include road reclamation, although because it would not build or open roads to motorized traffic it would maintain current road densities.

The No Action Alternative includes sweet clover (*Melilotus* spp.) in the seed mix which could create human-grizzly conflicts in areas where it is planted because it attracts grizzly bears. The No Action Alternative, if approved today, would not be in compliance with ESA because it creates human grizzly conflicts. Both the Proposed Action and the Agency-Mitigated Alternative would use native seed mixes for revegetation and neither alternative would use sweet clover.

The No Action Alternative and Proposed Action could adversely affect western toad individuals and breeding/metamorphosis habitat in the toe ponds at the tailings impoundment area during reclamation material excavation and by alterations to the toe ponds. Agency-Mitigated Alternative includes a variety of mitigation measures to avoid and minimize these potential impacts.

Table ES-1. Potentially Substantial Effects by Alternative

	No Action Alternative	**Proposed Action**	**Agency-Mitigated Alternative**
Fish	Alternative would result in potential water quality impacts from mine water discharge to Stanley Creek. Road reclamation would minimize potential sediment delivery to streams over the long-term.	Sediment delivery quantities to streams would continue because road reclamation would not occur; potential water quality and erosion impacts from potential breakage of tailings pipelines carrying mine water discharges.	Additional mitigation measures and monitoring would minimize potential for water quality violations (see ES.6.1 and ES.6.3). Road reclamation would minimize sediment delivery to steams over the long-term.
Geology	Alternative does not address subsidence.	Subsidence measures would not be adequate.	Subsidence effects would be mitigated.
Hydrology	Untreated mine water would be discharged to surface water and would violate water quality standards.	Alternative poses a high risk of short-term water quality violations because of the higher risk of accidental discharge of mine water from the tailings pipeline to Stanley or Lake creeks.	Additional mitigation measures and monitoring would minimize potential for water quality violations (see ES.6.3).

	No Action Alternative	Proposed Action	Agency-Mitigated Alternative
Reclamation Materials	Use of fine-grained soils that would not be stable on slopes over eight percent in the mine and mill area would result in erosion.	Alternative would not result in comparable utility on the reclaimed tailings impoundment.	Alternative would use the soil materials that were stockpiled prior to construction of the tailings impoundment and would include use of organic, wood-based amendments. Materials would be applied appropriately depending on slope and grain size (*e.g.* fine-grained materials on flatter areas, coarser grained materials on steeper slopes.)
Transportation	Alternative would reclaim and stabilize roads.	Alternative maintains the existing road system and related road maintenance costs.	Alternative would reclaim and stabilize roads. Road maintenance costs on NFSR 4626 would be further reduced compared to other alternatives.
Vegetation	Plant species mix proposed includes non-native species including sweet clover. Alternative would use the USFS borrow source which contains rush skeletonweed. The lacustrine and volcanic ash-derived soil materials from near the tailings impoundment would be used to reclaim the mine and mill areas, spreading meadow knapweed to these areas. Alternative would not comply with noxious weed and native species policies.	Alternative would use the USFS borrow source (which contains rush skeletonweed) and would not comply with noxious weed and native species policies.	The spread of noxious weeds would be minimized by restricting the use of the USFS borrow site and limiting use of lacustrine and volcanic ash-derived soils to the tailings impoundment area. Seed sources for native plant species would be from northwestern MT, if available at the time of reclamation. Alternative would comply with noxious weed and native species policies.

	No Action Alternative	Proposed Action	Agency-Mitigated Alternative
Wildlife	Alternative includes sweet clover in the seed mix which could create human-grizzly conflicts in areas where it is planted. The No Action Alternative, if approved today, would not be in compliance with ESA. Western toad habitat would be potentially affected by reclamation material excavation and alterations to the toe ponds.	Alternative would not reclaim roads and so would not result in an improvement in grizzly habitat parameters. Western toad habitat would be potentially affected by reclamation material excavation and alterations to the toe ponds.	Potential impacts to grizzly bear would be mitigated by requiring native plant in the revegetation mixes and road reclamation. Western toad habitat effects would be minimized through appropriate BMPs.

Chapter 1 Purpose of and Need for Action

1.1 Introduction

The United States Department of Agriculture (USDA) Forest Service (USFS) Kootenai National Forest (KNF) and the Montana Department of Environmental Quality (DEQ) have prepared this Environmental Impact Statement (EIS) in compliance with the National Environmental Policy Act (NEPA), the Montana Environmental Policy Act (MEPA), the Metal Mine Reclamation Act (MMRA), and with other relevant federal and state laws and regulations.

Troy Mine, Incorporated (Troy Mine, Inc.), a subsidiary of Revett Silver Company, operates the Troy Mine, an underground copper and silver mine in Lincoln County, Montana. Prior to December 2010, Troy Mine, Inc. was named Genesis, Incorporated (Genesis). Troy Mine, Inc., under the name Genesis, prepared the revised reclamation plan that is under review as the Proposed Action and which is referenced throughout this document as “Genesis 2006”. The name “Genesis” is used in this EIS when referencing documents that were prepared by the mining company when it was operating under that name.

In 1978, the Montana Department of State Lands (DSL) and KNF issued a Draft and Final Environmental Impact Statement (EIS) that addressed potential impacts from both the operation and reclamation of the Troy Mine. The purpose of this EIS is to evaluate the potential effects of the 2006 Revised Reclamation and Closure Plan for the Troy Mine (Proposed Action). This EIS discloses the direct, indirect, and cumulative environmental impacts that would result from the Proposed Action or from other alternatives on the natural and social environment. The 1978 reclamation plan is carried forward within the No Action Alternative of this EIS. Finally, this EIS presents mitigation measures for any potential impacts that are identified under the Agency-Mitigated Alternative.

1.2 Document Structure

This document is organized into eight chapters:

- *Chapter 1. Purpose of and Need for Action:* Includes information on the history of the project proposal, the purpose of and need for the project, a description of the Proposed Action, and the decision framework for evaluating alternatives’ effectiveness at achieving that purpose and need.
- *Chapter 2. Alternatives, including the Proposed Action:* Provides a description of the existing facility, a detailed description of Troy Mine, Inc.’s Proposed Action, and the Agencies’ alternative methods for achieving the stated purpose. The alternatives were developed based on the key issues raised by the public and other agencies. This section details how KNF and DEQ informed the public during scoping of the proposal and summarizes the key issues identified.
- *Chapter 3. Affected Environment and Environmental Consequences*: Describes the existing environmental resources in the project area and the potential environmental effects of implementing the Proposed Action and other alternatives. The analyses are organized by resource area and discuss potential impacts, including direct, indirect, and cumulative impacts. This discussion also addresses the effectiveness of mitigation measures.

- *Chapter 4. Consultation and Coordination:* Provides a list of preparers and agencies consulted during the development of the environmental impact statement and a summary of the results of this consultation.
- *Chapter 5. Index:* Provides a means of locating an assortment of key phrases used throughout the document.
- *Chapter 6. Acronyms:* Provides the compound term for the abbreviations used throughout the document.
- *Chapter 7. Glossary:* Provides definitions for technical terms used throughout the document.
- *Chapter 8. References:* Provides a list of documents used for background data throughout the document.
- *Appendices:* Provide detailed original information to support the analyses presented in the main environmental impact statement, such as public comments and responses, and various technical studies.

Additional documentation, including more detailed analyses of project area resources, may be found in the project record (PR) located at the main office of the DEQ (Lee Metcalf Building, 1520 E. Sixth Avenue, Helena, Montana) and at the KNF Supervisor's Office (31374 US Hwy 2, Libby, Montana).

The following disclaimer pertains to all Geographic Information System (GIS) maps used in this document: these products are reproduced from geospatial information prepared by the USFS. GIS data and product accuracy may vary. They may be developed from sources of differing accuracy, accurate only at certain scales, may be based on modeling or interpretation, or may be incomplete while being created or revised. Using GIS products for purposes other than those for which they were originally created may yield inaccurate or misleading results. Therefore, the USFS reserves the right to correct, update, modify, or replace GIS products without notification. For more information, contact the KNF Supervisor's Office.

1.3 Project Area Description

The Troy Mine is located about 15 miles south of Troy, Montana, in Lincoln County (**Figure 1-1**). The nearest towns to Troy are Libby, Montana, located 18 miles to the east and Bonners Ferry, Idaho (ID), located 33 miles to the west.

The Troy Mine is accessible from Montana Highway 56 (MT 56) and National Forest System Road (NFSR) 4626, both of which are paved. Approximately 57 percent of the project area is on private and patented land, and the other 43 percent is on the KNF. The project area lies within the KNF immediately west and north of Bull Lake and encompasses a major portion of the Stanley Creek drainage and portions of the Lake and Ross creek drainages. The area is popular for recreation, including boating, fishing, hunting, camping, winter recreation, pleasure driving, berry picking, and hiking.

The mine permit area covers 2,782 acres of public and private and patented land (SRK 2005). The Troy Mine is comprised of 24 patented lode-mining claims and approximately 188 unpatented lode-mining claims that are situated on National Forest System Lands (NFSL) managed by KNF (**Figure 1-2**). The patented lode-mining claims that are currently owned by Troy Mine, Inc. were originally acquired from

the American Smelting and Refining Company (ASARCO) in September of 1999. The mine facilities consist of an underground mine, the mill, and various office facilities; the tailings and reclaim water pipelines; a power line; a tailings impoundment; and associated support facilities. The tailings facility and associated disturbances are on Troy Mine, Inc.'s private land, and both the tailings and reclaim water pipelines and the power line are on NFSL and other private and patented land. The South Adit portal is located on patented land, while the North Adit portal and the mill and office/shop facilities are located on unpatented claims situated on NFSL.

The permit area falls within the following public land survey system (PLSS) sections (**Figure 1-2**):

- Township 30 North, Range 33 West, Sections 31 and 32;
- Township 29 North, Range 33 West, Sections 5, 6, and 7;
- Township 29 North, Range 34 West, Sections 12, 13, 14, 23, 24, 25, 26, 35, and 36; and
- Township 28 North, Range 33 West, Sections 5 and 6.

1.4 Background

1.4.1 Exploration and Operations

The Bear Creek Mining Company (a subsidiary of Kennecott Minerals) investigated the Stanley Creek area in the early 1960s and located copper and silver deposits along the south fork of Stanley Creek. Drilling operations conducted up to 1967 delineated the Troy deposit. Exploration adits were driven in 1967 and in 1968 to further evaluate the deposit.

In 1973, ASARCO leased the Troy Mine Project from Kennecott and began developing the mine. ASARCO began production in 1981, but suspended operations in April of 1993 due to low metals prices. In 1999, Genesis (now Troy Mine, Inc.) purchased the lease agreement for the Troy Mine Project from ASARCO and in 2000 purchased the property from Kennecott. Mining once again began in November of 2004 with the expectation of a 6-year mine life at a production rate of 6,000 tons per day.

1.4.2 Operating Permit History

In May of 1976, ASARCO applied for an operating permit from DSL, which was the Hard Rock Mining permitting agency prior to DEQ. ASARCO also applied for a Plan of Operations from KNF at the same time. The original application included the operating plan for the Troy Mine Project. ASARCO submitted a reclamation plan in December of 1976. Specifics on reclamation seeding mixtures and rates were submitted in a letter to DSL on December 20, 1976.

DSL and KNF issued a Draft and Final EIS in 1978 that addressed the potential impacts of both the operating and reclamation plans (DSL and KNF 1978). KNF issued a Record of Decision (ROD) on October 23, 1978. On November 27, 1978, DSL issued Operating Permit #00093 which permitted 2,751 acres.

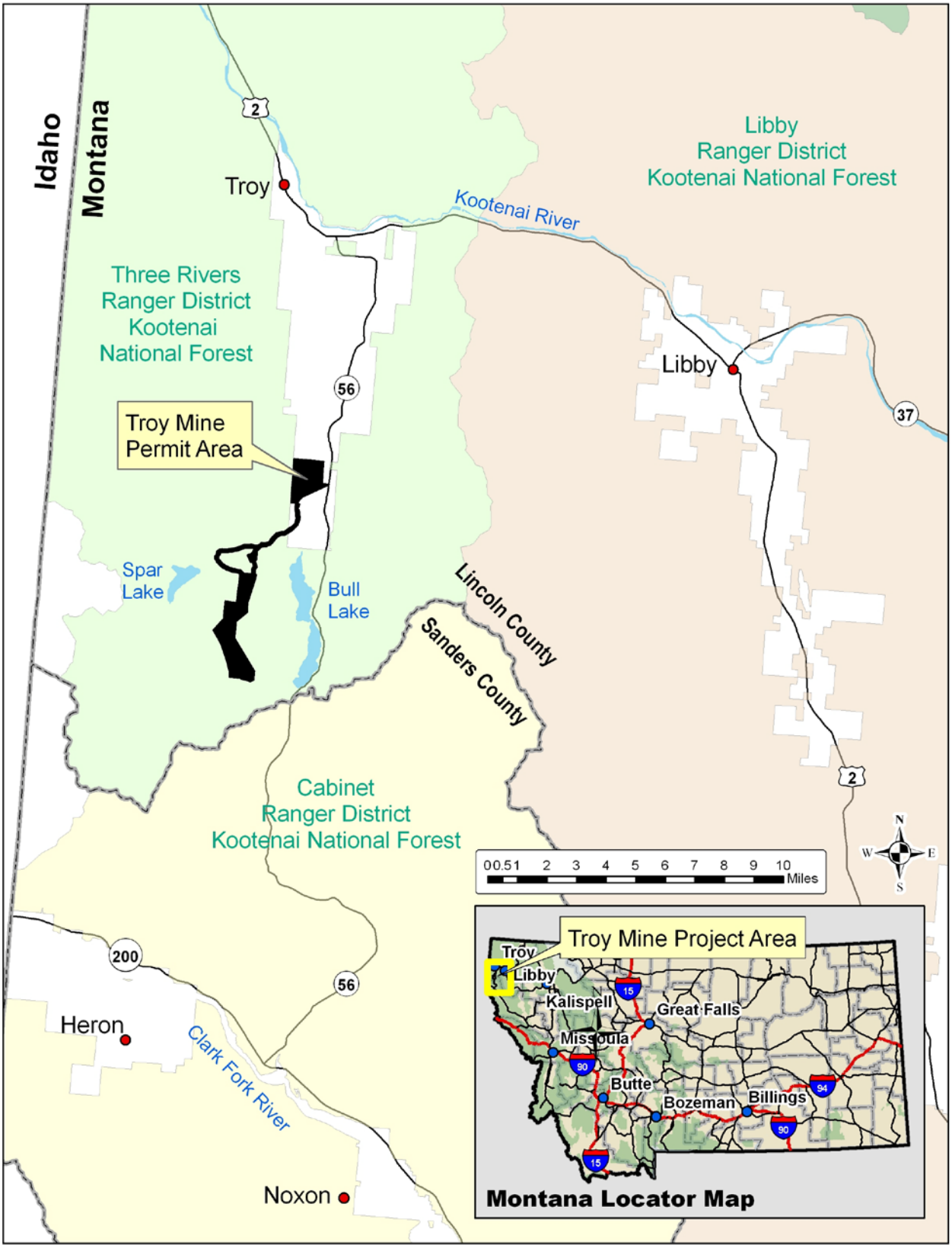

Figure 1-1. Project Area

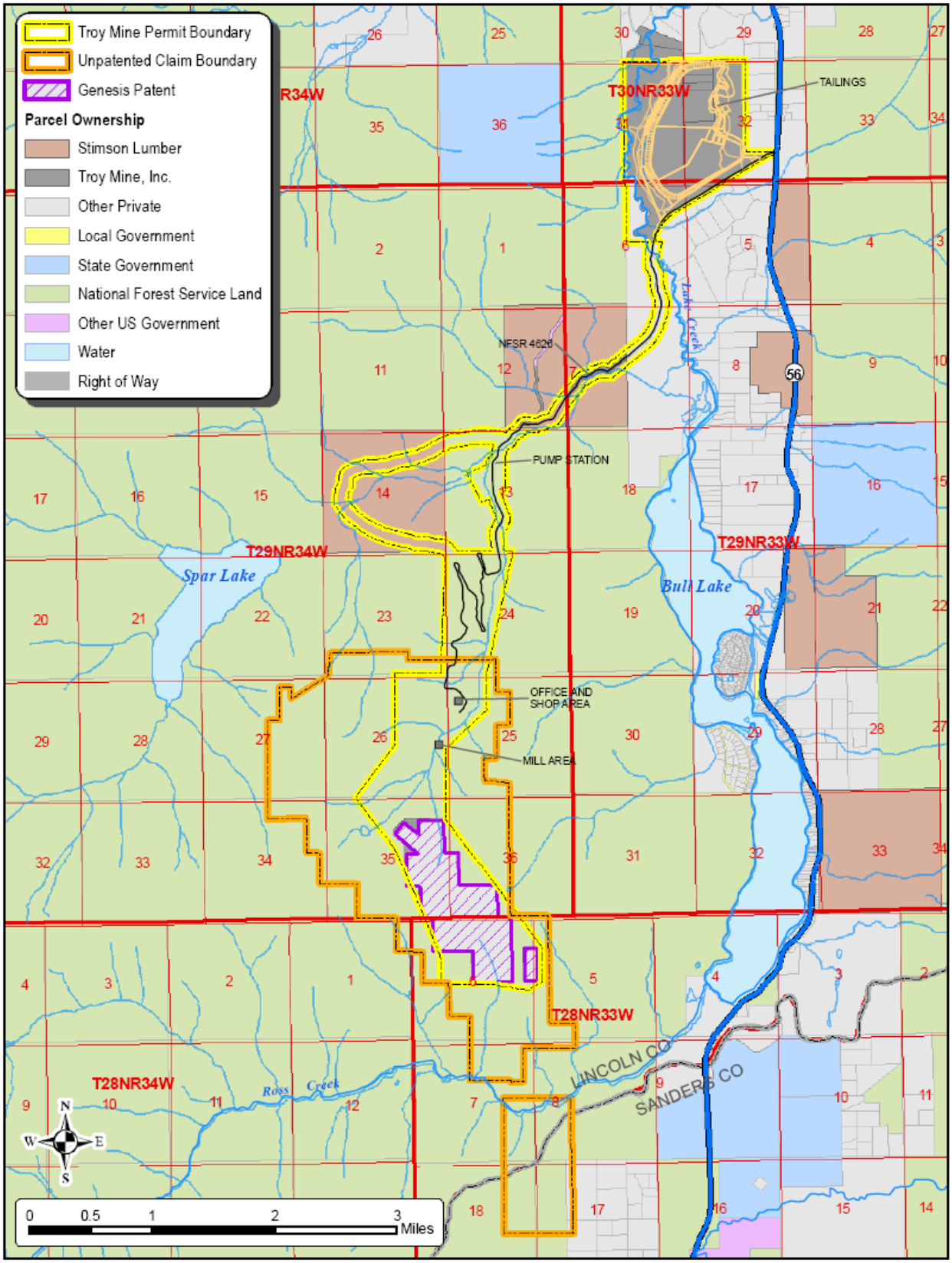

Figure 1-2. Troy Mine Permit Area and Ownership

Four amendments to Operating Permit #00093 were approved by DSL from 1979 to 1992:

- Amendment #001 (approved July 20, 1979) incorporated the construction of three facilities that were not addressed in the original mining and reclamation plans. These facilities included the tailings impoundment, the staging area, and an aggregate storage area.
- Amendment #002 (approved November 1982) incorporated a percolation pond and a 100-year flood analysis.
- Amendment #003 (approved July 1983) covered the construction of the toe ponds, the stockpiling of soil material, and the elimination of the requirement for the installation and use of perforated pipe beneath the tailings embankment.
- Amendment #004 (approved May 1992) allowed the construction of a new south ventilation adit and secondary escapeway, the deposition of development rock material from the new adit in the existing South Adit development rock dump, and the addition of one acre of disturbance at the portal of the new adit. This amendment increased the permitted acreage from 2,751 acres to 2,752 acres. The original reclamation bond was calculated on November 27, 1978, at $1,000 per acre. The new reclamation bond was inclusive of Amendment #004 and increased the 1978 bond amount by $11,500 to $2,763,500.

DEQ approved the assignment of Operating Permit #00093 from ASARCO, to Genesis (now Troy Mine, Inc.) in March of 2005. KNF approved the assignment to Genesis on April 1, 2005.

1.4.3 Revised Reclamation Plan and Bond Review

In the fall of 1999, DEQ and KNF (the Agencies) initiated a review of the reclamation bond. DEQ and KNF notified ASARCO that the approved 1978 reclamation plan needed to be revised and a substantial bond increase would be required. ASARCO and Genesis submitted a draft revised reclamation plan to the Agencies in January of 2000, which the Agencies reviewed. The Agencies notified ASARCO of the deficiencies identified in the plan and required an interim reclamation bond of $10.5 million during the review period, which ASARCO posted. A second revised draft of the reclamation plan was submitted to the Agencies in December of 2000. The Agencies reviewed the second draft of the revised plan and in February of 2001, identified further deficiencies. ASARCO responded to the Agencies' comments in May of 2004. The Agencies reviewed ASARCO's 2004 response and sent another letter outlining deficiencies. In March of 2005, the permit was assigned to Genesis. Genesis revised the reclamation plan in response to the Agencies' comments and submitted it in October of 2005. The final draft of the revised reclamation plan was submitted to the Agencies in March of 2006 (Genesis 2006) and is the subject of this environmental impact statement (the Proposed Action). In May of 2006, an agreement was reached between the Agencies and Genesis (now Troy Mine, Inc.). This latest agreement set the reclamation bond at $11.9 million with incremental increases to $12.9 million over the next three years.

1.4.4 Other Changes to the Operating Permit

Over time, there have been other changes to the Operating Permit, in addition to the amendments and bond revision discussed above, including:

- In January of 2005, DEQ approved relocation of the concentrate loadout facility from Troy to the industrial park in Libby.

- On March 16, 2007 DEQ approved a minor revision to cover the cost of reclaiming future potential subsidence areas along the East Fault resulting from the underground mine workings.
- On November 5, 2009 DEQ approved the mining of the C-Beds at Troy, and a permit boundary relocation at the mine site increased the permit boundary from 2,752 acres to 2782.3 acres.
- On May 10, 2010, DEQ approved a temporary loadout site in the industrial park in Libby to replace the old loadout which burned down.
- On February 16, 2011, DEQ approved a new loadout facility to replace the one that was destroyed by fire.

Other minor revisions have been approved over the years, including:

- A weed control plan;
- Two pumpback water systems;
- Installation of new water monitoring wells and a piezometer for sampling at the tailings impoundment;
- A new pipeline spill response plan; and
- New safety berms along the access road.

1.5 Proposed Action

Troy Mine, Inc. proposes to reclaim lands disturbed by mining activities with the following reclamation elements:

- Roads would remain in place per USFS requirements;
- Removal of buildings and structures;
- Non-hydraulic plugging (backfilling) of the adits and recontouring the slope of the South Portal patio;
- Minimal regrading of portal patios to close adits; angle-of-repose patio slopes would remain;
- Revegetation of most of the disturbed areas;
- Mine water disposal to the decant ponds by using the existing tailings pipelines and reclaim water line; and
- Monitoring of surface water bodies and embankment stability.

The Proposed Action is described in greater detail in Chapter 2, **Section 2.4.2**.

1.6 Purpose of and Need for Action

The purpose of the proposed reclamation plan is to return lands disturbed by mining to a condition appropriate for subsequent use of the area. The approved (1978) reclamation plan does not meet state or federal requirements for mine adit water discharge. The need for the revised reclamation plan stems from several objectives that need to be met after closure:

- Reclamation plans must meet state and federal requirements;

- Protection of surface and groundwater quality;
- Protection of public health and safety;
- Minimization of environmental risk; and
- Restoration of productive land use.

1.6.1 Kootenai National Forest

KNF's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for the Troy Mine. To satisfy this request, KNF must:

- Select an alternative that meets the requirements of 36 Code of Federal Regulations (CFR) 228.8 which directs that all mining operations shall be conducted, so as, where feasible, adverse environmental impact on National Forest surface resources are minimized;
- Ensure implementation of the selected alternative would assist in preserving and maintaining forest resources to meet the long-term management goals of the 1987 Land and Resource Management Plan (Forest Plan), as amended;
- Ensure compliance with other applicable federal laws; and
- Ensure the selected alternative, where feasible, would minimize adverse environmental impacts on National Forest System resources.

KNF also has responsibility jointly with DEQ to review, analyze, and calculate the reclamation bond amount.

1.6.2 Montana Department of Environmental Quality

DEQ's required action is to respond to Troy Mine, Inc.'s request to approve the proposed Revised Reclamation Plan for Troy Mine. To satisfy this request, DEQ must determine whether the Revised Reclamation Plan satisfies the requirements of the MMRA, Title 82, Chapter 4, Part 3, Montana Code Annotated (MCA).

1.6.3 Troy Mine, Incorporated

Under the MMRA, Troy Mine, Inc. is required to conduct reclamation in accordance with the provisions of an approved operating and reclamation plan. Troy Mine, Inc. has identified the following reclamation goals:

- Re-establish and improve wildlife habitat;
- Protect groundwater and surface water quality in Fairway, Stanley, and Lake creeks;
- Protect air quality in the surrounding areas;
- Provide public access to federal lands; and
- Protect public health and safety by removing potential hazards that could result from mine openings and facilities.

1.7 Agency Roles and Responsibilities

This Troy Mine EIS presents the Agencies' analysis of potential environmental impacts under both NEPA and MEPA regulations and guidelines. The Agencies will consider this analysis when making their final decisions concerning the approval of the revised reclamation plan. Under NEPA and MEPA, KNF and DEQ are required, within the confines of public and agency scoping, to consider reasonable alternatives to a proposed project. A brief description of agency roles and responsibilities, by agency, is provided below. A more detailed description is provided in the "Regulatory Framework" sections for each affected resource area in Chapter 3.

1.7.1 Federal Agencies

1.7.1.1 Kootenai National Forest

KNF is required to comply with NEPA regulations (40 CFR parts 1500 to 1508) to minimize adverse environmental impacts on NFSL surface resources through informed decision making. USFS regulations (36 CFR, Subpart A) apply to operations conducted under U.S. mining laws as they affect surface resources of NFSL under the jurisdiction of the Secretary of Agriculture. Compliance with all other applicable federal and state laws and regulations is also mandatory. These laws are discussed in Chapter 3 in greater detail. Furthermore, KNF will take all practical measures to harmonize final reclamation with scenic values and maintain and protect fisheries and wildlife habitat that may be affected by the Proposed Action. KNF must also ensure timely interim and final reclamation on NFSL.

KNF shares responsibility for monitoring and inspecting reclamation of the Troy Mine project area with DEQ. Both Agencies have authority to require a reclamation bond to ensure that the lands disturbed by the mining operation are reclaimed in accordance with an approved reclamation plan.

KNF is required by the Endangered Species Act of 1973 (ESA) (16 United States Code (USC) § 1531 *et seq*. and 50 CFR 17) to ensure that any actions it approves will not jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat for such species.

The National Forest Management Act (NFMA) requires that USFS "provide for the diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives, and within the multiple-use objectives of a land management plan adopted pursuant to this section, provide, where appropriate, to the degree practicable, for steps to be taken to preserve the diversity of tree species similar to that existing in the region controlled by the plan" (16 USC 1604(g)(3)(B)). The Kootenai Forest Plan requires "the maintenance of viable populations of existing native and desirable non-native vertebrate species, as monitored through indicator species, will be attained through the maintenance of a diversity of plant communities and habitats" (Forest Plan Volume 1, page II-22).

The 1987 Land and Resource Management Plan (Forest Plan) is the guiding USFS document for this EIS. The U.S. District Court, Northern District of California invalidated the 2008 USDA Forest Planning Rule on June 30, 2009. The court has vacated the rule and remanded the matter to the agency. USDA has

determined that the 2000 planning rule is now in effect, including its transitional provisions as amended in 2002 and 2003 and as clarified by interpretative rules issued in 2001 and 2004. Moreover, KNF is in the process of revising its 1987 Forest Plan.

1.7.1.2 United States Army Corps of Engineers

Modifications to the tailings embankment and other reclamation activities would not affect wetlands and therefore, would not require a permit under Section 404 of the federal Clean Water Act (33 USC §1251 *et seq*.). However, restoration of channels for the natural ephemeral drainages currently piped across the mill site may be considered an activity in a water of the U.S. that could be regulated under Section 404. The United States Army Corps of Engineers (USACE) is the permitting authority for the discharge of dredged or fill materials into waters of the U.S. Although USACE has issued a nationwide permit for restoration activities that may apply, use of the nationwide permit would still require review and authorization of the proposed activity by USACE.

1.7.1.3 United States Fish and Wildlife Service

The United States Fish and Wildlife Service (USFWS) has responsibilities under the Fish and Wildlife Coordination Act of 1934 (16 USC 661-667e), the ESA, and the Bald and Golden Eagle Protection Act (16 USC 668-668d). Responsibilities under the Fish and Wildlife Coordination Act require federal agencies issuing permits (*i.e.* USACE Section 404 Permit) to consult with the USFWS to prevent the loss of or damage to fish and wildlife resources where "waters of any stream or other body of water are proposed...to be impounded, diverted...or otherwise controlled or modified."

1.7.2 State or County Agencies

1.7.2.1 Montana Department of Environmental Quality

DEQ administers the MMRA, which governs the mine operating permit, as well as the Montana Clean Air Act (75-2-101, *et seq*., MCA), and the Montana Water Quality Act (75-5-101, *et seq*., MCA). DEQ must also comply with MEPA (75-1-101, *et seq.,* MCA) and other applicable state laws.

Hard Rock Operating Permit: The MMRA requires an approved operating permit for all mining activities that disturb more than 5 acres at any one time. The basic objective of the MMRA is to require reclamation of disturbances caused by mining to establish the plant cover, soil stability, water condition, and safety conditions that would be appropriate to any proposed subsequent use of the area.

DEQ is authorized to require a reclamation performance bond for mining operations governed by the MMRA. The reclamation bond amount is established by DEQ and KNF and must be sufficient for the Agencies to complete reclamation in the event of default by the operator. Reclamation bonds include the costs that would be paid by the Agencies to reclaim the site to comparable stability and utility and to assure that there would be no continuing impacts to the environment. Consequently, the capping of reactive rock dumps, cover placement on tailings impoundments, and long-term water treatment are often components of bond calculations. Bonding for water management and treatment is based on the quantity of water that must be managed, the expected water quality, and the method(s) of water treatment that may be used. Therefore, the analyses and findings in this EIS will provide the Agencies

with sufficient information to estimate the costs of reclamation should they need to conduct reclamation activities.

Water Quality Permits: The Montana Water Quality Act provides a framework for the classification of surface and groundwater according to their beneficial uses. The Montana Water Quality Act establishes water quality standards and permitting programs to control the discharge of pollutants into state waters. DEQ has been authorized by the U.S. Environmental Protection Agency (EPA) to administer water discharge permits, including storm water permits. Discharges to groundwater are regulated under the MMRA. Mining operations must comply with Montana ground and surface water quality standards.

If a permit under Section 404 is required (**Section 1.7.1.2**), then a 401 certification under Section 401 of the federal Clean Water Act (33 USC 1251, *et seq*.) may be required from the state. The 401 certification process ensures that discharges comply with applicable state water quality standards and that there would be no violation of state law if a federal permit or license is approved. In Montana, DEQ provides Section 401 certification pursuant to state rules (ARM 17.30.1701 *et seq*.).

1.7.2.2 Lincoln County Vegetation Management Board

The Lincoln County Vegetation Management Board implements a comprehensive vegetation management program to prevent, contain, reduce, or eradicate noxious weed species and to provide safe travel vectors within the boundaries of Lincoln County. Lincoln County's *Integrated Noxious Weed Management Plan*, January 2004, is available at this web site: http://www.lincolncountymt.us/weeds. The goals of the Board are to use education, management, and control to prevent the introduction and to reduce or limit the spread of noxious weed species in the county and to restore healthy plant communities. Thus, the Lincoln County Vegetation Management Board would cooperate with KNF and DEQ to coordinate weed management efforts during the reclamation process.

1.8 Decision Framework

KNF and DEQ signed a Memorandum of Understanding (MOU) "to more effectively review the reclamation plan and manage the environmental analysis of that plan." DEQ and KNF are the Lead Agencies and will be referred to throughout this document as the Agencies that are working cooperatively on this project. The Deciding Officers for the project are the DEQ Director and the KNF Forest Supervisor. Based on the analyses in this EIS, the Deciding Officers only determine whether the Proposed Action is in compliance with respective state and federal laws.

1.8.1 Federal Agencies with Permit or Plan Approval

1.8.1.1 Kootenai National Forest

The KNF Forest Supervisor will use the EIS process to develop the information necessary to make an informed decision as required by 36 CFR 228, Subpart A. Based on the information presented and alternatives developed in this EIS, the KNF Forest Supervisor will issue a Record of Decision (ROD) on Troy Mine, Inc.'s proposal. The decision objective is to select an action that meets both the purpose and

need of the project and respects the legal rights of Troy Mine, Inc., but still protects the environment in compliance with applicable laws, regulations, and policies.

The ROD would document the Forest Supervisor decision on one of the following:

- No Action Alternative
- Approval of the Revised Reclamation Plan as submitted (the Proposed Action) as an amendment to the existing Plan of Operations for the Troy Mine, or
- Approval of a Revised Reclamation Plan (Agency –Mitigated Alternative), as an amendment to the existing Plan of Operations for the Troy Mine. Amendment would incorporate mitigations and stipulations to meet the mandates of applicable laws, regulations, and policies.

1.8.1.2 United States Army Corps of Engineers

USACE has the authority to issue or deny 404 permits for work in waters of the U.S. Once reclamation commences at the Troy Mine, Troy Mine, Inc. would be required to submit detailed design plans for any work in surface waters to USACE for review so that USACE could evaluate the design and authorize the work if appropriate.

1.8.1.3 United States Fish and Wildlife Service

The USFWS will review the biological assessment prepared for this project and decide whether the determination of KNF concerning impacts to any federally listed species or habitat is sufficient and/or reasonable. If, during informal consultation, it is determined by KNF, with the written concurrence of the USFWS, that the action is not likely to adversely affect listed species or critical habitat, the consultation process is terminated, and no further action would be necessary (50 CFR 402.13).

The determination of "*Not Likely to Adversely Affect*" is made when effects on listed species or critical habitat are expected to be discountable, insignificant, or completely beneficial. A "*Not Likely to Adversely Affect*" determination requires written concurrence from the USFWS.

1.8.2 State Agencies with Permit or Plan Approval

1.8.2.1 Montana Department of Environmental Quality

The DEQ Director will use the EIS process to develop the information necessary to determine whether the Proposed Action meets the performance standards of the MMRA, including but not limited to:

- The removal of buildings and other structures at closure consistent with the post-mine land uses;
- Post-closure environmental monitoring programs and contingency plans;
- Compliance with state air and water quality standards.

Chapter 2 Alternatives

This chapter provides a description of the existing mine and facilities, a discussion of issues identified during scoping and interagency review, and a detailed description of the Proposed Action. The No Action Alternative and the Agency-Mitigated Alternative are also described in detail.

2.1 Existing Mine Facilities

The Troy Mine Permit Area totals approximately 2,782 acres and is distributed 57 percent on private and patented land and 43 percent on National Forest Service Lands (NFSL). The Troy Mine Permit Area includes several activity areas (*i.e.*, mine, office and shop area, mill site, and tailings impoundment area) connected by National Forest System Road (NFSR) 4626 (**Figure 1-2**). The following information describes the existing facilities at the Troy Mine, identifies facility locations, and clarifies the status of any past reclamation.

2.1.1 Land Ownership

Land ownership within the permit boundary is varied (**Figure 1-2**) and includes the following areas starting at the northern boundary at Montana State Route 56 (MT 56):

- The tailings facility, toe ponds, and several borrow areas lie within 780 acres of private land owned by Troy Mine, Inc.; land which is adjacent to the first 1.28 miles of access road off MT 56.
- The permit boundary extends across private lands with multiple owners along the next 1.06 miles of NFSR 4626 (approximately 77 acres).
- Along the next 1.14 miles of NFSR 4626, the permit area includes lands owned by Stimson Lumber (approximately 81 acres) with an additional tract of land owned by Stimson Lumber located west of NFSR 4626 in Section 14 (this 149 acres has no known facilities).
- Approximately 3.5 miles from MT 56, NFSR 4626 enters USFS lands and travels about 7.23 miles to the mine area (approximately 1,134 acres of USFS land are included within the permit boundary).

Troy Mine, Inc. patented mining claims cover approximately 420 acres and are located in the southern portion of the permit area. In addition to the permit area and the patented mining claims, Troy Mine, Inc. holds another 3,760 acres in unpatented mining claims, all of which are on National Forest System Lands (NFSL).

2.1.2 Tailings Impoundment Area

The tailings impoundment is located just west of MT 56 and is accessed from the local access road (**Figure 2-1**). The tailings facility covers approximately 430 acres of disturbed area (Genesis 2006, Table 4-1). Included in the 430 acres are the following components:

- Embankment – the face of the embankment has been reclaimed by placing soil, seeding with grasses and forbs, and planting of trees.
- Tailings impoundment – the surface is divided into three cells (Cells 1, 2, and 3 from south to north) by two interior dikes. A portion of Cell 3 has received interim reclamation.
- Decant ponds (or barge ponds) – these three ponds receive mine tailings water and storm water runoff from the impoundment surface.
- Borrow areas – three borrow areas are delineated at the tailings impoundment area; the Cell 3 Borrow Pit is located on the eastern edge of Cell 3; the East Borrow Pit is located adjacent to the tailings impoundment northeast of the decant ponds; and the North East Borrow Pit is located at the northeast corner of Cell 3.
- Soil stockpiles – soil removed from the tailings impoundment area was stockpiled between Lake Creek and the toe ponds west of the embankment. The stockpiles function as a berm to contain the toe ponds. A second small soil stockpile is located just east of the Cell 3 Borrow Pit.
- Toe ponds – water seeping through the impoundment embankment emerges at the base of the embankment. The four toe ponds contain impoundment seepage, natural groundwater, and runoff from the embankment face. The southernmost toe pond is typically dry. The three northern toe ponds usually contain standing water, which is sometimes pumped to the impoundment during the spring snowmelt runoff period of each year. The pumping keeps the toe pond levels low when the mill is operational and also helps to control nitrate migration.
- Other features:
    - Reclaim Water Pump Station and Pond– water is pumped from the decant ponds to this station and then pumped to the mill;
    - Tailings Embankment Monitoring System – eleven piezometers are used to monitor the water table level (phreatic surface) in the tailings embankment;
    - Ground and Surface Water Monitoring System – includes twelve wells, six springs or surface water expressions, and the toe ponds;
    - Quonset Hut – located southeast of the impoundment, is used to store equipment and has a domestic well and septic system;
    - Toe Pond #2 Sump and Pumping System – is an Enviro-pump that captures spring water below toe pond #2;
    - Equipment Storage Area – east of the impoundment;
    - 115-kiloVolt (kV) Power Lines owned by Northern Lights, Inc.;
    - Local Access Roads; and
    - Maintenance Sump – located southwest of the impoundment.

2.1.3 Office/Shop and Mill Areas

The office/shop and mill areas are located approximately 8 miles south of the impoundment area **(Figure 2-2**). The disturbed acreage for this area of the mine is approximately 34 acres and includes the following components:

- two percolation ponds (1.5 acre lower percolation pond and 0.5 acre upper percolation pond) to capture and infiltrate storm water runoff;
- storm water sump;
- wood-frame storage building;
- steel tailings thickener tank;
- office building;
- shop building;
- mill water pump building;
- warehouse shed, steel shed, and storage building;
- above ground 200,000-gallon-capacity diesel fuel tank;
- two 30,000 gallon propane tanks;
- core storage building;
- mill building;
- secondary crusher building;
- steel fine ore bin;
- sewage treatment building;
- steel water tank; and the
- Service and Conveyor adits.

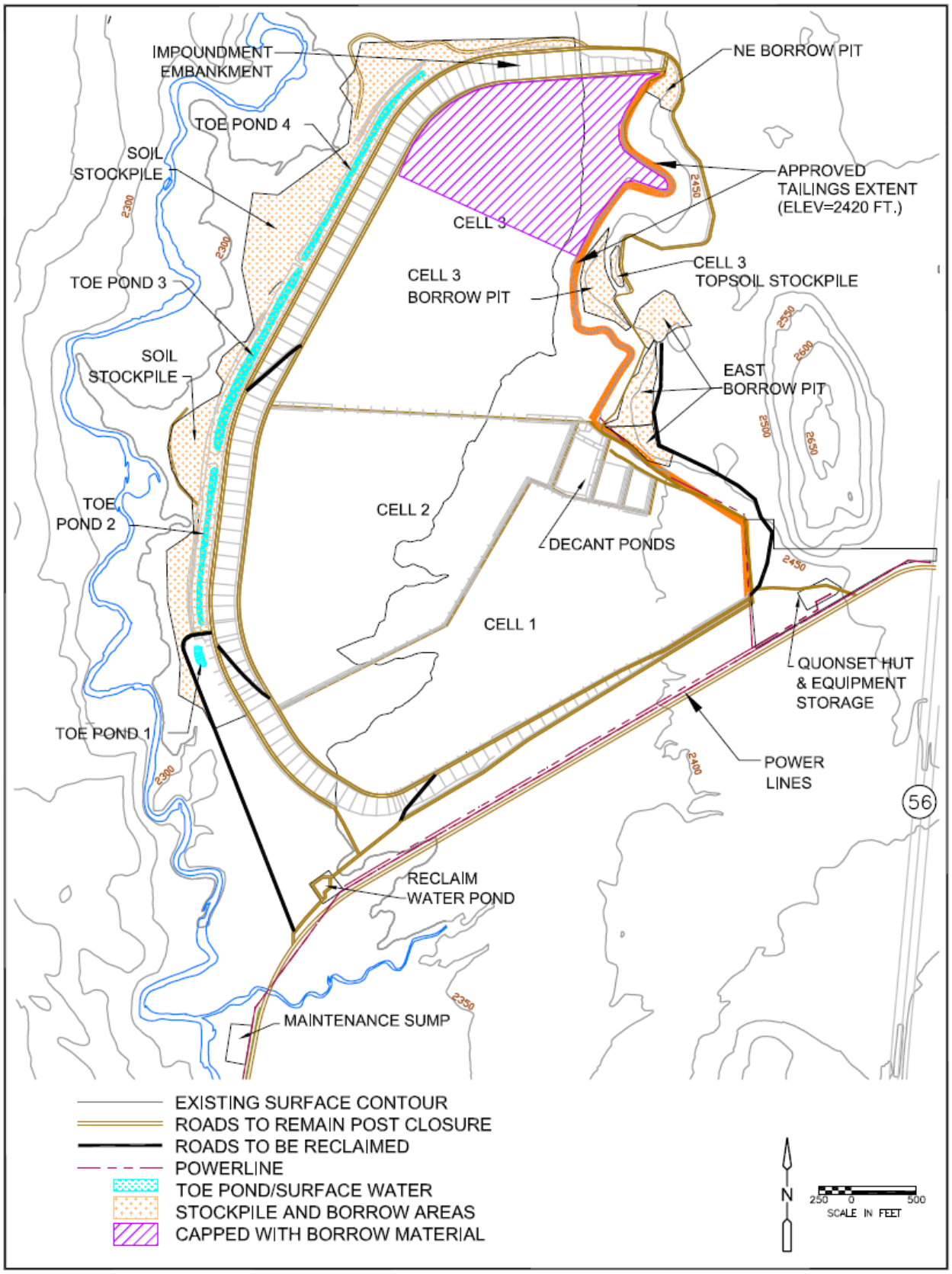

Figure 2-1. Tailings Impoundment Area

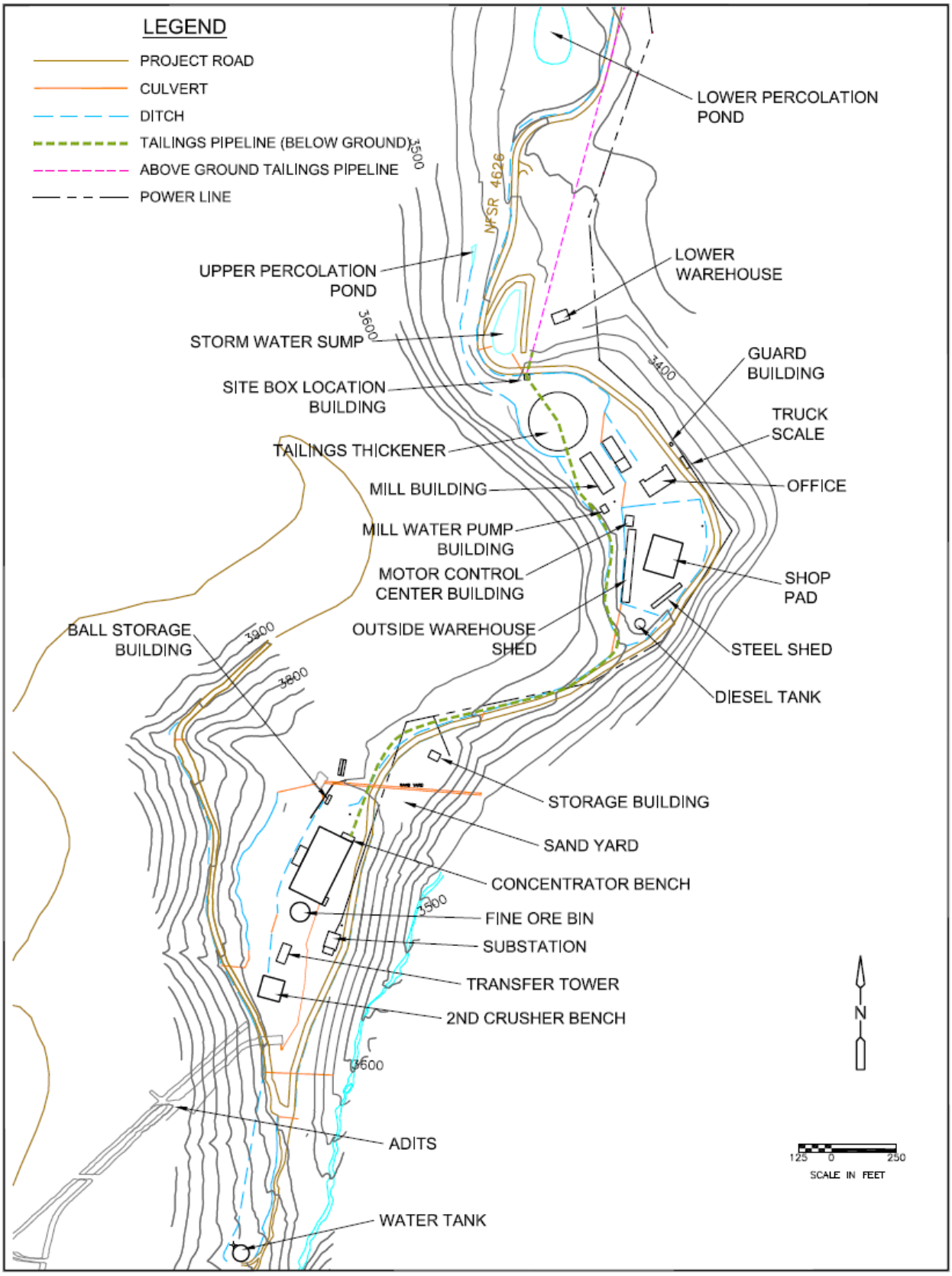

Figure 2-2. Office/Shop and Mill Areas

2.1.4 Other Mine Components

Other mine components include the underground mine workings and operational areas outside of those previously described:

- Mine portals (entrances) at the North Ore Body and South Ore Body - there are nine portals into the mine, accessing seven adits. There are three north portals that branch off a single adit (the North Adit) and two east portals that lead into the mine workings (the two east adits). Additionally, there is one west portal, one south portal, one Conveyor portal, and one Service portal leading to the West, South, Conveyor, and Service adits, respectively. Portals and adits are shown in **Figure 2-3**.
    - The Service Adit carries all mine water outflows and serves as the primary personnel and equipment access to the North Ore Body.
    - The one-mile-long Conveyor Adit runs parallel to the Service Adit and is used for transporting crushed ore to the surface.
- Portal patios - the North Portal patio is approximately 12 acres in size and includes the North, East, and West portals. The South Portal patio is approximately 3.6 acres in size and includes the South Portal.
- Ventilation adits - there are four ventilation adits at the Troy Mine. One ventilation adit leading to each of the North, East, and West portals, and one ventilation adit located at the South Adit portal (the exploration adit developed by Kennecott in the 1960s).
- Underground equipment (jaw crusher, conveyor belt, rollers, ventilation system, etc.).
- Loadout facility located in Libby, Montana (**Figure 2-4**).
- A utility corridor that contains the tailings lines, a buried reclaim water line, and the 115-kV electrical power line that runs from the mill site to the tailings impoundment (**Figure 2-2**). After construction of these facilities, the disturbed area was seeded with a grass mix. Small trees that established in the corridor have been thinned out as required for pipeline and power line maintenance since construction in 1980.
- Pump station – there is one pump station located between the tailings impoundment area and the office/shop and mill areas (**Figure 1-2**).

A plan view of existing underground facilities is shown in **Figure 2-3**.

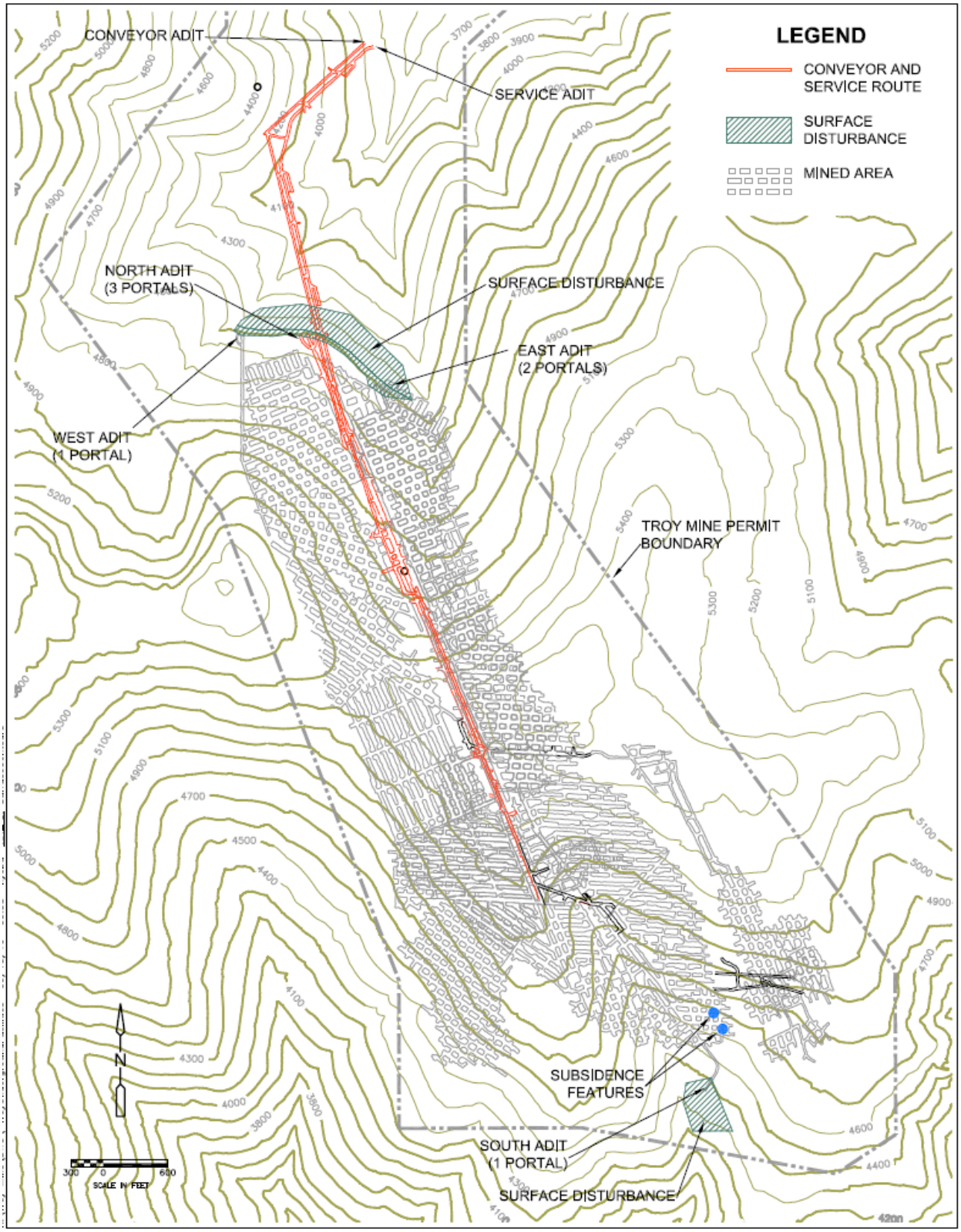

Figure 2-3. Underground Facilities

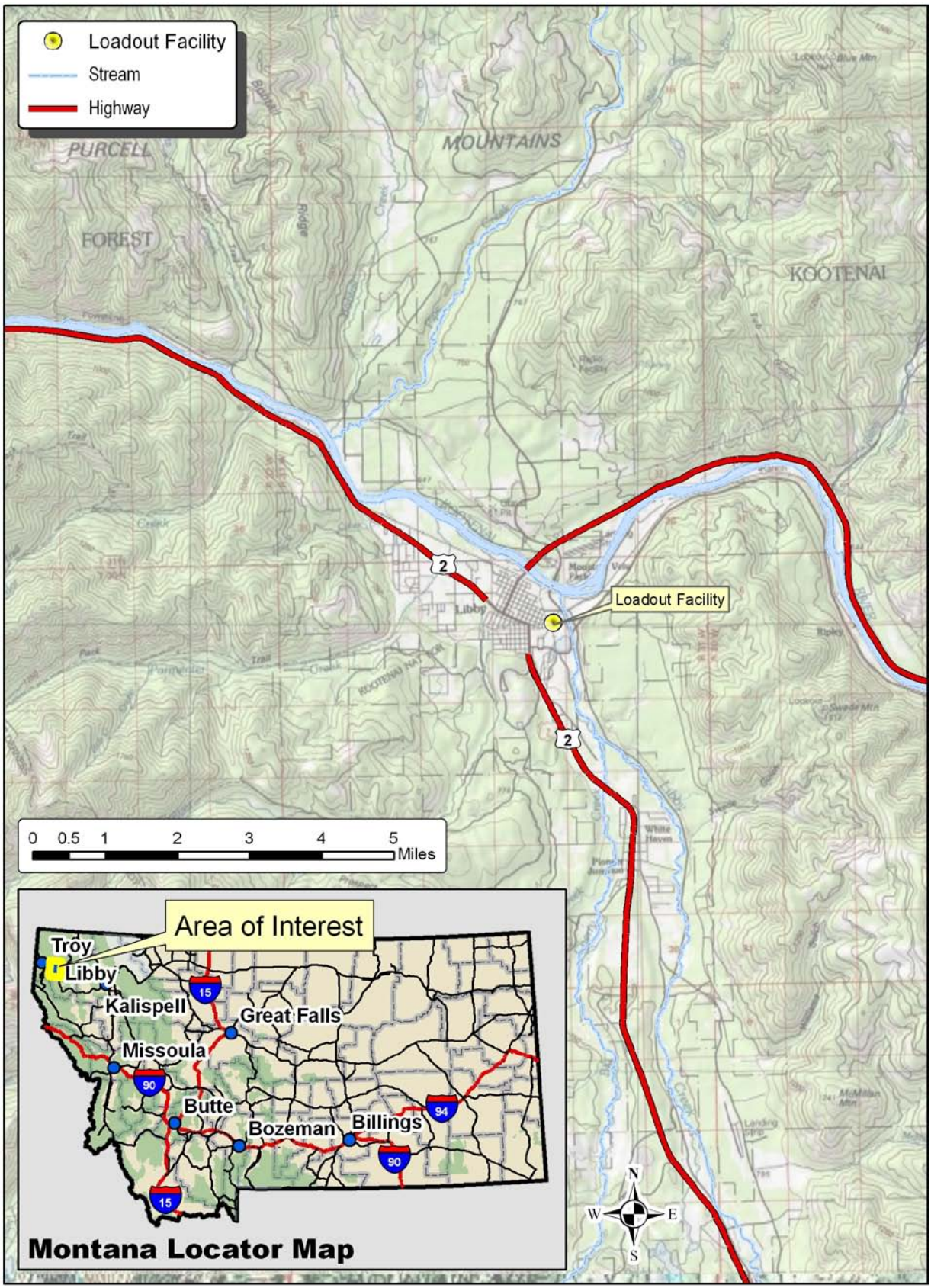

Figure 2-4. Libby Loadout Facility Location

2.2 Public Involvement

At the beginning of the NEPA/MEPA process, scoping began by involving the public. A press release was published in area newspapers and announced on local TV and radio stations on October 11, 2007. This press release requested public input on Genesis's *2006 Revised Reclamation Plan*. USFS ran an advertisement in four area newspapers: the *Western News* on October 24, 2007; the *Sanders County Ledger* on October 25, 2007; the *Daily Inter Lake* on October 21, 2007; and in the *Bonner County Daily Bee* on October 24, 2007. The comment period extended from October 11, 2007, through December 28, 2007.

The public scoping meeting and open house were held at the Kootenai Senior Citizens Center in Troy, Montana, on Tuesday, October 30, 2007, and began at 6:30 pm with a presentation that was followed by an open house.

The Agencies agreed upon the format for the scoping meeting prior to the event. The project consultant Camp Dresser and McKee, Inc. (CDM) started the meeting with a 20-minute presentation that introduced the project team and discussed the scoping process, history of the mine, and the potential remedial alternatives. Following the presentation, an open house was set up for meeting attendees. Seven different tables, each representing a particular topic, were set up in a large meeting room. Each table was staffed by one or more KNF, DEQ, or consultant team (CDM and AMEC) employees, and two copies of the revised reclamation plan were available for review. The following topic areas were included:

- NEPA and MEPA;
- engineering and geotechnical;
- hydrology and water quality;
- reclamation, soils, and vegetation;
- permit amendment process;
- wildlife and fisheries; and
- Troy Mine and Genesis (now Troy Mine, Inc.)

Thirty-three people signed into the meeting and open house. Attendees were encouraged to move freely from table to table, depending upon their interests, and to list questions. A detailed description of the scoping process is described in the Scoping Report in **Appendix A**.

During the course of preparing an EA, several potential water quality impacts were identified that the Agencies determined were of sufficient significance to warrant the preparation of an EIS. These issues include:

- The potential for mine water to discharge to springs, seeps, or streams after mine closure, potentially causing surface water standards for aquatic life to be exceeded.
- The potential for the tailings pipeline to fail, potentially resulting in erosion and the discharge of metals, nutrients, and sediment into Stanley or Lake creeks.
- The issue of long-term maintenance of the pipeline.

Given these potential impacts, KNF did not believe that it could conclude the EA process with a Finding of No Significant Impact under 40 CFR 1508.13 and FSH 1909.15(b). DEQ believes that these potential impacts are sufficiently significant to trigger the need to prepare an EIS under the criteria set forth in ARM 17.4.608. The potential contamination of surface water from mine water-impacted springs and seeps could last for a significant period of time. In keeping with the potential severity of impacts from potential seeps and springs and the potential for discharge from the pipeline to surface water, there did not appear to be sufficient assurance that the impacts would not occur. Finally, the surface waters around the Troy Mine are of sufficient value to further justify the preparation of an EIS given the potential impacts to this environmental resource.

Therefore, the document preparation process was revised prior to the release of a public draft EA to preparation of a draft EIS. KNF published a Notice of Intent (NOI) in the *Federal Register* on April 14, 2011. The NOI described KNF and DEQ's intent to prepare an EIS for the Troy Mine Revised Reclamation Plan and referenced the scoping process where public comment on the proposal had been solicited.

2.3 Issue Identification

Issues were identified through the agency and public scoping process, through the Agencies' review of the *2006 Revised Reclamation Plan*, and through interagency discussions on the development of alternatives. An Interdisciplinary Team (IDT) consisting of lead agency personnel and the consultant team preparing the environmental impact statement (EIS) helped identify issues. Agency personnel included staff from the co-lead Agencies. Input from other agencies (as discussed in Chapter 1) was also solicited. Both DEQ and KNF provided ongoing policy guidance and oversight while this EIS was being prepared. Agency personnel also contributed information on land use and management practices throughout the project.

A *Scoping Report* was prepared to describe the results of scoping activities conducted between October and December 2007 (see **Appendix A**). This *Scoping Report* summarized major issues identified during the scoping period and identified those carried forward for further evaluation in this EIS. At the time of scoping, the Agencies proposed preparing an EA, however, as analyses proceeded, potential significant impacts were identified that resulted in the preparation of an EIS instead. Throughout the scoping process, opportunities were available for the public and agencies to present concerns and issues for consideration during the EIS process.

Issues obtained via scoping were separated into two groups: Major Issues and Issues Considered but Not Evaluated.

- Major issues were defined as those for which:
  - there may be potentially significant impacts;
  - there may be a concern about potential effects directly or indirectly resulting from implementation of the Proposed Action; or
  - there may be a concern about the effectiveness of proposed mitigation measures.
- Issues considered but not evaluated were those that were:
  - outside the scope of the analysis;
  - already decided by law, regulation, Forest Plan, or other higher-level decision;
  - irrelevant to the decision to be made; or
  - conjectural and not supported by scientific or factual evidence.

Major issues may guide development of alternatives. Issues considered but not evaluated further are those that do not affect the development of a range of reasonable alternatives.

Issues were evaluated to determine whether the proposed action or an alternative would result in significant impacts. The Council on Environmental Quality (CEQ) regulations define significant impacts in terms of both context and intensity (40 CFR 1508.27). CEQ implementing regulations (40 CFR 1500 *et seq.* 2003) for NEPA explain this delineation in Section 1501.7 as a process to "…identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review…" (40 CFR 1501.7 (a)(3); 2003). MEPA also provides direction on determining the significance of impacts similar to the definitions used under NEPA (ARM 17.4.608(1), MCA 75.1.201). Non-relevant issues must be addressed briefly to document why each issue is considered non-relevant and does not need further evaluation (ARM 17.4.608(1)).

A number of the issues identified during scoping were carried forward as major issues for further consideration in the EIS process. During the evaluation of potential impacts, some issues were found to have potentially significant impacts which led to the preparation of this EIS rather than an EA as had been proposed during early scoping. Several issues were considered but were not recommended for further evaluation by consensus of the IDT. The issues that were considered but eliminated from further evaluation are discussed and summarized in **Section 2.3.2**.

2.3.1 Major Issues

The following information covers major issues identified during scoping and by the IDT, along with a summary of how each issue was evaluated for this EIS. Major issues, as previously defined, are those that may have significant impacts or where there is disagreement about potential effects or the effectiveness of mitigation measures. Major issues may be any number of social, environmental, or economic effects or influences that would potentially result from implementation of an alternative.

Major issues identified primarily relate to adit closure, mine water distribution, mine water treatment and disposal, the longevity and success of copper attenuation mechanisms, disposition of building materials, subsidence, and to the source of reclamation materials.

2.3.1.1 Water Management

Adit Closure and Mine Water Distribution

One of the primary issues identified through the scoping process and interagency review concerns the closure of the adits and treatment of water that may flow from the mine upon closure. Issues involved with adit closure focused on the following questions:

- Should hydraulic or non-hydraulic plugs be used to close adits? Non-hydraulic plugs pass water thus preventing pressure from building up on the plug itself, but hydraulic plugs are sealed to prevent water from passing through the plug. These plugs allow hydraulic pressure to build up and, in turn, may create the possibility for seeps or springs to develop in other areas.
- How much water will be held in the mine when it floods and what is its quality?
- Where will mine water drain, and does it have the potential to reach ground and surface waters?
- Does the 30 year-old tailing pipeline have the integrity to be used as a mine water discharge line?
- What is the quality of water over time?

Both the closure of adits and the destination of water from underground workings were analyzed in order to address concerns relating to surface and groundwater quality (**Section 3.9**).

Water Treatment and Disposal

Concerns were received regarding Troy Mine, Inc.'s intent, as outlined in the *2006 Revised Reclamation Plan*, to send mine water to the tailings impoundment area for long-term water treatment and disposal. Some of the comments about water treatment included:

- Would there be any treatment of discharged mine water?
- Could mine water be treated in the Service Adit prior to discharge?
- Could decant ponds be replicated at the mill site and the seven-plus miles of tailings pipelines be removed?
- Could mine water be treated in the short term rather than over the long term (indefinitely)?

The need for mine water treatment depends on future anticipated levels of metals in mine water and the duration and success of attenuation mechanisms, both primary and secondary. Information on water quality, treatment, and disposal is summarized in Chapter 3 (**Section 3.9**).

Groundwater Quality

The following comments were received on groundwater protection, which includes the natural attenuation process for copper and the length of time that natural processes could be sustained:

- After 20 years of diverting water to the decant ponds, why would groundwater be an issue under this proposal?
- Will a Montana Pollutant Discharge Elimination system (MPDES) permit be required for the discharge of mine water?

Several studies and an assessment of natural attenuation of metals in the decant pond disposal system have been completed. The results of these studies are summarized in Chapter 3 (**Section 3.9**).

Surface Water Quality

Concerns on mine water reaching surface waters included:

- How does the *2006 Revised Reclamation Plan* address long-term seepage and groundwater discharge to Lake Creek?
- What are the potential impacts of increased flows from the underground workings on water quality in nearby streams, creeks, and the toe ponds?
- Statement of concern that discharges from the mine have begun to appear in the vicinity of Ross Creek.

Ground and surface water data and monitoring reports were reviewed and are summarized in Chapter 3 (**Section 3.9**).

Long-Term Monitoring of Water Quality

The following comments were received on potential long-term impacts to water quality and on the feasibility of long-term monitoring:

- What will mine water copper concentrations be in the future?
- What is the likelihood of copper reaching Lake Creek?
- What are the potential impacts to Ross Creek?
- How long could monitoring realistically continue?

Chapter 3 (**Section 3.9)** summarizes the assessment of natural attenuation of metals in the decant pond disposal system.

2.3.1.2 Reclamation

Reclamation Materials

Soil intended for reclamation of the tailings impoundment was originally stockpiled between the base of the impoundment embankment and Lake Creek. This stockpiled soil currently serves as a berm to contain seepage from the base of the impoundment. The toe ponds have developed into wetland habitat used by many species. Public comments on reclamation includes the following:

- One comment stated a preference for using the soil stockpiles at the toe ponds instead of disturbing new areas.
- Another comment stated that impacts would be lessened if the soil stockpiles at the toe ponds were not disturbed.

The volume and type of soil that would be needed to meet revegetation goals is evaluated in Chapter 3 (**Section 3.13**).

Subsidence

Comments were received both on subsidence during operations and on the potential for post-closure subsidence.

- One comment questioned how future occurrences of subsidence would be addressed.
- Another comment questioned how hydrology would be affected by future subsidence.
- A comment was also received stating that the amount of the reclamation bond should be commensurate with mitigation of possible further incidents.

The potential for subsidence is analyzed in Chapter 3 (**Section 3.8**).

Revegetation

Proposed seed mixes need to reflect current standards for using native species. Current revegetation standards are included and addressed in this EIS (**Section 3.16**).

- Comments were received on the potential for dust blowing from the tailings impoundment. Revegetation and its effect on blowing dust are addressed in Chapter 3 (**Section 3.16**).
- A comment from the public stated a preference for releasing water through the pipelines to the tailings impoundment to provide water needed for revegetation.

This EIS analyzes irrigation and dust control methods with respect to revegetation (**Section 3.16**).

Infrastructure

The IDT agreed that appropriate and current standards on disposition of buildings and other structural materials at the mine on NFSL be followed and be an issue to be included and addressed in this EIS (**Table 2-1**).

Topography

The IDT identified several changes and refinements to the Proposed Action, including regrading at the decant ponds, borrow areas, and at the toe ponds. All of this information is included and addressed in this EIS (**Section 3.13**).

2.3.2 Issues Considered and Not Evaluated Further

The scoping process provided many opportunities for the public to present concerns and issues to be considered during the EIS process. Concerns that were determined to be outside the scope of the analysis, those already decided by law or regulation, irrelevant to the decision to be made, or conjectural in nature were not evaluated in detail in this EIS. Concerns that were considered but not

evaluated further are also summarized in this section. After each comment, the Agencies' response is presented in italics.

1. The milling process uses iron, but occurrences of iron staining have been attributed to natural processes. Fate and transport of iron should be studied as carefully as copper.

   *The natural attenuation processes for iron were studied in CDM's Troy Mine Copper Attenuation Study – Secondary Processes (**Appendix D**). Although this study did not directly discuss the use of iron in the milling process, it verifies that reductions in concentrations of iron were observed as a result of mixing mine or decant water with existing groundwater. Although iron concentrations exceeding standards are occasionally observed in Lake Creek, iron is a naturally-occurring element in the project vicinity:*

   > *A number of springs that occur along the Lake Creek terrace have been investigated throughout the life of the mine; one of these was identified through observation of iron staining. Springs with iron staining occur naturally throughout the Kootenai, Clark Fork, and Lake Creek valleys. The source of iron is naturally occurring in sedimentary beds of Pleistocene lake sediments likely deposited from prehistoric glacial lakes (Genesis 2006, page 3-11).*

   Regardless of its source, iron is a naturally-occurring element in the project vicinity; and its concentration in mine waters lessens when combined with existing groundwater. Please refer to The Troy Mine Copper Attenuation Study – Secondary Processes Report (Appendix D). This potential issue will not be evaluated further.

2. Concerns were raised about the stability of the impoundment, the potential effects of continued discharge of mine water, and about the effect of placing additional tailings lifts upon impoundment stability. Also raised was a question about what the potential effect on operation of the Northern Lights Dam would be if the impoundment failed.

   The tailings have been permitted by the Agencies to an elevation of 2,420 feet for Cells 1, 2, and 3. Impoundment stability has been addressed in many previous documents and inspection reports, including Knight Piésold's 2007 report "Genesis Inc. Troy Mine Report on Phase 2 Program to Define the Maximum Safe Elevation for the Tailings Embankment." The Genesis 2006 Revised Reclamation Plan includes a geotechnical monitoring plan that calls for yearly inspections to ensure impoundment stability. The yearly inspections would continue for five years after mine closure or until Troy Mine, Inc. and the Agencies agree to discontinue monitoring. An inspection report prepared for verification of stability would be required by a geotechnical engineer at mine closure. Finally, the impoundment would be more stable after closure when wet tailings are no longer being added to the impoundment; at that point, groundwater elevation levels would decrease near the embankment.

3. A cash bond should be required to cover all obvious and potential problems that could be associated both with reclamation and with perpetual maintenance, which would include mandatory review at 10-year intervals.

Section 82-4-338 (1)(a) MCA describes the bond instruments that the applicant for an operating permit may file that are acceptable to DEQ. Bond types acceptable to USFS for mineral activities are found at 36 CFR 228.13 and in Forest Service Manual 2817.24

The instruments deemed adequate by the State of Montana and USFS include: a cash deposit, an assignment of a certificate of deposit, an irrevocable letter of credit, or other surety acceptable to the Agencies. Pursuant to a Memorandum of Agreement, the Agencies have accepted a joint bond for the Troy Mine project. Once the environmental documentation process is complete, the joint bond will be recalculated to address all requirements identified and deemed necessary in the final decision. Long-term water treatment would be included in the recalculated bond only if it is considered necessary at the conclusion of the analysis.

During operations, bonds are reviewed for adequacy at a minimum every five years, when there is a change to the plan of operations, or when changes in environmental conditions warrant a review. After closure, the bond amount would be reviewed on a minimum five-year basis until needed reclamation is deemed complete and the bond could be released. Additionally, DEQ reviews each bond for adequacy on an annual basis.

This potential issue is addressed by law or regulation.

4. A concern was raised regarding whether buried drums were addressed in the Genesis *2006 Revised Reclamation Plan* and if they would be unearthed and sampled.

In December of 2002, the Cabinet Resource Group (CRG) initiated a lawsuit against ASARCO and Sterling Mining Company (now Revett Silver Company). This lawsuit alleged that barrels of hazardous waste were buried within the tailings impoundment during ASARCO's operation of the Troy Mine. CRG also claimed that barrels containing solvents, waste oil, and grease were buried in the tailings impoundment. The allegations were never substantiated, and in July of 2006, the U.S. District Court dismissed the case without prejudice. ASARCO has admitted to burying drums but has also stated that the drums did not contain contaminants. This potential issue is beyond the scope of this analysis.

5. A commenter proposed that the action should include replicating the decant ponds at the mill site so that the tailings pipelines could be removed.

For a number of reasons, the mill site likely would not be a suitable location for metals attenuation to occur. First, the decant ponds are underlain by natural subsoils and thick glacio-alluvial deposits that provide both slow percolation of the water and adequate residence time for metals removal reactions to take place. The mill pad would be covered with 12 inches of growth medium underlain by permeable development rock fill. Should any metals-bearing water reach the development rock fill below, this water would reach Stanley Creek, which is in close proximity to the pad. At the tailings facility, there are iron-bearing natural groundwaters that provide a

*secondary mechanism to attenuate metals should the primary removal processes fail to operate in the future. Such a secondary process would not be present at the mill pad. Please see Chapter 3, **Section 3.9**, for further discussion on the natural attenuation mechanisms at the decant ponds. This potential issue is not considered further, because it is not a feasible alternative.*

6. A concern was raised about the potential for contamination at the mouth of Lake Creek from Troy Mine operations. The Northern Lights Dam traps sediment at the mouth of Lake Creek. This section of the creek has been dredged twice, but no analysis of sediments has been conducted to determine if the sediments are contaminated from Troy Mine operations.

   In 2009, 24 years of data were compiled. A study was conducted of macro-invertebrates at locations both above and below mining operations in Fairway-Stanley and Lake creeks. The purpose was to determine whether significant non-point source pollution was occurring in local streams due to Troy Mine, Inc.'s activity (the Troy Mine has no point sources reaching any streams). This study concluded that over the last 23 years, no biologically-significant changes in macroinvertebrate communities at either of the creeks have been observed that could be attributed to the mine. Both creeks continue to have key species known to be especially sensitive to metal concentrations (Parametrix 2009). Because the Northern Lights Dam is at the mouth of Lake Creek (downstream of the macroinvertebrate study), the potential for contamination at the Northern Lights Dam has been eliminated by scientific evaluation.

7. A commenter proposed that no reclamation other than tree planting should occur and that the mine should be left open as an educational resource and a tourist attraction.

   This suggestion is not feasible because potential impacts to water quality, land use, public safety, wildlife, and fisheries would greatly outweigh any benefits of leaving the mine open. Moreover, leaving the Troy Mine open as a tourist attraction does not meet the purpose and need of the reclamation project.

2.4 Comparison of Alternatives

Three alternatives are evaluated in this EIS. The No Action Alternative consists of the reclamation plan provided by ASARCO in 1978 and the reclamation work that has been completed through August of 2010 by Genesis (now Troy Mine, Inc.). The Proposed Action describes the Revised Reclamation Plan submitted by Genesis to the Agencies in March of 2006. The Agency-Mitigated Alternative was developed by the Agencies and is based on issues derived from interagency and public scoping comments on the Proposed Action.

The alternative descriptions are aligned with the issues that were carried forward from the public scoping process as described earlier in this chapter and include the following:

1. Water Management
   - Adit Closure and Mine Water Distribution
   - Water Treatment and Disposal

- Groundwater Quality
- Surface Water Quality
- Long-Term Monitoring of Water Quality

2. Reclamation
    - Reclamation Materials
    - Subsidence
    - Revegetation
    - Infrastructure (buildings and other structural materials and how they would be removed or reclaimed)
    - Topography (disturbed areas)

A description of each alternative, including a discussion of how each alternative addresses the issues is presented in **Table 2-1** and in the following sections.

Table 2-1. Comparison of Alternatives

	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
	Water Management				
	Adit Closure and Mine Water Distribution				
1	Adit Closure - Service and Conveyor Adits		The portals would be sealed with concrete, and water drainage from the Service and Conveyor adits would be allowed to discharge onto the development rock patio fill (pg. 65).	Concrete non-hydraulic plugs would be constructed in the Service and Conveyor adits to funnel water into the collection pipe for conveyance to the decant ponds. Plugs would consist of concrete followed by coarse rock from the portal patios (pg. 7-6). No access to intake would be provided.	Modifications to the Proposed Action include: 1) Concrete plugs would not be installed. 2) In the Service and Conveyor adits, a concrete structure would be installed to capture mine water and funnel it to the collection pipes. 3) Additional monitoring of seeps and springs would be required to verify whether state water quality standards have been met. 4) Closure devices would be installed to prevent unauthorized access to the Service and Conveyor adits and to allow cleanout of the intake structures.
2	Mine Site and Closure of Other Adits	Adits (North-3, South-1, East-2, West-1)	Upon closure of the mine, the entrance would be sealed with concrete and drainage for water would be provided. (pg 65). Portals would be sealed with concrete.	Development rock would be used as backfill from the adit opening back 30 feet into the adit and tight against the roof (pg 4-4); rock remaining after adit plugging would be graded against the side of the slope to form a wedge (pg. 4-1, Table 4-2). The South Adit would decline back into the mine (pg 4-4). Adits that are not expected to discharge water, would be backfilled with coarse rock from the patios but would not receive concrete plugs (pg. 7-4 to 7-7).	Modifications to the Proposed Action include: 1) Development rock would be used at the portal patio to plug the South Adit. The South Adit plug would extend approximately 130 feet into the adit, rather than the 30 feet as in the Proposed Action. 2) Development rock that has accumulated in stream channels adjacent to the mine site would be removed from channels and included in the backfill materials for the South and West adits.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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3	Outflows from Adits		Mine water would be discharged to Stanley Creek; groundwater flows into the surrounding groundwater system and would gravity-flow from the Service Adit (pg 7-2). Drainage from the adits would be allowed to infiltrate at the point of discharge outside the portals (pg. 65).	Mine water would discharge to the decant ponds and/or tailings impoundment surface (pg 7-4). Mine water would only discharge from the Service and Conveyor adits. Mine water would then be conveyed through the tailings pipelines and discharged to the decant ponds (pg. 4-4).	Modifications to the Proposed Action include: 1) The reclaim water line would be used as a secondary water conveyance line. Inspection of the reclaim water line would be required prior to use. 2) A new, buried water line would be designed and installed adjacent to the reclaim water line. The new water line(s) would be designed to handle the anticipated volume of mine discharge. 3) The design for the new lines would include the installation of remote safety measures that would identify changes in flow and automatically change flow to the other pipeline until repairs have been made. 4) The intake structure would be designed to collect water from both the Conveyor and Service adits. 5) A channel would be constructed from the Service and Conveyor adits to the mill site stream channels for emergency overflow from the adits in case the design capacities are ever exceeded (Appendix E and **Figure 3-3**).
4	Tailings Pipelines	Two 8-inch steel Tailings Pipelines	The tailing pipelines would be removed, and disturbed areas would be reclaimed and revegetated (pg. 66)	The tailings pipelines would be retained to convey water from the mine site to the decant ponds. Once the mine water is of sufficient quality for direct discharge to Stanley Creek, the tailings pipelines, portions of which are buried less than 3 feet, would be removed. (pg. 4-14).	The tailings pipelines would be removed after new mine water pipeline and safety measures are in place and tested. Disturbed areas would be reclaimed and revegetated.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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Reclaim Water Line and Pump Stations	One 10-inch steel pipeline	The reclaim water line and pump stations would be removed, and disturbed areas would be reclaimed (pg. 66)	Until it wears out, the reclaim water line would be retained to convey water from the mine site to the decant ponds. Once the mine water is of sufficient quality for direct discharge to Stanley Creek, the remaining pipeline would be capped and abandoned in place. Reclaim pump stations would be salvaged and the buildings would be removed (pg 4-19).	The reclaim water line would be used as an emergency water conveyance line. Inspection of the reclaim water line would be required prior to its use and remote safety measures would be installed as in the new pipeline. A new, buried water line would be designed and installed adjacent to the reclaim water line. The water line(s) would be designed to handle the anticipated volume of mine discharge and would be buried or double-lined at stream crossings. When the mine water is of sufficient quality for direct discharge to Stanley Creek, the installed pipelines less than three feet deep would be removed, and the pipeline corridor and decant pond would be reclaimed.
Mill Site and Office and Shop Areas	Drainages	Not Addressed	Two separate stream channels would be constructed across the mill pad and down the fill slope. Channels would be armored with coarse rock sized to provide stability in 100-year, 24-hour storms. An energy dissipation basin would be created at the toe of the fill slope (pg. 4-7, Figures 4-3 and 4-3).	Modifications to the Proposed Action include: 1) Both drainage channels would be combined into one channel. 2) The channel would be lined with an impervious liner. 3) Development rock would not be used to construct the drainage channel. 4) Rock structures in the channel would be angular and sized for the 100-year flow. 5) The new channel would be routed across the mill site and down the fill slope to the pre-existing channel location (**Figure 3-3**).
Tailings Impoundment Surface		Surface drainage ditches would conduct storm water to a natural drainage. A spillway would be constructed to divert drainage (pg. 66)	The existing drainage that slopes toward the decant ponds would be maintained. There would be no need for a spillway (pg. 7-9).	Modifications to the Proposed Action include construction of berms to prevent storm water run-on from entering the decant ponds.
Water Treatment and Disposal				
Decant Ponds		Not Addressed	When mine water is no longer routed to the decant ponds, the ponds would be recontoured to form shallow depressions to capture runoff and to provide wetland habitat (pg 4-18).	In order to maintain existing geochemical conditions, the decant ponds would be maintained as deep ponds (10 to 15 feet deep and approximately 4 acres in size with a divider berm to provide for periodic cleanout of the pond).

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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9	Tailings Impoundment Surface	Cells 1,2,3	The surface of the impoundment would be graded and reworked to provide a suitable area for revegetation (pg 66).	No major regrading of the tailings impoundment surface is proposed; the surface would slope to the east, draining to the decant ponds (pg. 4-15 and 4-18)	Modifications to the Proposed Action include: 1) Final permitted elevation of the tailings is 2,420 for Cells 1, 2, and 3. 2) A berm would be created to prevent storm water runoff from the impoundment surface from draining directly to the decant ponds.
	Groundwater Quality				
10	Seepage from Tailings Embankment		The toe ponds were constructed by ASARCO in 1983 to capture seepage and embankment runoff (pg. 3-6). Enviro-pump S-1 is used to convey groundwater seepage to Toe Pond 2 (pg. 3-10). Snowmelt or runoff from toe ponds 2, 3, and 4 is currently pumped to the impoundment (pg 7-10).	The current system would be maintained post-closure until the water quality is suitable for release to Lake Creek.	Same as Proposed Action
11	Monitoring Wells		Not Addressed	Remain as long as needed, then plugged and abandoned as per ARM 36.21.810) (Genesis 2006, pg 4-19, Appendix F and Table F-1).	Same as Proposed Action
	Surface Water Quality				
12	Surface Water Quality		A sampling program was designed and implemented to determine baseline conditions for surface waters for analysis in the 1978 Draft EIS (DSL and KNF 1978, page 107). Surface water monitoring of Stanley, Fairway, and Lake creeks has been conducted since 1986. The program included bioassay testing, macroinvertebrate monitoring, and water quality and flow monitoring three times per year (Genesis 2006, Appendix F, page 5). The seven water quality monitoring stations listed in **Table 2.3** would continue to be sampled post-reclamation for flow and water quality three times per year until the Agencies agree that monitoring is no longer necessary (Genesis 2006, Appendix F, pages 5-6).	The Proposed Action Water Monitoring Plan includes annual macroinvertebrate monitoring and water quality and flow monitoring three times per year (Genesis 2006, Appendix F, page 5). The water quality monitoring program would continue under the Proposed Action until the Agencies agree that monitoring is no longer necessary. The surface water quality monitoring sites that would be sampled are the same as those listed in **Table 2.3**.	There would be additional monitoring of surface water at the mine during closure to verify whether state water quality standards have been met.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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	Long-Term Monitoring of Water Quality				
13	Water Quality Monitoring		Scheduled monitoring of the two test wells drilled in July of 1976 would continue throughout the life of the project (DSL and KNF 1978, page 58). Surface water monitoring of Stanley, Fairway, and Lake creeks has been conducted since 1986. The program included bioassay testing, macroinvertebrate monitoring, and water quality and flow monitoring three times per year (Genesis 2006, Appendix F, page 5).	Water quality monitoring would continue during and after reclamation until the Agencies agree that monitoring is no longer necessary.	Modifications to the Proposed Action include additional monitoring of surface waters including seeps and springs to verify whether state water quality standards have been met. In addition to the two Ross Creek springs RCT1 and RCT2 currently in the 2006 monitoring plan, this alternative adds SC-15 on upper Stanley Creek. In the vicinity of the decant ponds, additional wells would monitor water quality annually to verify geochemical conditions in the area of the mine water discharge are maintained. These wells are MW01-15, MW01-16, MW-95-7, and MW-95-8 (**Figure 2-5**).
	Reclamation				
	Cover Source Materials				
14	Stockpile at Toe Ponds	Troy Mine, Inc. indicates that a volume of 818,500 cubic yards (cy) of soil is stockpiled at/around impoundment with 162,000 cy at Cell 3 soil stockpile	The soil was salvaged from the upper 24 inches of a 40-acre area in the east half of Section 31, T30N, R33W (pg. 66) under the impoundment.	The soil stockpiled to the west of the tailings embankment would be left in place to maintain wildlife habitat (pg. 4-16).	Up to 90% of the soil stockpiled west of the toe ponds would be removed and used for reclamation. BMPs would be used during removal to protect water quality and the western toad. Soil would be amended with an agency-approved, wood-based, organic amendment to add 1,100 lbs of nitrogen per acre. The soil remaining in the stockpile would be configured so surface water is protected from sediment and the toe pond berm is maintained.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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15	Tailings Impoundment Surface	2006 bond calculation assumes 766,600 cy would be needed to cover impoundment surface with 18 inches of soil	The tailings impoundment surface would be covered with approximately 18 inches of stockpiled soil near the impoundment and vegetated (pg. 66).	The 18 inches of reclamation material for the surface of the tailings impoundment would be obtained from borrow sources located east of the impoundment (pg. 4-16).	Up to 90% of the stockpiled soil west of the toe ponds would be used first, then borrow east of the impoundment would be used for the balance of soil, if needed. The soil would be placed in one soil lift to prevent compaction. The soil would be ripped before seeding. Soil would be amended with an agency-approved, wood–based, organic amendment to add 1,100 lbs of nitrogen per acre. Any materials originating in borrow pits to be used in reclamation would be in accordance with Agencies' growth media specifications.
16	Mill Site and Office and Shop Area	27 acres @ 12 inches of cover = 43,560 cy growth media needed	Following removal of unneeded buildings and resurfacing of the bench, no additional capping at the mill and plant site would be proposed (pg. 65).	The growth media within the mill and office/shop pads, the upper percolation pond embankment, old warehouse pad slope, or the USFS borrow site (in Section 24) would be used for reclamation use in the mill area (pg. 4-7 to 4-11, Table 4-1).	Growth medium from the mine and mill area would be used first, then rocky glacial borrow east of the impoundment would be used for the balance, if needed. The mill site and office and shop areas would be covered with 12 inches of growth media. The USFS borrow site and stockpiled soil west of the impoundment would not be used. Growth material would be amended with an agency-approved, wood-based, organic amendment to add 1,100 lbs of nitrogen per acre. Woody material greater than 3 inches in diameter would be scattered at the rate of 25 tons per acre. Any materials originating in borrow pits to be used in reclamation must be in accordance with Agencies' growth media specifications.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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17	North and South Portal Patios	15.28 acres total, 11.6 acres to be left as talus and cut slopes; 3.7 acres to be reclaimed @ 12 inches of cover = 5,969 cy cover growth media needed	Not Addressed	A 12-inch layer of cover growth media from a local borrow source would be placed over the regraded surface (pg. 4-1).	Growth medium from the mine and mill area would be used first, then rocky glacial borrow east of the impoundment would be used for the balance, if needed. Growth material would be amended with an agency-approved, wood-based, organic amendment to add 1,100 lbs of nitrogen per acre. Woody material greater than 3 inches in diameter would be scattered at the rate of 25 tons per acre.
	Subsidence				
18	Subsidence	Existing surface expression of subsidence totals less than 1 acre.	Potential subsidence was not addressed in the reclamation plan approved in 1978. Two surface subsidence features, most likely chimney subsidence, have formed during operations. Subsidence occurs due to wide roof spans and poor ground conditions associated with the weak rock mass along the East Fault zone. Efforts to reclaim subsidence areas occurred in 2005 and 2006. As of 2010, one area appears to have returned to adequate stability and utility. Reclamation of the other subsidence area was not successful. Reclamation of one future subsidence feature has been covered by a minor revision to the operating permit (Montana DEQ MR 07-001). A bond is in place for a future subsidence event.	Not Addressed	The Agencies would require Troy Mine, Inc. to repair the existing surface subsidence feature that has not achieved a level of stability and utility comparable to the pre-disturbance condition. The reclamation bond would be increased to address the possibility of future subsidence, including surface subsidence occurring on steep slopes.
19	Subsidence Monitoring		Not Addressed	Not Addressed	Annual aerial inspections of the mine shadow area would be conducted by Troy Mine, Inc. with agency participation. Surveys would be conducted until bond release, and the subsidence portion of the reclamation bond would be held for a minimum of twenty years after the mine has been decommissioned and the adits have been plugged.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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	Revegetation				
20	General		Vegetation would consist of a mixture of mostly introduced grasses and legumes and native shrubs and trees (pg. 67)	Vegetation types would be determined based on pre-mine occurrence, establishment potential, growth characteristics, soil stabilization qualities, commercial availability, experience from on-site tests, and post-mine land use objectives. Native species would be emphasized (pg. 6-1) and noxious weed-free seed would be used (pg 6-2). A wetland mix would be provided for designated areas (pg 1-4). Annual ryegrass would be added to forest mixes to provide initial rapid stabilization (pg. 6-2). Fertilizer would be applied except within 200 feet of a perennial stream; mulching would be applied to slopes steeper than 20% with less than 50% coarse fragments (pg 6-8). Irrigation may be used during the first season to ensure initial stand development (except for slopes steeper than 10% or upper elevation sites) (pg 6-9).	Modifications to the Proposed Action include the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation. Organic fertilizer would be used rather than chemical fertilizer.
21	Tailings Impoundment Surface	303 acres	The tailings impoundment surface would be covered with 12 to 24 inches of soil. Container grown tree seedlings would be planted at a spacing of 680 trees/acre. Shrubs would be planted between the trees. The seed mix would be applied after 2-3 growing seasons (pgs. 68-69).	The lower elevation forest mix would be seeded over the majority of the tailings surface, with the addition of some grassland and wetland mix (pg 6-2). During the initial growing season, Irrigation may be used (pg. 4-18).	Modifications to the Proposed Action include: 1) The wetland mix would not be used on the tailings impoundment. 2) Trees would be planted as in No Action Alternative. 3) The seed sources for native plant species should be from northwestern MT, if available at the time of reclamation.
22	Tailings Embankment Slopes and Benches	42 acres	Tree species would be planted on benches at an 8-foot spacing, with shrubs in between. All slopes would be seeded and fertilized. South-facing exposures would be mulched and irrigated if necessary (pg. 68). Over the period 1995-98, over 35,000 tree seedlings were planted on the 42-acre tailings embankment (833 trees/acre). The slopes and benches are currently covered with grass and trees. No additional revegetation of the tailings embankment is proposed; a 42-acre surface on the impoundment has been reclaimed (pg 2-5).	Same as No Action	The Agencies would perform a field review of previously reclaimed areas to determine if additional areas need covering with soil, revegetation, or reseeding. If areas are reseeded, the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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23	Troy Mine, Inc. Borrow Sites	East Impoundment and NE Impoundment areas, Cell 3 borrow	Not Addressed	The borrow sites would be planted with lower elevation forest type vegetation (pg. 4-18 and 6-2).	Modification to the Proposed Action includes the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation.
24	Reclaim Water Pump Station		Not Addressed	The reclaim water pump station would be revegetated to grassland and would rely on natural establishment of woody species (pg 4-19).	Modification to the Proposed Action includes the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation.
25	Mill Site and Office and Shop Areas		Fertilizer would be added at 200 lbs/acre prior to seeding. South-facing exposures would be mulched (pg. 68).	The mill site office and shop area would be planted with an upper elevation forest mix (pg 6-2).	Modification to the Proposed Action includes the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation. Disturbed ground would be mulched and plants would be inoculated with appropriate mycorrhizal fungi if available. Organic fertilizer would be used rather than chemical fertilizer.
26	North and South Portal Patios		Details for revegetation of the portal patios were not discussed in the 1978 EIS. In 1997 and 1999, 3,750 trees were planted in the North Portal area (pg. 2-3).	The recontoured portal patios and development rock fill would be revegetated with an upper elevation forest mix (pg. 4-1). The exterior face of the adit plugs would be covered with borrow material and fine-grained material to provide copper attenuation in event of leakage (pg 7-6).	Modification to the Proposed Action includes the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation. Disturbed ground would be mulched and plants would be inoculated with appropriate mycorrhizal fungi if available. Organic fertilizer would be used rather than chemical fertilizer.
27	USFS Borrow Source		Not Addressed	The borrow sites would be planted with upper elevation forest type vegetation (pg. 4-11).	Modifications to the Proposed Action include: 1) The seed sources for native plant species should be from northwestern MT, if available at the time of reclamation. 2) The USFS borrow area would not be used in order to prevent the spread of rush skeletonweed. USFS would be responsible to reclaim this borrow area.
28	Smaller disturbed areas	Tailings pipelines and reclaim line, roads, power line corridors, storage areas, etc.	Revegetated (pg 66).	Smaller disturbed areas would be planted with grassland mix (pg 6-2) and would rely on natural establishment of woody species.	Modification to the Proposed Action includes the provision that the seed sources for native plant species should be from northwestern MT, if available at the time of reclamation.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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29	Wetlands		Not Addressed	Wetlands would be reclaimed with an herbaceous wetland mix and a forested wetland mix (pg 6-5).	Modifications to the Proposed Action include: 1) The seed sources for native plant species should be from northwestern MT, if available at the time of reclamation. 2) The decant ponds and tailings impoundment surface area would not be reclaimed with a wetland seed mix.
30	Revegetation Monitoring		Not Addressed	Monitoring of revegetation success would occur during pre-closure and closure phases; if poor growth was noted, additional site remediation would occur (Genesis 2006, pg 8-1, Appendix G). The duration of revegetation monitoring would depend on results (pg. 8-3).	Modification to the Proposed Action includes monitoring until the requirements for bond release are met. This includes long-term monitoring of noxious weeds, including meadow knapweed and rush skeletonweed.
31	Noxious Weed Management		Not Addressed in the 1978 plan but a county and KNF approved weed plan is currently in place.	The Weed Management Plan proposed in 2006 Revised Reclamation Plan, Appendix E would be followed. Revegetated areas would be monitored for noxious weeds, forest would be established to shade out weeds, a cover crop may be used, and limited use of herbicides would occur (pg. 6-9).	Modifications to the Proposed Action include the provisions that equipment would be washed prior to coming on site and other weed prevention BMPs would be required.
32	Air Quality		Not Addressed	BMPs and irrigation would be used as needed to suppress dust until vegetation is established (pg 8-3).	Modification to the Proposed Action includes monitoring until vegetation is established to maintain air quality.
	Infrastructure				
33	Storm Water Collection and Diversion		Not Addressed	Existing storm water collection and diversions would remain in place with BMPs as required with appropriate velocity control structures and riprap to prevent erosion (pg. 4-13).	Modifications to the Proposed Action include: 1) The gunite liner would be removed from existing collection/diversion ditches and the surface would be regraded to slope to a ditch on the uphill side of the access road. This ditch would drain to the large, natural drainage across the mill pad. 2) An approved Storm Water Pollution Prevention Plan (SWPPP) would be required for all reclamation activities.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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34	Mill Site and Office and Shop Areas	Asphalt (parking lots, etc)	Paving was completed after the Plan was approved. Removal of asphalt was not addressed	Asphalt would be ripped and buried on site with minimum of 3 feet cover material (pg. 4-6).	Asphalt from paved areas would be pulverized and used for NFSR 4626 road gravel.
35		Concrete from buildings	Concrete would be removed from the site. The bench surfaces would be regraded to 1.5H:1V slopes (pg 65).	Concrete would be buried on site with minimum of 3 feet cover material (pg. 4-6).	Modification to the Proposed Action includes the provision that materials would be disposed of off NFSL in appropriate disposal areas in compliance with the MT Solid Waste Act.
36		Metal, glass, plastic wood from buildings	Construction debris would be removed from the site. The bench surfaces would be regraded to 1.5H:1V slopes (pg 65).	The buildings would be demolished and construction debris materials buried on site with minimum of 3 feet cover material (pg. 4-6).	All materials would be disposed of in appropriate disposal areas off NFSL in compliance with the MT Solid Waste Act.
37		Water diversion culverts	Not Addressed	Culverts would be sealed by plugging upper ends with concrete (pg. 4-7).	Both ends of the culverts would be plugged with concrete.
38	Fuel/Other tanks	Surface diesel fuel tank, two large and numerous small propane tanks	Not Addressed	Removed from site (pg. 4-13).	Same as Proposed Action
39	Water Tank	300,000 gallons	Not Addressed	The water tank would be sold or scrapped (pg. 4-14).	The water tank would be removed from site.
40	Water Supply Lines		Not Addressed	The water supply lines would be abandoned in place (pg. 4-14).	When no longer needed for mine closure, any water supply lines would be removed off NFSL.
41	Domestic Water Well		Not Addressed	The domestic water well would be used for irrigation during the first growing season after reclamation if needed, then abandoned/plugged per ARM 36.21.810 (pg. 4-14).	The domestic water well or mine water from the decant ponds would be used for irrigation for the first 3 growing seasons if needed.
42	Large-Capacity Make-up Wells Near Stanley Creek		Not Addressed	Plugged/abandoned per ARM 36.21.810 (pg.4-14).	Same as Proposed Action
43	Small Pump Buildings		Not Addressed	Reclaimed (pg. 4-14).	Same as Proposed Action
44	Surge Pond		Not Addressed	Reclaimed (pg. 4-14).	Same as Proposed Action
45	Sewage Treatment Facility		Not Addressed	Removed and salvaged (pg. 4-14).	Removed from site.
46	Tailings Irrigation System		Not Addressed	The tailings irrigation system would be left in place to assist in reclamation then salvaged and removed (pg 4-18 and 4-19).	The tailings irrigation system would be left in place to assist in reclamation and then removed.
47	Reclaim Water Pond		Not Addressed	The liner for the reclaim water pond would be cut, folded in, and buried in place (pg 4-19).	Modification to the Proposed Action includes the provision that the buried liner would be covered with 3 feet of soil.
48	Quonset Hut		Not Addressed	Left in place for storage and office space (pg 4-19).	Same as Proposed Action
49	Fences		Not Addressed	Removed (pg 4-20).	The fence surrounding the USFS borrow area would be left in place to avoid use and subsequent spreading of rush skeletonweed.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

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	Access Roads				
50		#4551	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road would be converted to a trail.
51		# 4624	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to KNF specifications.
52		# 4624 B	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to KNF specifications.
53		Main access # 4626 to mill site	The main access road would be retained to provide recreational access to Spar Lake and Mt. Vernon areas (pg 65).	The current paved surface of the main access road would remain (pg. 4-1).	Modifications to the Proposed Action on NFSL include: 1) Asphalt surface would be pulverized and ripped in place. 2) A 4-inch lift of aggregate would be placed on the pulverized surface. 3) Approximately 300 feet of asphalt would be repaired and maintained on the Stanley Creek bridge approaches. Guardrails and safety berms would be removed. The Stanley Creek Bridge would be left in good condition meeting current safety standards and capable of supporting legal highway loads.
54		# 4626 from mill site to junction with #4 629	The main access road would be retained to provide recreational access to Spar Lake and Mt. Vernon areas (pg 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Implement BMPs on any segments or stream crossings at risk of contributing sediment to streams.
55		# 4626C	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to USFS specifications.
56		# 4626D	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to USFS specifications.

[1] *Page numbers referenced under the Proposed Action are for the 2006 Revised Reclamation Plan*

	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
57		# 4626F	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to USFS specifications.
58		# 4626G	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to USFS specifications.
59		# 4628	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Stabilize road for intermittent stored service; install water bars; upsize culverts or construct armored overflows to pass 100-year flows; remove unstable sections of road fill. Road work would not be permitted until after June 15 for grizzly bear protection.
60		# 4628C	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Road fully recontoured; all culverts removed; stream crossings reconstructed; seeded and planted according to USFS specifications.
61		# 4629	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	From MP 0.0 to 0.8: Stabilize road for intermittent stored service; install water bars; upsize culverts or construct armored overflows to pass 100-year flows; remove unstable sections of road fill. From MP 0.8 to 1.34: Implement BMPs on segments at risk of contributing sediment to streams.
62		# 4630A	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Stabilize road for intermittent service; install water bars; upsize culverts or construct armored overflows; remove unstable sections of road fill; seeded and planted according to USFS specifications.
63		# 9003	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Scarify; seed and plant according to USFS specifications.

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	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
64	Mining Related Roads on NFSL	# 4626E, # 4626H, # 4626I, # 4628, # 4628B, # 4628D, # 4628F, # 4628G, # 4628J, # 4642, # 4642A, # 4642B, # 4645, # 14391, # 14993	Disposition up to USFS at time of closure (pg. 65).	The existing USFS roads would remain in place per USFS requirements (pg 4-1). Agencies interpret this to mean that roads would not be reclaimed at the time of closure.	Decommission by Abandonment.
65	Private Roads on Patented Lands	# 4624, # 4624A; # 4626 (private portion), # 4626J, K and L; # 4628D, E, F, G, H, I, J ; # 4629A, B, C; # 4642 # 4645 # 14386 # 14387 # 14398 # 14398A # 54628 # 54628A # 54628B # 54629	Not Addressed	Not Addressed	Roads would be field reviewed by the Agencies to identify reclamation needs. Roads would be waterbarred or otherwise reclaimed as needed to reduce adverse impacts to water quality.
66	Private Roads on Troy Mine, Inc. Land by Tailings Impoundment	Various roads used for access to tailings impoundment	Not Addressed	Not Addressed	Roads would be field reviewed by the Agencies to decide if they are needed for the proposed post-mine land use. Roads not needed would be reclaimed.
67	Transmission Line	115 kV	Removed and disturbed areas reclaimed and revegetated (pg. 66).	Northern Lights Inc. would have the final decision regarding removal or preservation of all or portions of the 115-kV power line.	Modifications to the Proposed Action include consideration of the needs for routing and disposal long-term. The transmission line would be maintained in place until no longer needed for reclamation. On NFSL, Northern Lights Inc. would be required to follow the terms and conditions of their Special Use permit issued by KNF.
68	Substation		Not Addressed	Left in place for future use by Northern Lights (pg. 4-13).	Same as Proposed Action

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	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
69	Maintenance Sump		Not Addressed	Regraded to blend with surrounding topography (pg. 4-15).	Remove remaining contaminants and restore to original floodplain contours. Any tailings or contaminated soil would be removed before regrading.
70	Tailings Impoundment Geotechnical Monitoring		Not Addressed in the 1978 EIS but has been addressed operationally.	Annual inspections of the tailings embankment would occur (Genesis 2006, pg 8-2 and Appendix H). Geotechnical monitoring would continue until Troy Mine, Inc. and the Agencies agree to discontinue it.	Modifications to the Proposed Action include the provisions that a qualified professional engineer would annually monitor and verify the stability of the embankment for a minimum of five years after reclamation is completed. The engineer's report would be submitted to the Agencies. The Agencies would be consulted for concurrence before monitoring ceases.
	Topography				
71	Mine Site	North and South Portal Patios	The slopes of the mine development rock patio fill would remain at the natural angle-of-repose and would be capped with 12 inches of soil (pg. 64-65). The northeast face of the development rock patio fill slope below the North Adit has been recontoured and revegetated (pg. 2-3 and Figure 4-1).	The slopes would be regraded by pulling edges up and filling against the cut slope/roadway, covered with growth medium (coarse fraction from patios, field-reviewed for adequacy of volume and placement). Flat areas would be covered with 12 inches growth medium, if available, from patios, then ripped and seeded (pg. 4-1).	Modifications to the Proposed Action include: 1) All growth medium for the mine and mill area would be salvaged from the mill site fill. 2) If there is not enough material at the mill site, rocky glacial borrow east of the impoundment would be used. 3) A stream channel would be constructed at the west ventilation adit portal.
72	Mill Site and Office and Shop Areas	Entire Area	Regrade the bench surfaces to a 1.5H:1V slope (pg 65). The mill site bench and cut fill slopes would be left in their current configuration. After removal of the buildings, the bench surfaces would be graded smooth.	Same as No Action, except some demolition debris would be buried on site (pg. 4-6 and 4-7, Figure 4-2 and 4-3, Exhibit F) - see Infrastructure section above, lines #35-38. The office and mill pads would be outsloped at approximately 6 – 7% (pg. 4-7, Figure 4-2).	Modifications to the Proposed Action include: 1) All demolition materials would be disposed of off NFSL in appropriate disposal areas in compliance with the MT Solid Waste Act. 2) Development rock fill would be minimized. 3) The area would be regraded and fill would be at least 3 feet deep over debris.
73	Tailings Embankment		No regrading of the tailings embankment is proposed.	Same as No Action	All eroded or bare areas on the embankment would be repaired by spreading 12 inches of the stockpiled growth medium. The areas would be seeded and/or planted with agency-approved mixes.

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	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
74	Toe Ponds		Not Addressed	Connected by inter-pond channels with armored outfall (installed as safety measure) (pg 4-15, Figure 4-6).	Modification to the Proposed Action includes the provision that MT Department of Fish, Wildlife, and Parks (FWP) would survey the ponds for non-native fish species and determine whether removal of the fish is recommended; if so, FWP would issue a permit for this activity. Inter-pond channel construction and fish removal would not begin until September or when juvenile western toads are no longer observed at the breeding site.
75	Borrow Sites	Borrow sites (USFS)	Not Addressed	Borrow sites would be regraded to match existing slopes upon completion of borrow activities and planted with upper elevation forest type vegetation (pg. 4-11, Figure 4-5).	The USFS borrow area would not be used in order to prevent the spread of rush skeletonweed. KNF would be responsible to reclaim this borrow area. The fence surrounding the USFS borrow area would be left in place to avoid use and subsequent spreading of rush skeletonweed.
76	Troy Mine, Inc. Borrow Sites (East Impoundment and NE Impoundment Areas and Cell 3 Borrow Pit)		Not Addressed	The borrow sites would be graded to a 2:1 slope reduction including the upper slope diversion ditches (pg 4-18).	The borrow sites would be graded to 3:1 slopes. The upper layers of soil would be salvaged and stockpiled. Once the borrow site was used, the salvaged soils would be replaced and seeded/revegetated. Troy Mine, Inc. would provide the Agencies with a quantification of the volume of borrow to be removed and location(s) for the soil stockpile(s).
	Underground Equipment				
77	Mobile Equipment		Not Addressed	Not Addressed	All mobile equipment would be removed from mine, if possible. If abandoned in place, all fluids would be drained and disposed of properly.

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	Component	Specific Features	No Action (1978 EIS pgs 64-70) and Existing Conditions / Reclamation completed to date (2006 Revised Rec. Plan pgs 1-1 - 10-1)	Proposed Action (2006 Revised Reclamation Plan)[1]	Agency-Mitigated Alternative
78	Jaw Crusher		Not Addressed	The jaw crusher would be salvaged if possible or abandoned in place (and oil sumps and reservoirs cleaned) (pg. 4-4 and 4-6).	The jaw crusher components on NFSL would be removed; other components would be removed as necessary to close the adits and remaining equipment may be abandoned in place or removed from the mine. A final agency inspection of the workings would be required.
79	Conveyor		Not Addressed	Salvaged if possible or abandoned in place (pg. 4-4 and 4-6).	The conveyor components on or that extend onto NFSL would be removed; other components would be removed as necessary to close the adits and remaining equipment may be abandoned in place or removed from the mine. A final agency inspection of the workings would be required.
80	Ventilation System		Not Addressed	Fans, motors, and attached electrical equipment would be removed and disposed of off-site; metal, fiberglass, wood, concrete, etc. would be abandoned in place (pg. 4-6).	Any ventilation system components at the surface and at least 100 feet back into the adits would be removed. Components further underground would be abandoned in place or removed from the mine. A final agency inspection of the workings would be required.
	Libby Concentrate Loadout				
81	Loadout Facility		Not Addressed in the 1978 Reclamation Plan but there is an approved reclamation plan for the facility (Minor Revision 04-001 to operating permit #00093)	The concentrate loadout was in a building with a concrete floor which received periodic cleaning. Operationally, rail cars were covered before leaving the building (pg. 3-13).	The former concentrate loadout facility burned down in 2010. A new covered facility was approved in 2011 in Libby. Cleanup of the former loadout would be per the approved reclamation plan. Any monitoring wells would be plugged and abandoned per ARM 36.21.810.

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2.4.1 No Action Alternative

The No Action Alternative consists of the original 1978 Reclamation Plan and includes reclamation activities that have already been completed. The reclamation plan was first analyzed in the *1978 Draft Environmental Impact Statement* (Draft EIS) (DSL and KNF 1978) and later approved by the Agencies.

2.4.1.1 Water Management

Adit Closure and Mine Water Discharge

The 1978 reclamation plan proposed to close the adits by shutting them with concrete; however, no additional detail was provided (DSL and KNF 1978, page 63). After mine closure, surface and groundwater would be expected to enter and accumulate in the mine, eventually exit the mine,

discharge onto the development rock fill patio, infiltrate into groundwater, and ultimately enter Stanley Creek.

Water Treatment and Disposal

The No Action Alternative does not address water treatment. Mine water outflows would be allowed to exit the mine, infiltrate into the portal patio, discharge into the groundwater system, and flow into Stanley Creek.

Toe ponds at the base of the tailings impoundment were constructed by ASARCO in 1983 to capture seepage and embankment runoff. The sump and pumping system (Enviro-pump) was installed to convey groundwater seepage to toe pond 2. Snowmelt from toe ponds 2, 3, and 4 is currently pumped to the impoundment, but this pumping would not continue long-term after reclamation. Surface drainage would be provided from the low point of the impoundment surface to an appropriate natural drainage (DSL and KNF 1978).

Groundwater Quality

The No Action Alternative does not address groundwater quality beyond operational monitoring. **Section 3.9** describes groundwater quality in more detail. Groundwater is monitored during operation at the locations and frequencies shown in **Table 2-2**.

Table 2-2. No Action Alternative Groundwater Monitoring Sites and Schedule

Monitoring Site	Monitoring Parameter	Monitoring Frequency
Mine water - outflow, adit pipe (SA-P)	Quality	Quarterly
Mine water - outflow, adit pipe (SA-P)	Flow	Continuous (daily average)
Mine water - Service Adit ditch (SA-D)	Quality	Quarterly
Mine water - Service Adit ditch (SA-D)	Flow	Continuous (daily average)
MW-1	Water level and quality	Annually
MW-2	Water level and quality	Annually
MW-3	Water level and quality	Annually
MW-4	Water level and quality	Annually
IW-1	Water level and quality	Annually
Toe ponds	Water level and quality	Quarterly
S-1 (Spring near toe ponds)	Water level and quality	Quarterly

Monitoring Site	Monitoring Parameter	Monitoring Frequency
MW-95-4	Water level and quality	Spring, summer, fall
MW-95-7	Water level and quality	Spring, summer, fall
MW-95-8	Water level and quality	Spring, summer, fall
MW-97-12	Water level and quality	Spring, summer, fall
MW-97-14	Water level and quality	Spring, summer, fall
MW-01-15	Water level and quality	Spring, summer, fall
MW-01-16	Water level and quality	Spring, summer, fall
MW-2010-1	Water level and quality	Spring, summer, fall
MW-2010-2	Water level and quality	Spring, summer, fall
Surface water – Ross Ck RCT 1	Quality and flow	Annually – during low flow
Surface water – Ross Ck RCT 2	Quality and flow	Annually – during low flow
Surface water – Emma Gulch	Quality and flow	Annually – during low flow
Surface water – Weasel Gulch	Quality and flow	Annually – during low flow
Surface water – Stanley Creek	Quality and flow	Annually – during low flow

In addition to the mine groundwater monitoring, groundwater was monitored at the concentrate loadout in Libby in accordance with Operating Permit #00093 Minor Revision 04-001. Two existing shallow wells, new groundwater wells, and a drain have been sampled at the loadout facility. This facility burned down in 2010, and a temporary loadout facility was used until a new covered facility was approved in 2011 near the temporary facility. The new wells to be installed at the new loadout facility would be monitored until the site is reclaimed and the bond is released.

Under the No Action Alternative, groundwater would enter the mine, flood the workings, and eventually exit the mine and discharge into the groundwater system and Stanley Creek.

Surface Water Quality

A sampling program was designed and implemented to determine baseline conditions for surface waters for analysis in the 1978 Draft EIS (DSL and KNF 1978, page 107). Four toe ponds were installed in 1983 to contain storm water runoff (Genesis 2006, page 7-10). Operationally, the three northern toe ponds usually contain standing water, but the southernmost toe pond is typically dry. A sump and pumping system is currently used to capture groundwater that emerges downhill from the toe ponds.

During operations, water is continuously pumped from the sump to toe pond #2 to prevent migration of nitrate.

Surface water monitoring of Stanley, Fairway, and Lake creeks has been conducted since 1986. The program included bioassay testing, macroinvertebrate monitoring, and water quality and flow monitoring three times per year (Genesis 2006, Appendix F, page 5). The seven water quality monitoring stations listed in **Table 2-3** would continue to be sampled post-reclamation for flow and water quality three times per year until the Agencies agree that monitoring is no longer necessary (Genesis 2006, Appendix F, pages 5-6).

Under the No Action Alternative, precipitation would enter the mine through fractures, the workings would flood, and the water would eventually exit the mine and discharge into groundwater and Stanley Creek.

Table 2-3. No Action Alternative Surface Water Monitoring Sites and Schedule

Monitoring Site	Monitoring Parameter	Monitoring Frequency
LC-1	Quality and flow	Spring, summer, fall
LC-2	Quality and flow	Spring, summer, fall
LC-4	Quality and flow	Spring, summer, fall
FC-1	Quality	Spring, summer, fall
SC-2	Quality and flow	Spring, summer, fall
SC-15	Quality	Spring, summer, fall
SC-17A	Quality	Spring, summer, fall

Long-Term Monitoring of Water Quality

As part of the baseline sampling program described above, the 1978 Draft EIS includes continued monitoring of the two test wells drilled in July of 1976 throughout the life of the project (DSL and KNF 1978, page 58). Operational monitoring consists of periodic water level and water quality sampling of monitoring wells, springs, and areas of groundwater expression in the vicinity of the mine. Operational groundwater monitoring site locations are listed in **Table 2-2,** and locations are shown on **Figure 2-5**. The three sites shown for SC-15 on **Figure 2-5** are added under the Agency-Mitigated Alternative.

The five surface water sites listed in **Table 2-2** represent the farthest upgradient expressions of groundwater in drainages around the mine and were chosen to monitor changes in the quality of groundwater discharging to these drainages (Genesis 2006, Appendix F, page 2). In coordination with the Agencies, Genesis (now Troy Mine, Inc.) has also monitored groundwater in a tributary below the South Adit portal to evaluate any effects on groundwater seepage as the mine floods. These monitoring

sites would continue to be evaluated to determine potential mine water influence on surface and groundwater. Scheduled monitoring of the two wells drilled in July of 1976 would continue throughout the life of the project (DSL and KNF 1978, page 58).

Surface water quality monitoring as described above would continue post-reclamation three times per year until the Agencies agree that monitoring is no longer necessary (Genesis 2006, Appendix F, pages 5-6).

2.4.1.2 Reclamation

Reclamation Materials

Soil was salvaged from the east half of Section 31 in Township 30 North, Range 33 West (west side of the tailings impoundment) to a depth of 24 inches. The salvaged soil would be used to provide an average 12-inch cover over the mine development rock-fill patio at the mine and at those areas where buildings and facilities would be removed (DSL and KNF 1978, page 66).

The surface of the tailings impoundment and the embankment would be covered with 18 inches of the stockpiled soil and revegetated (DSL and KNF 1978, page 66). The Draft EIS does not specifically identify the source of these stockpiled soils. The soil needed to complete reclamation would likely come from the soil stockpiled from the construction of the tailings facility.

Approximately 162,000 cubic yards of soil were stockpiled in Section 32 of Township 30 North, Range 33 West (just east of the tailings facility) (Genesis 2006) and revegetated to prevent erosion (DSL and KNF 1978, page 67). In addition, approximately 818,500 cubic yards of soil were stockpiled outside the perimeter of the tailings impoundment between the toe ponds and Lake Creek for use in reclaiming the impoundment area (Genesis 2008). These west stockpiles are located on the bench above the Lake Creek floodplain and were stabilized with a grass and legume mixture until needed for reclamation. Reclamation plans call for stockpile sites to be revegetated and planted with trees and shrubs after the soil has been used (DSL and KNF 1978, page 67).

Subsidence

Subsidence was not addressed as part of the original 1978 reclamation plan. During operations, two surface subsidence features developed along the East Fault. Genesis (now Troy Mine, Inc.) made an effort to reclaim the subsidence in 2005 and 2006. In 2007, Genesis applied for a permit revision to address these subsidence issues. During an inspection in fall of 2010, reclamation success at the two features was evaluated. While the first subsidence feature appeared to be successfully reclaimed, the second area of disturbance was located on a steep slope and showed evidence of erosion and instability. There was little vegetative cover established on the disturbance. It is possible that further subsidence could occur in the future, particularly in the poor ground conditions encountered in the vicinity of the East Fault. Although the Agencies currently hold a bond for reclamation of possible future surface subsidence, they have determined that a bond increase may be required to cover mitigation for surface subsidence on steep slopes, especially near the East Fault.

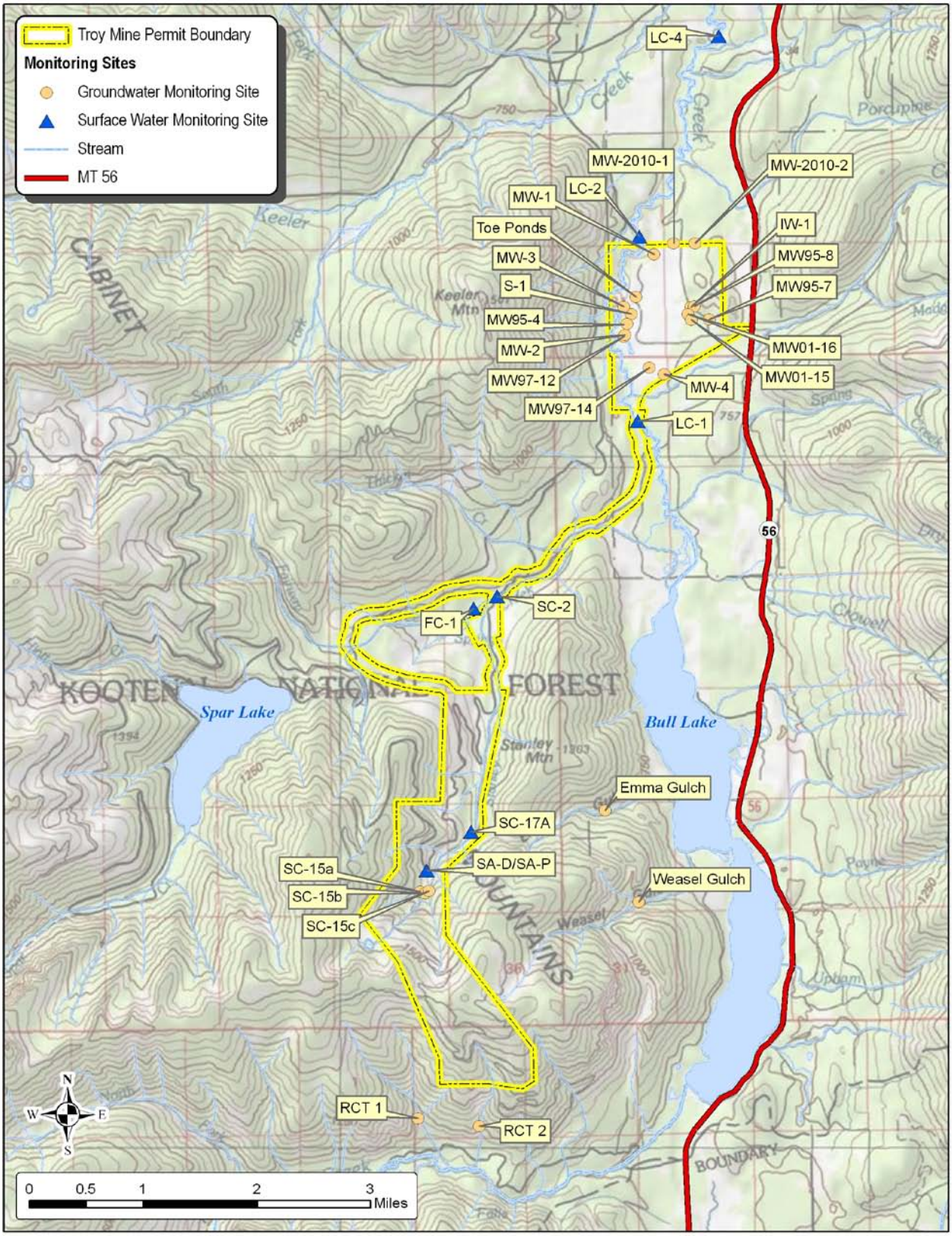


Figure 2-5. Proposed Surface and Groundwater Monitoring Sites

Revegetation

The No Action Alternative proposes a mixture of introduced grasses and legumes and native shrubs and trees to cover all disturbed areas upon reclamation (DSL and KNF 1978, page 67).

Soils would be seeded during the first appropriate growing season after necessary surface grading and preparation has been completed. If primary reclamation attempts fail, the Agencies would be consulted before replanting occurred (DSL and KNF 1978, page 67). Cut and fill slopes resulting from access roads, the mill and office sites, development rock fill patio, utility corridors, and other disturbances would be seeded with the grass and legume mixture, fertilized at 200 lb/acre, and mulched on south-facing slopes. Tree and shrub species would be seeded both on cut-and-fill slopes and on flat surfaces to stabilize soil while areas infill with naturally seeded native trees (DSL and KNF 1978, page 68).

Slopes and benches of the tailings embankment would be capped with 12 to 24 inches of soil (average 18 inches), and ponderosa pine, Douglas-fir, western larch, and shrubs would be planted on benches. A grass and legume seed mix would be applied on slopes and would be expected to eventually fill in the benches. Fertilization and irrigation would depend on reclamation progress and other indicators (DSL and KNF 1978, page 68). The operational irrigation system includes large irrigation sprinklers and aluminum sprinkler pipe.

The tailings impoundment surface would have 18 inches of stockpiled lacustrine and volcanic ash-derived soil materials spread on the surface. Container-grown tree seedlings would be planted (680 trees/acre density) with container-grown shrubs interspersed among the trees. After two to three growing seasons, a grass and legume mixture would be applied to provide complete vegetative cover (DSL and KNF 1978, page 68-69).

In 1978, ASARCO proposed construction of a small tailings impoundment to be used to experiment with reclamation studies and revegetation success during mine operation. The intent was to improve reclamation success through application of test results (DSL and KNF 1978, page 66). Although the small impoundment was never constructed, ASARCO conducted testing and reclamation studies at Cell 2 of the tailings impoundment in 1995. Three vegetation test plots, covering 30 acres, were planted with a grass seed mixture and 20,400 seedlings, in addition to 200 large transplanted native trees (Genesis 2006 page 2-5 – 2-6). See **Section 2.4.2.2** for further discussion of the findings.

In 1997 and 1999, 3,750 trees were planted in the North Adit area (Genesis 2006, page 2-3).

In the interim, noxious weed invasion has occurred at the mill site, tailings line corridor on road cuts and fills, and along the periphery of the tailings facility (Genesis 2006). Although the 1978 Plan did not specifically address noxious weed control, there is a current noxious weed control plan approved by Lincoln County and KNF in place. The No Action Alternative would continue the current noxious weed control plan which includes chemical weed control.

Under the 1978 Plan, there was no provision to monitor dust or to minimize the potential for blowing dust through irrigation or revegetation.

Infrastructure

If a suitable use for the buildings is not identified, the buildings and all materials would be removed from the project area under the No Action Alternative (DSL and KNF 1978, page 65).

After reclamation has been completed, the No Action Alternative would leave the main mine access road (NFSR 4626) open for public recreation access to Spar Lake and Mt. Vernon. KNF would have the final decision regarding the disposition of NFSR 4626. All other roads would be removed and reclaimed, pending approval of KNF. But if roads remain at KNF's request, maintenance would become the responsibility of KNF (DSL and KNF 1978, page 65).

The No Action Alternative includes removal of the tailings pipelines, the reclaim water line, and the 115 kV transmission line (DSL and KNF 1978, page 66).

Topography and Reclamation Materials

Under the No Action Alternative, the surface of the tailings impoundment would be graded and reworked to provide areas suitable for revegetation, but no changes in the configuration of the tailings embankment at closure were proposed (DSL and KNF 1978, page 66).

When the original mill site was constructed, several cut and fill benches were created, and upon reclamation, these benches would be left flat or nearly flat. The cut and fill slopes would be regraded and re-established at 1.5 horizontal to 1 vertical (1.5H:1V) slopes (DSL and KNF 1978, page 65). According to Troy Mine, Inc., the northeast face of the slope below the North Adit has been recontoured and revegetated (Genesis 2006, page 2-3). Approximately 2.5 acres have not been revegetated at the North Portal (Genesis 2006, page 2-2).

At the mine itself, the slopes of the development rock fill patio would remain at their existing angle. The surface and edges of the development rock fill patios would be graded both to distribute surface water runoff and to prevent erosion. The development rock fill patios would be capped with 12 inches of soil (DSL and KNF 1978, page 64-65).

2.4.2 Proposed Action

The original reclamation plan for the Troy Mine was submitted by ASARCO in 1976 as part of the operating permit application and was adopted in 1978. In the fall of 1999, the Agencies reviewed the reclamation bond. They notified ASARCO that a substantial bond increase would be required and that the 1978 reclamation plan needed to be revised. Thus, ASARCO and Genesis (now Troy Mine, Inc.) submitted a draft revised reclamation plan to DEQ and KNF in January of 2000. The Agencies reviewed several drafts of the plan between 2000 and 2005 (see **Section 1.4.3**). The Revised Reclamation Plan, which is the Proposed Action under this EIS, was submitted to DEQ and KNF in March of 2006.

The Proposed Action would reclaim the land to allow current or historic activities to continue or resume once reclamation has been completed. NFSL are managed by the direction of the 1987 Forest Plan. Private land in the project area is primarily managed for forest production, recreation, and mining.

Historic use of private property in the tailings facility area included tree farming. These uses would continue after closure.

Under the Proposed Action, the proposed reclamation would be accomplished in three phases: pre-closure, closure, and post-closure. Pre-closure tasks include on-going monitoring, testing, and evaluations necessary to complete design of reclamation elements that include a short-term water management plan and engineering design of the adit plugs. Closure tasks would take place two years after final cessation of mining and would include facility removal, regrading, revegetation, and maintenance of short-term components of the water management plan. Adit plugs would be installed during the closure period. Post-closure tasks would include management of mine water flowing through pipelines, maintenance of pipelines, and monitoring of water quality (mine water and surface/groundwater). Under the Proposed Action, the post-closure phase is estimated to last two to five years after mining ends.

2.4.2.1 Water Management

Adit Closure and Mine Water Distribution

The Proposed Action would seal all mine openings against entry by backfilling with mine development rock or with material obtained during regrading of the portal areas. Backfill would be placed from the adit opening back 30 feet into the adits and tight to the roof (Genesis 2006, page 4-4). Rock remaining after adit plugging would be graded against the side of the slope to form a wedge (Genesis 2006, page 4-1). The fill material at the adits is primarily composed of large-sized development rock. Material for the portal closures would be obtained from each portal's patio crest. A 12-inch layer of growth medium from a local borrow source would be placed over the regraded surface (Genesis 2006, page 4-1).

Approximately 4,421 cubic yards of fill material would be needed to backfill the adits (Genesis 2006, page 4-5). The North Adit would be closed last because it is located at the highest elevation and would provide ventilation and access while other adits are being closed. No long-term access to the underground workings is proposed. During operations, the South Adit was reconfigured to create a decline into the mine to prevent water from discharging from the mine. Two concrete non-hydraulic plugs are proposed for the Service and Conveyor adits and would be installed at an elevation of 3,720 feet. No concrete plugs are proposed for the North or South adits because their portal elevations (4,490 feet and 4,310 feet, respectively) are above that of the intersection of the Service Adit with the mine void (4,225 feet) where mine water would discharge. Both the North and South adits would be backfilled and their faces revegetated. No concrete plugs are proposed for the remaining adits (Genesis 2006, page 7-6).

Under the Proposed Action, the two tailings pipelines and the reclaim water line would be used until they wear out or until water quality is suitable for release into Stanley Creek (Genesis 2006, page 4-14 and 7-4). In the event that the pipeline in use needs repair, water would be diverted through the other pipeline until the first pipeline is repaired or replaced. The Proposed Action recommended that the non-hydraulic plugs installed at the Service and Conveyor adits include partial concrete dams or bulkheads that would allow water flowing down the adits to be collected and funneled into a pipe. Additional

design details would be needed before final locations and construction requirements could be prepared and would consider:

- local geology;
- potential head (hydraulic pressure) of water above the adit plug, including the rate of inflows from the surface; and
- integrity of the local rock.

The non-hydraulic adit plugs would be located behind the portal closures at stable locations. The portal backfill would be covered with local borrow material to provide an additional metal attenuation mechanism should the adit plugs leak (Genesis 2006, pages 7-4 to 7-6). These adit plugs would be designed to allow small amounts of seepage through the rock backfill and growth medium. The Service Adit plug would be designed to prevent a pool of water from building up behind the portal reclamation cover material (Genesis 2006, page 7-6).

The mine pool level would seasonally fluctuate with inflowing water and reach hydraulic equilibrium in the different workings at different elevations. Both the North and the East Ore Body workings are connected by a drift (horizontal mine tunnel) at an elevation of 4,186 feet. Once this elevation was reached, the mine pool in the North Ore Body would flow into the East Ore Body pool. The mine pool equilibrium elevation would be at 4,225 feet in the North and East Ore bodies. The mine pool in the South Ore Body would not flow into the North Ore Body pool, but would reach equilibrium at approximately the 4,248-foot elevation (Genesis 2006, page 7-6). Some groundwater would likely dissipate into fracture zones.

Water Treatment and Disposal

The 2006 Reclamation Plan states that its water management goals include reducing long-term management requirements, protecting water resources, and integrating water management facilities and functions with other reclamation components. Water management would consist of effective control, conveyance, and passive treatment of water from the reclaimed mine facilities. Water that would require active management includes water from the underground workings, surface water runoff from the tailings facility, and from groundwater captured by the sump (Enviro-Pump). The Proposed Action includes continuation of active management of tailings facility water until natural attenuation processes remove nitrogen and copper compounds to an acceptable background quality (Genesis 2006, page 7-8).

The Proposed Action would route mine pool water through the tailings pipelines to the decant ponds and continue to use the toe ponds to capture seepage and embankment runoff. After reclamation, snowmelt and runoff from toe ponds 2, 3, and 4 would be pumped to the impoundment to supply irrigation water for the newly-reclaimed surface, if needed, or would be pumped directly to the decant ponds (Genesis 2006, page 7-10).

Groundwater Quality

The Proposed Action includes continued use of the decant water disposal system to passively and effectively achieve metal attenuation in the mine water (Land and Water Consulting, Inc. 2004 in Genesis 2006, Appendix C). Genesis (now Troy Mine, Inc.) proposed a water monitoring plan in Appendix F of the 2006 reclamation plan. The monitoring plan would be modified as needed and would include groundwater monitoring to evaluate potential sources of groundwater seepage from the mine as it floods. Proposed groundwater monitoring sites are listed in **Table 2-2**. Overall, this water quality monitoring program would continue under the Proposed Action until the Agencies agree that monitoring is no longer necessary (Genesis 2006, page 8-2).

Surface Water Quality

The Proposed Action water quality monitoring plan includes both annual macroinvertebrate monitoring and water quality and flow monitoring three times per year (Genesis 2006, Appendix F, page 5). This water quality monitoring program would continue under the Proposed Action until such time as the Agencies agree that monitoring is no longer necessary. The surface water quality monitoring sites that would be sampled are the same sites which are listed in **Table 2-3**.

After the impoundment is finally reclaimed under the Proposed Action, surface water from the toe ponds may be used to irrigate a small portion of the impoundment or may be piped directly to the decant ponds (Genesis 2006, page 7-10). The toe pond pumping system would be maintained post-closure until the quality of groundwater seepage would be suitable for release (Genesis 2006, page 7-10).

The Proposed Action would also retain the toe ponds as permanent features to provide wildlife and wetlands habitat. After operations have ceased, the toe ponds would be connected by inter-pond channels. Although no outfall from the toe ponds is expected, an armored outfall would nonetheless be installed to protect against erosion. No channel to Lake Creek would be constructed (Genesis 2006, page 4-15).

After mine closure, the Proposed Action would continue to direct storm water runoff to the decant ponds. Surface contouring (placement of final lifts of tailings before mine closure) would maintain the general flow direction toward the decant ponds. Moreover, this same collection system would be maintained following final reclamation (Genesis 2006, page 7-9 – 7-10).

Long-Term Monitoring of Water Quality

Water quality monitoring under the Proposed Action would continue during and after reclamation until such time as the Agencies agree that monitoring is no longer necessary (Genesis 2006, page 8-2). The purpose of the Proposed Action's water quality monitoring plan is to:

- Continue collecting hydrologic data for a statistically valid database in areas of environmental concern;
- Monitor water resources in the area for potential changes from historic baseline data; and
- Address water-related issues which may arise during reclamation of the Troy Mine.

The Proposed Action long-term groundwater quality monitoring plan is the same as the No Action Alternative plan as listed in **Table 2-2**.

2.4.2.2 Reclamation

Reclamation Materials

Troy Mine, Inc. states that the stockpiled soil (composed of lacustrine and volcanic ash-derived soil material), the native borrow (composed of glacial outwash) at the tailings impoundment, and the rocky glacial material at the mine site all show little difference in composition. The main difference is that the stockpiled soil is fine-grained with a low coarse-fragment content, and the borrow and rocky glacial materials have a higher coarse-fragment content. As necessary, all cover sources would be chemically fertilized to promote successful revegetation. Finally, the Proposed Action would not add organic matter to any reclamation materials (Genesis 2006, page 5-4).

The Proposed Action would leave the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to provide wildlife and wetlands habitat (Genesis 2006, page 4-15) where they would act as a berm to maintain the toe ponds and to minimize the potential for sediment to reach Lake Creek.

The stockpiled material at the tailings facility has been vegetated. Reclamation materials for the tailings impoundment surface would be obtained from the borrow sites which are located east of the impoundment. Under the Proposed Action, approximately 766,600 cubic yards of reclamation material would be needed to cover the tailings facility surface with an average of 18 inches of growth medium (Genesis 2006, Table 4-1 and page 4-16).

The Proposed Action would cover development rock at the portal patios with a finer-grained material on the surface to promote revegetation. These areas would be covered with a 12-inch layer of growth medium from local borrow sources (Genesis 2006, page 4-1). However, the Proposed Action does not specify or directly identify potential local borrow source locations.

Subsidence

Subsidence was not addressed as part of the Proposed Action.

Revegetation

The revegetation goals under the Proposed Action include:

- stabilizing disturbed areas through erosion and sediment control;
- re-establishing vegetative cover that has comparable stability and utility to pre-mine vegetation communities; and
- restoring watershed, wildlife, recreational, and aesthetic values to meet post-operation land use objectives (Genesis 2006, page 6-1).

Under the Proposed Action, the borrow sites (USFS Borrow, Cell 3 Borrow, East Borrow, and North East Borrow) would be reclaimed after completion of all excavation activities. Impoundment-area borrow sites would be planted with plant species typical of lower elevation forest types. The USFS borrow site

would be revegetated with plant species typical of upper elevation forest types (Genesis 2006, page 4-11). Revegetation at the mine portal patios would also use the same upper elevation forest mix. The angle-of-repose rock slope below the portal patios would not be regraded (Genesis 2006, page 4-1). The borrow area on the east side of the impoundment would be reclaimed after cover-soil spreading activities are completed (Genesis 2006, page 4-16).

When the tailings pipelines are no longer needed, reclamation of the tailings pipelines would only occur at the locations of the support structure footprints (about 3 feet by 7 feet in size). These areas would be regraded after the concrete is removed and would be seeded with a grassland seed mix (Genesis 2006, pages 4-14 – 4-15).

Under the Proposed Action, the operational irrigation system would be used under gravity pressure to irrigate during the first growing season so that pumps would not be needed (Genesis 2006, page 4-18). Irrigation would be expected to continue for the one to two years following final reclamation as a way to establish vegetative cover and to prevent wind erosion (Genesis 2006, page 4-18).

Irrigation would not be proposed at the upper elevation sites or on slopes steeper than 10 percent. However, if needed, the surface of the tailings facility would be irrigated during the first growing season after seeding and planting by using the sprinkler system currently in place (Genesis 2006, page 6-9). The mill site water well would be available for irrigation during the first growing season (Genesis 2006, page 4-14).

The reclaim water pond near the impoundment would be revegetated to grassland and would rely on the natural establishment of woody species. The Quonset Hut industrial site currently located near the tailings facility would not be reclaimed, because the area would be retained for industrial uses during post-reclamation activities (Genesis 2006, page 4-19).

The *2006 Revised Reclamation Plan* covers specific information on seed mixes for disturbed lands (Genesis 2006, page 6-1) and includes three upland mixes to account for the different post-mining proposed vegetation communities and for the elevation differences in the project area. The upper elevation forest mix would be used at the mill site and other upper elevation disturbance areas, and the lower elevation forest mix would be used over the majority of the tailings facility and over the borrow areas east of the impoundment. The grassland mix would be used on smaller disturbed areas peripheral to the tailings facility (roads, power line corridors, etc.) and would also be used on the tailings impoundment surface to establish a diversity of vegetation. Annual ryegrass would be added to the upland mixes (Genesis 2006, pages 6-2 – 6-3). Two wetland seed mixes would be used for reclamation of herbaceous and forested wetlands (Genesis 2006, page 6-5). Finally, trees and shrubs would be established on areas designated as forested areas (Genesis 2006, page 6-7).

The Proposed Action includes specific seeding rates, seed application methods (Genesis 2006, page 6-5), fertilizer, and mulching specifications (Genesis 2006, page 6-8), tree and shrub planting (Genesis 2006, page 6-7), and irrigation and noxious weed management (Genesis 2006, page 6-9) (Section 6 of the *2006 Revised Reclamation Plan*). Also included would be continuation of chemical weed control under the approved noxious weed control plan.

Under the Proposed Action, monitoring of revegetation would continue during the pre-closure and closure phases of mine operation. Specifically, the revegetation monitoring plan (Genesis 2006, page 8-1) would evaluate:

- adequacy of revegetation to limit off-site sedimentation;
- woody plant survival rates;
- vegetation vigor to assess whether supplemental fertilization may be desirable;
- diversity of seeded and invading species;
- competition between herbaceous and woody species to determine if lower herbaceous seeding rates or other measures are desirable to promote woody species survival and growth;
- noxious weed presence; and
- prevalence of hydrophytic species (plants that flourish in saturated soils) in areas designated for wetlands establishment.

If poor vegetation growth is noted, the above areas would be evaluated and, if necessary, reclamation techniques would be modified (Genesis 2006, page 8-1).

Infrastructure

Under the Proposed Action, underground equipment would be salvaged if possible. If a salvage market cannot be found, this equipment would be abandoned in place. Underground equipment includes the jaw crusher, the conveyor belt, rollers, the ventilation system, and oil-filled switches and transformers. If salvage and removal are not possible, all fluids would be removed, and the equipment would be cleaned and abandoned in place (Genesis 2006, page 4-4 – 4-6). Any oils, lubricants, cleaners, or chemicals used underground would be removed at the end of mining. All oil-filled switches, transformers, and motors with oil sumps would be removed from underground equipment, but removal of the rest of the underground electrical service is not proposed. The mechanical ventilation system is located primarily underground; and ventilation fans, motors, and attached electrical components would be removed and disposed of off-site. Other inert components of the ventilation system, including metal, fiberglass, wood, and concrete, would remain underground (Genesis 2006, page 4-6).

The office/shop area includes buildings, parking areas, culverts, and water tanks. The Proposed Action would rip asphalt and bury it on site with a minimum of 36 inches of cover material (includes asphalt from parking areas) (Genesis 2006, page 4-6). The buildings would be demolished so that materials such as concrete, metal, glass, plastic, and wood would be buried on-site with a minimum of 36 inches of cover material. Fuel, water, and other tanks would be removed from the site, and the water tank would be sold or scrapped (Genesis 2006, page 4-14).

Any existing USFS roads would remain in place per USFS requirements (Genesis 2006, page 4-1). Agencies interpret this requirement to mean that no roads are proposed for reclamation under the Proposed Action.

Table 2-4. Proposed Action Road Reclamation

Road	Status	Reclamation
NFSR 4626 from HWY 56 to mine	Remain Open	Leave paved
NFSR 4626C to percolation pond	Remain Open	None
NFSR 4626/4628 Mill to South Portal	Preexisting; Remain Open	None
NFSR 4626F to North Portal	Preexisting; Remain Open	None
NFSR 4628C to South Portal	Remain Open	None

Source: Genesis. 2006. *Genesis Incorporated Troy Mine Revised Reclamation Plan, excerpted from Table 4-1*. March 2006.

Existing water diversion culverts at the mill site would be sealed with concrete at the upper ends and left in place. The two drainage channels to be constructed would be armored with coarse rock to protect against the 100-year, 24-hour storm design flow. Flows from natural drainages would be routed through the mill site in the armored channels, and a rock catch basin at the bottom of the slope would provide energy dissipation and erosion control (Genesis 2006, page 4-7). Water supply lines would be buried and abandoned in place (Genesis 2006, page 4-14).

The existing storm water collection system would remain in place during the entire building demolition phase, with additional best management practices employed (such as silt fences to control erosion and protect surface water runoff). The final grading plan would use diversion ditches, culverts, velocity control structures, and riprap in high runoff areas to reduce the potential for sedimentation in Stanley Creek. Areas of high runoff would be rip rapped to control erosion (Genesis 2006, page 4-13).

All surface pipelines would eventually be removed and salvaged. The two operational 8-inch steel tailings pipelines would be used in succession to pipe mine water to the tailings facility until they wear out or until water quality improves enough to permit discharge into Stanley Creek. Once the pipelines are no longer needed, any sections that are buried less than three feet deep would be removed. Pipeline sections that are buried more than three feet deep would be capped and abandoned in place. All of the surface pipeline support structures would be removed from the pipeline corridor and disposed of at the tailings facility or at the mill site (Genesis 2006, page 4-14).

The 200,000-gallon surface diesel fuel tank would be sold or cut up for scrap. The two 30,000-gallon propane tanks and other smaller propane tanks would be removed from the project area (Genesis 2006, page 4-13).

The main power line is the property of Northern Lights Inc. Northern Lights Inc. would have the final decision on removal or preservation of all or portions of the 115-kV power line.

Water supply at the mill site includes a well, piping, and a 300,000-gallon capacity water tank. The tank would be sold or cut up for scrap metal, and the buried pipelines would be abandoned in place. A domestic water well located southeast of the tailings impoundment would be used, if necessary, for irrigation during the first growing season; after which time, the well would be plugged and abandoned as required by ARM 36.21.810. The large capacity make-up water wells near the Stanley Creek Bridge would also be plugged and abandoned. The small pump buildings and the surge pond would be reclaimed (Genesis 2006, pages 3-7 and 4-14).

The sewage treatment facility would be removed and the building would be salvaged. The reclaim pump stations located south of the impoundment next to Stanley Creek would be salvaged and the buildings removed (Genesis 2006, page 4-14). The liner of the reclaim water pond near the tailings impoundment would be cut, folded in, and buried in place. The Quonset Hut would be used for storage and office space after removal of the mill site facilities. All fences would be removed during demolition of the mill site (Genesis 2006, page 4-19).

Topography

Under the Proposed Action, the volume of material to be moved as part of regrading the mill site would be approximately 27,000 cubic yards, and the total volume for the office/shop area would be approximately 54,000 cubic yards. Rocky glacial materials stored beneath the mill site and office/shop area building pads would be used for reclamation at the mill site. Should additional growth media be needed during reclamation, the upper percolation pond embankment, the old warehouse pad slope north of the office building, and/or the USFS borrow site would be used (Genesis 2006, page 4-7). The Proposed Action assumes that the original mine and mill site growth media had a considerable coarse fragment content. If sufficient growth media with a large coarse fragment content are not available, rocky glacial materials from the USFS borrow area would be used to cover steeper slopes (Genesis 2006, page 4-11).

Since the development rock piles are part of the plant site, once the buildings have been removed, the development rock would be incorporated into the final grading plan for the plant site. However, the grading would be minimal (Genesis 2006, Figure 4-2).

Slopes of the portal patios would be regraded by pulling the edges up and filling against the cut slope/roadway. The regraded areas would be covered with 12 inches of growth medium, if available, from patios and then ripped and seeded (Genesis 2006, page 4-1). Development rock would be used as backfill from the adit opening back 30 feet into the adit and placed tight against the roof (pg 4-4); rock remaining after adit plugging would be graded against the side of the slope to form a wedge (pg. 4-1, Table 4-2). During operations, the South Adit would be reconfigured to create a decline into the mine to

prevent water from discharging from the mine (pg 4-4). Two concrete non-hydraulic plugs are proposed for the Service and Conveyor adits (pg. 7-6).

The maintenance sump located south of the tailings impoundment is an unlined 0.5-acre excavation, about four to five feet deep (**Figure 2-1**). This sump would be regraded to blend with surrounding topography, and original soil from the area would be spread over the disturbed area and seeded (Genesis 2006, page 4-15). The reclaim water pond would also be regraded to blend with surrounding topography and would be seeded (Genesis 2006, page 4-19).

Impoundment-area borrow sites would be graded to reduce slopes to 2H:1V and to establish upper slope diversion ditches (Genesis 2006, page 4-18). The USFS borrow site would be regraded to blend in with the surrounding topography (Genesis 2006, Figure 4-5 and page 4-11).

Once ore milling has ceased, the tailings impoundment surface is expected to slope to the east at an approximate grade of about one-half of one percent. Thus, no surface regrading would occur under the Proposed Action. The slope to the east would allow surface water to flow to the eastern edge of the impoundment and into the decant ponds, where it would infiltrate and recharge groundwater (Genesis 2006, page 4-15 and 4-18).

When mine water is no longer routed to the tailings facility, the decant ponds would be regraded to form one shallow depression which would be able to capture runoff from the tailings facility surface and to prevent surface water runoff from leaving the impoundment. This depression would also provide an ideal wetland habitat (Genesis 2006, page 4-18).

2.4.3 Agency-Mitigated Alternative

The Agency-Mitigated Alternative is based upon the Proposed Action, but includes additional mitigation measures and monitoring requirements that address major issues identified during the earlier scoping and IDT review process. **Table 2-1** highlights the modifications proposed under the Agency-Mitigated Alternative as compared to the Proposed Action. The Agency-Mitigated Alternative includes the following major modifications to the Proposed Action:

- Hydraulic plugs would not be used at the Service and Conveyor adits. Concrete structures would be constructed to capture mine water and route it to the tailings impoundment for treatment and disposal.
- A closure device would be incorporated into the Service and Conveyor adits to prevent unauthorized public access, to allow maintenance of the underground workings that lead to the intake structures, and to facilitate maintenance and cleanout of the intake structures in the Service and Conveyor adits.
- A new buried water pipeline would be built to transport water from the mine to the decant ponds rather than using the 30+ year-old tailings lines.
- Additional monitoring of seeps and springs would be required to verify that water quality standards were met.

- The toe ponds between the tailings impoundment and Lake Creek would be surveyed by FWP prior to mine closure. FWP would determine whether non-native fish species occupy the toe ponds and whether a potential risk exists to native fish resources in Lake Creek and the Kootenai River. FWP would then make the subsequent decision and recommendation on removal of any fish. If fish removal is recommended, FWP would issue a permit to the contractor or company conducting the removal of any unwanted fish species. Inter-pond channel construction and fish removal would not begin until September or when juvenile western toads are no longer observed at the breeding site.
- The existing surface subsidence feature that has not yet achieved a level of stability and utility comparable to the pre-disturbance condition would be required to be reclaimed. The reclamation bond would be increased to address the possibility of future subsidence, including surface subsidence occurring on steep slopes.

2.4.3.1 Water Management

Adit Closure and Mine Water

The Agency-Mitigated Alternative differs in several ways from the Proposed Action. The Agency-Mitigated Alternative would use development rock at the portal patio to plug the South Adit. The South Adit plug would extend approximately 130 feet into the adit, rather than just the 30 feet as stated in the Proposed Action. The Service and Conveyor adits would be closed with development rock instead of with concrete non-hydraulic plugs. Concrete intake structures would be installed in both the Service and Conveyor adits to capture mine water and to funnel it to the collection pipelines. Closure devices would be installed to prevent unauthorized public access to the Service and Conveyor adits and to allow for periodic cleanout of the intake structures (see **Appendix G**). The concrete structures are needed because of the volume of water anticipated and because of the need for active management of the water collection system. The adits would be closed by the combination of the development rock backfill and the intake structures and secured against unauthorized access by the closure devices.

The two existing 8-inch surface tailings pipelines would be removed after a new, buried, mine water pipeline is in place and after safety measures are implemented and the pipelines have been tested. Any disturbed areas would be reclaimed and revegetated. The original 10-inch reclaim water line would remain in place and be used as an emergency water conveyance line. However, inspection of the reclaim water line would be required prior to using the line for this purpose. This new, buried, mine water pipeline would be designed and installed adjacent to the existing reclaim water line. This new mine water pipeline would be designed to handle the anticipated volume of mine discharge and would include options for routing water through both buried pipelines during high flows, as described in **Appendix G**.

The new mine water pipeline would be designed to follow the route of the existing tailings pipelines and would have the hydraulic capacity to handle the estimated peak discharge of 6.9 cfs (**Appendix G**). The land gradient is rather steep near the adit openings but flattens as it approaches the decant ponds. The new mine water pipeline would be designed to accommodate changes in slope. The new mine water pipeline would vary between 10-inch to 18-inch diameter and would likely be constructed of butt-welded high-density polyethylene (HDPE) pipe. The actual pipe diameter and material would be

determined during the final design phase at closure (**Appendix G**). The pipeline would be buried or double-lined at stream crossings to minimize risk to surface and groundwater systems.

A leak detection system would monitor for any potential failure of both the new mine water pipeline and the retrofitted old reclaim water pipeline. The six-mile long pipelines would be monitored using flow meters placed close to the mine adit (upper) and close to the discharge end (lower). Values from both meters would be compared in conjunction with a calculated time delay to compensate for the length of pipe between the flow meters. The values at the two monitors should correspond within an adjustable percentage. If the flows do not correspond, a leak or break in the pipeline would be indicated and an automated alarm would activate. Transmission of mine water would be shifted to the backup pipe. The damaged pipe would then be taken out of commission and the discrepancy would be investigated for repair. In the unlikely event that the pipeline capacity of both lines is exceeded, mine water would flow over the intake structure in the Service and Conveyor adits and would pass through the rock backfill. At the mine portal, mine water would drain to a constructed channel which would lead to Stanley Creek (**Appendix F**). Finally, the old line would be retrofitted with a leak detection system similar to the new line installed at closure.

Should mine water be of sufficient quality for direct discharge to surface water without treatment, it would be rerouted to a designed channel to discharge to Stanley Creek. At that time, both the new mine water and the old reclaim pipelines buried less than three feet deep would be removed, and the pipeline corridor and decant pond would be reclaimed. Reclamation of decant ponds would include regrading the decant pond berms to form gently sloping terrain within the reclaimed tailings impoundment. After regrading, cover soil would be placed, and the area would be reseeded with an upland species seed mix. Water discharging from the Service Adit would be routed overland through a constructed channel to Stanley Creek in the vicinity of the closed portal (**Appendix E**).

Water Treatment and Disposal

Mine water would be disposed of at the location of the existing decant ponds as described in the Proposed Action. Under the Agency-Mitigated Alternative, the ponds would be maintained as deep ponds in order to maintain geochemical functions. A berm would be created to prevent storm water runoff from the tailings impoundment surface from draining directly to the decant ponds. Preventing runoff to the ponds would minimize hydraulic overloading of the ponds and would prevent clogging with additional sediment and debris. The ponds would be approximately four acres in size and would be 10-15 feet deep to maintain existing geochemical conditions. The ponds would contain a central divider berm to allow periodic cleanout of sediment and other debris as needed.

Groundwater Quality

The Agency-Mitigated Alternative would continue the Proposed Action seepage pumping activities at the toe ponds until such time as water quality standards are met. Any monitoring wells would be plugged and abandoned per ARM 36.21.810.

Surface Water Quality

There would be additional monitoring of seeps and springs at the mine during closure to verify whether state water quality standards have been met. Water quality monitoring locations would be determined based on the results of the spring and seep survey of upper Mount Vernon that would be conducted during operations under the Agency-Mitigated Alternative. The spring and seep survey would include a review of the upper, northern tributary to Ross Creek and would identify where perennial flow begins and whether there are obvious springs and seeps in these areas. Based on the results, additional sites would be identified for water quality monitoring post-closure.

Long-Term Monitoring of Water Quality

In addition to water quality monitoring at closure under the Proposed Action, the Agency-Mitigated Alternative would include post-closure water quality monitoring for a minimum of five years after mine water discharge actually commences. Post-closure water quality monitoring of seeps and springs would verify whether state water quality standards were met. In addition to the sites listed in Table 2-3, all three sites at SC-15 (SC-15A, SC-15B, and SC-15C) would be monitored three times a year. Tables 2-2 and 2-3 include all sites expected to be monitored after mine closure.

2.4.3.2 Reclamation

The Agency-Mitigated Alternative would differ from the Proposed Action in the following measures:

- Growth material for the tailings impoundment would be amended with an agency-approved, wood-based, organic amendment to raise the organic matter content in the upper six inches to achieve 1,100 lbs of nitrogen per acre. Any materials originating in borrow pits to be used in reclamation would be in accordance with Agencies' growth media specifications. Mine and mill site reclamation material would be amended to achieve 1,100 lbs of nitrogen per acre by using an agency-approved, wood-based, organic amendment. This organic matter would be mixed into the top 12 inches of reclamation material.
- The Agencies would perform a field review of previously reclaimed areas to determine if areas need additional cover materials, revegetation, or reseeding. Any additional seeding would include the provision that seed sources for native plant species should be from northwestern Montana, if they are available at the time of reclamation.
- On the portal patios, growth medium from the mine and mill area would be used first, and then if needed, rocky glacial material from the borrow area east of the impoundment would be used for the balance of soil. All covered areas would be seeded with an agency-approved native seed mix.
- On the tailings impoundment surface, the stockpiled lacustrine and volcanic ash-derived soil material next to the toe ponds would be used first, then if needed, the borrow area east of the impoundment would be used for the balance of soil. Soil would be placed in one 18-inch lift to prevent compaction, and the soil would be ripped before seeding. Any materials originating in borrow pits to be used in reclamation would meet the Agencies' growth media specifications.
- If available at the time of reclamation, seed sources for native plant species should be from northwestern Montana.

- To prevent the spread of rush skeletonweed, the USFS borrow area would not be used. KNF would be responsible to reclaim this borrow area.
- In order to maintain existing geochemical conditions, the tailings impoundment decant ponds would not be reclaimed to a wetland habitat (**Section 3.18.5.3**).
- Monitoring of revegetation efforts would continue until bond release and would include long-term monitoring of noxious weeds, such as meadow knapweed and rush skeletonweed.
- Any existing surface subsidence feature that does not achieve a level of stability and utility comparable to the pre-disturbance condition would be reclaimed. The reclamation bond would be increased to address the possibility of future subsidence and would include surface subsidence occurring on steep slopes.
- All disturbed ground at the mine and mill site would be covered with an agency-approved mulch.
- Twenty-five tons/acre of coarse woody debris (greater than 3 inches in diameter) would be scattered across reclaimed areas both at the mine portals and at the mill.
- If available, plants would be inoculated with mychorrizal fungi appropriate to the species.

Reclamation Materials

The Agency-Mitigated Alternative would use the stockpiled lacustrine and volcanic ash-derived soil materials west of the toe ponds to cover the tailings facility. The lowest portion of the vegetated outer slopes of the stockpile would be maintained to minimize water runoff and to prevent sediment from leaving the majority of the disturbed stockpile surface. The soil would be removed in a manner that would prevent soil from spilling towards Lake Creek or the toe ponds and that would protect the western toad (see **Section 3.18.5.10**). A field review of existing reclamation would be conducted to determine if additional soil would need to be spread on the embankment face and benches where soil is thin and revegetation is not adequate.

If needed for the tailings impoundment surface, additional growth medium would be salvaged from the borrow sites adjacent to the tailings impoundment (**Figure 2-1**). Borrow areas would be reclaimed to a 3H:1V slope. Salvaged growth medium would be spread over the area to be reclaimed, seeded, and revegetated. Growth medium would be placed in one lift to prevent compaction and ripped to loosen soil before seeding takes place. Materials used from borrow pits would comply with the Agencies' growth media specifications for coarse fragment content.

At the mill site, the Agency-Mitigated Alternative growth medium soil would be the same as in the Proposed Action. Twelve inches of fill material from regrading the mill area would be used, but the USFS borrow area material would not be used because of the presence of rush skeletonweed. If additional growth medium is needed, material would be obtained from agency-approved borrow materials from the impoundment area. All areas would be ripped before seeding.

Both the North and South portal patios would be covered with growth medium from the mine and mill areas; a 12-inch layer would be placed over regraded areas; and all areas would be ripped before seeding.

Geotechnical monitoring of the tailings embankment would be the same as under the Proposed Action, including annual inspections for a minimum of five years after closure. Verification of embankment stability by a qualified professional engineer would be required post-closure, and the Agencies would be consulted before monitoring ceases.

Subsidence

The existing surface subsidence feature that has not achieved a level of stability and utility comparable to the pre-disturbance condition would be reclaimed post-closure. The reclamation bond would be increased to address the possibility of future subsidence on potentially steep terrain.

Revegetation

Plant species selection for revegetation under the Agency-Mitigated Alternative would be based on the goal of re-establishing native species-dominated vegetation communities. Seed sources for native plant species should be from northwestern Montana to the extent that these species are commercially available at the time of reclamation. Overall, the species mix would be dominated by species native to northwestern Montana. Specific species mixes would be adjusted to account for site-specific conditions. For harsher growing conditions, such as south-facing slopes, more drought-tolerant plant species would be used. For moist conditions, appropriate species would also be used. Prior to reclamation, a final revegetation plan would document components of both the primary seed mixtures and of alternate seed mixtures if invasive species dominate the originally planned revegetation. This plan would be submitted to the Agencies for review and approval. Based on availability of species, KNF may adjust seed mixtures as appropriate for site conditions.

The Agencies would perform a field review of previously reclaimed areas to determine if areas need additional cover materials, revegetation, or reseeding. Any additional seeding would include the provision that seed sources for native plant species be from northwestern Montana, if available at the time of reclamation.

Infrastructure

Road reclamation for the Agency-Mitigated Alternative is described in **Table 2-1**, Lines 50 through 65. Berms and guardrails would be removed from inactive NFSRs.

The Agency-Mitigated Alternative differs from the Proposed Action in the following ways:

- The gunite liner would be removed from the existing collection/diversion ditches, and the surface would be regraded to slope towards a ditch on the uphill side of the access road that would route water to the large drainage that crosses the mill site. An approved SWPPP would be required for all reclamation activities. Appropriate BMPs would be used to control erosion, and temporary BMPs would be removed when no longer needed.
- All demolition materials, whether originating above or below ground, would be disposed of off NFSL in appropriate disposal areas to comply with the Montana Solid Waste Act.
- Water diversion culverts at the mill site would have both ends plugged with concrete, and culverts under roads would be left in place.

- The water tank would be removed from site.
- When no longer needed for mine closure, any water supply lines would be removed from NFSL.
- If needed, the domestic water well located southeast of the tailings impoundment would be used for irrigation during the first three growing seasons; after which time, the well would be plugged and abandoned as required by ARM 36.21.810.
- The reclaim water pond liner would be buried in place with three feet of soil.
- The fence surrounding the USFS borrow area would be left in place to avoid use and subsequent spreading of rush skeletonweed.
- Asphalt from the parking lots and other paved areas would be crushed and used for road gravel on NFSR 4626 or hauled to an approved landfill off NFSL.
- The Stanley Creek Bridge on NFSL would be left in good condition, would meet current safety standards, and would be capable of supporting legal highway loads. Approximately 300 feet of asphalt would be repaired and maintained on the Stanley Creek bridge approaches.
- The tailings irrigation system would be removed from the site after reclamation irrigation is no longer needed.

Topography

The Agency-Mitigated Alternative differs from the Proposed Action in several areas, including:

- Development rock at the portal patio would be used to plug the South Adit. The South Adit plug would extend approximately 130 feet into the adit, rather than the 30 feet as stated in the Proposed Action. Development rock that has accumulated in stream channels adjacent to the mine site would be removed from channels and used to backfill the South and West adits.
- Both the Service Adit and the adjacent Conveyor Adit would be closed with development rock from the portal patio instead of with concrete non-hydraulic plugs. A concrete intake structure would be installed in both the Service and Conveyor adits to route mine water to pipelines (see **Appendix G**). Closure devices would be placed in both adits to provide access for cleaning out the intake structures to the pipelines.
- All drainage channels would be constructed from imported non-mineralized rock rather than from mine development rock to minimize the potential for metal leaching. Alignment of the larger drainage channel would be down the angle-of-repose mill fill slope. A third channel would be designed from the Service and Conveyor adits to connect with the mill site drainage channels for overflow from the adits if the design capacities are ever exceeded (see **Appendix E**).
- The final permitted elevation of the tailings is 2,420 for Cells 1, 2, and 3. A berm would be created to prevent storm water runoff from the impoundment surface from draining directly to the decant ponds.
- The decant ponds would be maintained as deep ponds in order to maintain existing geochemical conditions (10 to 15 feet deep and approximately 4 acres in size with a divider berm to provide for periodic cleanout of the ponds).
- A qualified engineer would annually monitor and verify the stability of the embankment for a minimum of five years after reclamation is completed. The engineer's report would be submitted to the Agencies.

- All eroded or bare areas on the embankment would be repaired by spreading 12 inches of the stockpiled growth medium. These areas would be seeded and/or planted with agency-approved seed and plant mixes.
- FWP would survey the toe ponds for non-native fish species and determine whether removal of the fish is recommended; if so, the FWP would issue a permit for this activity.
- To prevent the spread of rush skeletonweed, the USFS borrow area would not be used. KNF would be responsible to reclaim this borrow area. The fence surrounding the USFS borrow site would stay in place to help prevent the spread of rush skeletonweed.
- The other borrow sites would be graded to 3H:1V slopes, and the upper layers of soil would be salvaged and stockpiled. Once the borrow site is used, the salvaged soils would be replaced and seeded or revegetated. Troy Mine, Inc. would provide the Agencies with an estimate of the volume of borrow to be removed and would specify location(s) for the soil stockpile(s).
- To protect bull trout rearing habitat in Lake Creek, sediment-generating activities occurring within Riparian Habitat Conservation Areas (RHCA) in Ross and Stanley creeks and the upper Lake Creek subwatershed would not occur before July 15th or after October 15th unless activities are upstream of dry channel segments and cannot deliver sediment downstream. Regrading work at the tailings impoundment would be excepted because appropriate BMPs would be installed to prevent sediment delivery to Lake Creek.

2.4.3.3 Additional Considerations

Underground Equipment

The Agency-Mitigated Alternative would include a final agency inspection of the underground mine prior to mine flooding and would cover the following modifications to the Proposed Action:

- All mobile equipment would be removed from the mine, if possible. If equipment is abandoned in place, all fluids would be drained and would be disposed of properly.
- Jaw crusher components on NFSL would be removed; other components would be removed as necessary to close the adits and any remaining equipment would be abandoned in place or removed from the mine.
- Conveyor components on or that extend onto NFSL would be removed from the mine.
- Any ventilation system components at the surface and at least 100 feet back into adits would be removed from the mine.

Libby Concentrate Loadout

The former concentrate loadout facility burned down in February of 2010. A temporary outdoor facility in Libby was used until a new facility was constructed and approved in 2011. Cleanup of the former loadout would occur per the approved reclamation plan. Any monitoring wells would be plugged and abandoned per ARM 36.21.810.

2.5 Mitigation and Monitoring Measures Common to All Alternatives

The No Action Alternative does not address many of the issues that are addressed by the other alternatives. The Proposed Action and Agency-Mitigated Alternative have the following common mitigations:

- The surface diesel fuel tank and the two large and numerous small propane tanks would be removed from the site.
- The large-capacity make-up wells near Stanley Creek would be abandoned per ARM 36.21.810.
- The small pump building and surge pond would be reclaimed.
- Monitoring wells would remain as long as needed and then plugged and abandoned per ARM 36.21.810.
- The mill site and office/shop areas would be planted with upper elevation forest plant mix.
- The East Impoundment, North East Impoundment, and Cell 3 borrow areas would be planted with lower elevation forest type vegetation.
- Small disturbed areas (such as the tailings pipeline, reclaim line, roads, power line corridors, storage areas) would be planted with grassland mix on the assumption that woody species would establish naturally.
- The reclaim pump station site would be revegetated to grassland and would rely on natural establishment of woody species.
- The current system which uses Enviro-pump S-1 to convey groundwater seepage to toe pond 2 and pump snowmelt or runoff from toe ponds 2, 3, 4 to the impoundment would be maintained.

In addition, the Proposed Action and the Agency-Mitigated Alternative have the same following design features in common:

- The Quonset Hut (located on private land) would be left in place for storage and office space.
- Northern Lights Inc. would have the final decision on removing or preserving all or portions of the 115-kV power line; although, it would be maintained until it was no longer needed for reclamation and monitoring activities.
- The substation would be left in place for future use by Northern Lights.

2.6 Alternatives Considered but Eliminated from Detailed Study

Federal agencies are required by NEPA to explore and objectively evaluate all reasonable alternatives and to briefly discuss the reasons for eliminating any alternatives that were not developed in detail (40 CFR 1502.14). Likewise, state agencies are required to investigate an alternative approach or course of action that would accomplish the same objectives or results as the Proposed Action. DEQ is required to consider only alternatives that are realistic, technologically available, and that represent a course of action that has a logical relationship to the proposal being evaluated (ARM 17.4.603(2)(b)).

One complete alternative, along with several components of alternatives, were analyzed and subsequently eliminated. These are identified in this section.

Issues were identified through the agency and public scoping process, through agency review of the *2006 Revised Reclamation Plan*, and through interagency discussions on development of alternatives. Several issues were eliminated from further consideration because they were either outside the scope of the analysis; already decided by law, regulation, Forest Plan, or other higher level decision; irrelevant to the decision to be made; or they were conjectural and not supported by scientific or factual evidence. These issues are described in **Section 2.3.2** and include fate and transport of iron; the stability of the impoundment; the potential effects of continued discharge of mine water; bond requirements; potential hazards from buried drums; replicating the decant ponds at the mill site; the potential for contamination from Troy Mine operations upon the Northern Lights Dam; and leaving the area as-is for an educational/tourist attraction.

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative were assessed on the basis the major issues developed during the scoping process. Major issues were defined in **Section 2.3.1** as those for which:

- there may be potentially significant impacts;
- there is a concern about potential effects directly or indirectly resulting from implementation of the Proposed Action; or
- there is a concern about the effectiveness of proposed mitigation measures.

The alternative descriptions include details on the issues that were carried forward from the public scoping process as described earlier in this chapter. These issues include:

Water Management

- Adit Closure and Mine Water Distribution;
- Water Treatment and Disposal;
- Groundwater Quality;
- Surface Water Quality; and
- Long-Term Monitoring of Water Quality

Reclamation

- Reclamation Materials;
- Subsidence;
- Revegetation;
- Infrastructure (buildings and other structural materials and how they will be removed or reclaimed); and
- Topography (disturbed areas)

The No Action Alternative, which consists of the reclamation plan provided by ASARCO in 1978 and reclamation work that has been completed through August of 2010 by Genesis (now Troy Mine, Inc.), does not address the measures needed to treat mine water prior to distribution to Stanley Creek. Mine water that would be allowed to flow directly to surface water would not meet current water quality and

human health standards set forth by Montana Law. In addition, the No Action Alternative does not address several other reclamation components, as shown in **Table 2-1**. Due to the violation of state water quality standards and incompleteness of the No Action Alternative, the No Action Alternative would not be feasible. It is carried forward into Chapter 3 as a baseline for comparison.

Several mitigation options were presented and discarded throughout the development of this EIS. Specific mitigation measures and reasons for their elimination are listed below:

- Constructing an additional decant pond was discussed but eliminated. The IDT team evaluated the potential need for and sizing of an additional decant pond and decided that existing decant ponds would have the capacity to infiltrate the mine water. Storm water would be kept out of the ponds in the Agency-Mitigated Alternative. In addition, the ponds would be divided into two cells so that one can be cleaned out periodically to maintain infiltration capacity and geochemical conditions that are conducive to copper attenuation. A bond would be held for periodic cleaning of the pond cells.
- A detention pond at the Service Adit was discussed but eliminated. The IDT team evaluated the need for storage of mine outflow water and determined that the pipes used to convey water from the mine to the impoundment area could be designed to accommodate the expected mine drainage volume.
- Constructing a wastewater treatment system was considered but eliminated. Water quality studies were done on the attenuation of metals in mine water. These studies showed that the natural attenuation process is sufficient and that active water treatment would not be necessary (see **Section 3.9.4.2** and **Appendix D**). Construction and operation of a wastewater treatment system would require installation of additional infrastructure and would also include additional costs to operate and maintain the system. Moreover, a wastewater treatment facility would create additional waste close to the treatment facility that would also need to be treated or hauled away from the site.
- The concept of installing hydraulic plugs was discussed but eliminated. Hydraulic plugs in the mine adits have the potential to stop water discharge from the adits, but they add the uncertainty of where water might then discharge and create the risk of adding mine water directly to Stanley Creek from seeps and springs. Overall, this alternative would be impracticable.

Chapter 3 Affected Environment and Environmental Consequences

3.1 Introduction

This chapter describes the existing environment and environmental components and resources in the analysis area that would be affected either by the Proposed Action or by the Agency-Mitigated Alternative. **Figure 1-1** and **Figure 1-2** give an overview of the analysis area. The No Action Alternative is described in the following sections solely as a baseline for comparison with the Proposed Action and the Agency-Mitigated Alternative. The No Action Alternative is not a feasible alternative because it would not meet current water quality standards for discharge of adit water to Stanley Creek.

In addition to describing existing conditions, this chapter analyzes the potential impacts that would result from implementation either of the Proposed Action or of the Agency-Mitigated Alternative. Environmental components related to major issues identified in Chapter 2 are also described in more detail while other resources are described briefly. Major issues include the following:

Water Management

- adit closure and mine water distribution;
- water treatment and disposal;
- groundwater quality;
- surface water quality; and
- long-term monitoring of water quality.

Reclamation

- reclamation materials;
- subsidence;
- revegetation;
- infrastructure; and
- topography.

3.2 Past and Current Actions

Past and current actions are important to consider in evaluating the potential cumulative direct and indirect impacts of the proposed project. Cumulative impacts are impacts on the environment, that result from the combination of potential impacts from the project with impacts from other closely-related past, present, and reasonably foreseeable future projects. Cumulative impacts are the result of individually minor, but collectively significant, actions taking place over a period of time, regardless of the agency or person undertaking the project. This section describes those past and current actions within the Lake Creek watershed that could be relevant to the proposed project.

3.2.1 KNF Management Activities

Two projects are located in the Three Rivers Ranger District of the Kootenai National Forest (KNF) and are briefly described below. Additionally, past timber harvest activities are included below.

3.2.1.1 Motor Vehicle Use Map Project

Following analysis in an Environmental Assessment (EA), a Decision Notice (DN) and Finding of No Significant Impact (FONSI) were issued September 2009 for the Motor Vehicle Use Map Project situated within the Three Rivers Ranger District of KNF. The alternative selected for this project prohibits motorized use of all the District's trails, prohibits cross-country motor vehicle use on NFSL located in Idaho (excluding over-snow vehicles), designates approximately 500 miles of currently open National Forest System Roads (NFSR) open to highway legal vehicles, and allows 300 feet of cross-country motor vehicle use off designated NFSR to access dispersed camping in specific locations (KNF 2009a).

3.2.1.2 Kootenai National Forest Invasive Plant Management

In 2007, USFS made a decision to implement an invasive plant management plan for 2,225,000 acres of KNF, including Lincoln County. A maximum of 30,000 acres of noxious weed infestations may be treated annually for up to 15 years. As stated in the project decision notice, this "decision will also allow for an adaptive and integrated weed management strategy which includes: treatment of new weed species, new weed patches, and new control methods (biological control agents, hand-pulling, cultivation, cultural, mechanical treatment, and new herbicides)" (USFS 2007).

3.2.1.3 Timber Harvest

The most recent large timber sale projects in the Lake Creek watershed are described in the Sparring Bulls Draft EIS and are shown in **Table 3-1**. The Spar and Lake Subunits Record of Decision (ROD) authorized approximately 2,173 acres of harvest; approximately 70 percent was intermediate harvest methods and 30 percent regeneration harvest methods (KNF 2010).

In 2006-2007, the State of Montana harvested 587 acres on the east side of the Lake Creek watershed in Township 31 North, Range 34 West, Section 16; approximately 65 percent used regeneration harvest methods and 35 percent used intermediate harvest methods. Previously in 2001-2002, the state harvested 380 acres on the west side of the Lake Creek watershed in Township 30 North, Range 34 West, Section 36 (Keeler Mountain); approximately 10 percent were regeneration harvests and 90 percent were intermediate harvests (KNF 2010).

Table 3-1. Recent Timber Sales within Lake Creek Watershed

Timber Sale	Timber Sale Date	NEPA Decision Document
Keeled Over	2007-2009	Forest-wide Blowdown EA
Spar Copter	2004-2005	Spar and Lake Subunits ROD 2001
Keeler Heli	2002-2004	Spar and Lake Subunits ROD 2001
Keeler Bottoms	2005	Spar and Lake Subunits ROD 2001
Whitetail Salvage/ Shimmering Grouse	2002	Spar and Lake Subunits ROD 2001
Hiatt Ho Salvage	2000-2004	Hiatt Ho Decision Memo Decision Memo 1997
Plopped Pony Salvage	1998	Plopped Pony Salvage Decision Memo 1997
Imadgine Salvage	1998	Imadgine Salvage Decision Memo 1995

Source: Sparring Bulls Draft EIS, KNF, 2010.

3.2.2 Private and State Land Actions

DEQ reviews all preliminary plats and certificate of surveys for suitability for septic or community water systems in the unincorporated areas in Lincoln County. Between 1999 and 2006, DEQ approved an average of 45 septic permits per year near the Troy and Bull Lake areas (Lincoln County 2009).

On December 15, 2009, an application was submitted for a 6.62 acre, two-lot, residential subdivision known as the O'Neal Subdivision to be located east of MT 56 near the Troy Mine tailings impoundment area. Lot 1 consists of timbered land with an existing home, shop, and business, all known as Ray O'Neal Welding and Exhaust, and Lot 2 is vacant. Both lots propose to use existing roads and access to MT 56. The Final Lincoln County Subdivision Planning Staff Report for the O'Neal subdivision notes that mitigation measures would be applied to reduce subdivision effects on the natural environment including, but not limited to, wildfire protection standards, noxious weed control, floodplain management, and state and local sewage disposal requirements. Because this area may contain winter and general range for big game, restrictive covenants intended to protect wildlife and wildlife habitat would reduce potential wildlife conflicts (Lincoln County Planning Department 2010).

3.3 Reasonably Foreseeable Future Actions

Reasonably foreseeable future actions are important to consider in evaluating potential cumulative direct and indirect effects of the proposed project. This section describes reasonably foreseeable future actions that could incrementally contribute to the cumulative effects on resources affected by the proposed project.

3.3.1 Kootenai National Forest

3.3.1.1 Troy Mine Mining and Exploration

Troy Mine, Inc. expects to continue mining operations at the Troy Mine at its current rate of production for another 5-7 years and has been conducting exploration drilling for additional ore reserves from 2004 to the present. These exploration projects have been approved by the USFS and DEQ as addendums to Troy Mine, Inc.'s approved plan of operation for drilling. Troy Mine, Inc. also continues to explore ore bodies below and adjacent to the ore body currently being mined that may extend mining activity.

3.3.1.2 Sparring Bulls Draft EIS

In February of 2010, the USFS distributed a Draft EIS analyzing commercial and non-commercial vegetation management and road stabilization activities for a project area located south of Troy, Montana. The proposed action includes approximately 690 acres of intermediate harvest, 704 acres of regeneration harvest, 216 acres of non-commercial fuels reduction, 3,820 acres of prescribed burning, and 34 miles of roadway for watershed improvements (KNF 2010).

3.3.1.3 Forest Plan Revision

The Kootenai and Idaho Panhandle National Forests are currently in the preliminary stages of preparing an EIS for a revised land management plan. The intent of the revised plan is to achieve quality land management for the forests over the next 10 to 15 years. The EIS process will help develop alternatives and provide the basis for a decision on which alternative best meets the stated needs. A proposed plan and Draft EIS are expected to be completed in 2011 with a final plan and Final EIS completed within the following year.

3.3.1.4 Motorized Access Management within Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones

A Draft Supplemental EIS (USFS 2008) was prepared to analyze proposed amendments to the Forest Plans and includes motorized access and security guidelines to meet USFS's responsibilities under the Endangered Species Act (ESA) in order to enhance recovery of grizzly bears. These plans encompass 4,560 square miles of habitat of the Selkirk and Cabinet-Yaak Recovery Zones. The Draft Supplemental EIS addresses amendments to the Forest Plans for the Kootenai, Lolo, and Idaho Panhandle National Forests. A Final Supplemental EIS and Record of Decision are anticipated for early spring 2011.

3.3.1.5 Draft EIS for the Montanore Project

The Draft EIS (KNF and DEQ 2009) for the Montanore Project describes the land, people, and resources potentially affected by the Montanore Minerals Corporation's (MMC) proposed copper and silver mine, which is located about 18 miles south of Libby under the Cabinet Mountains of northwestern Montana. As proposed, this project would consist of eight primary components: the use of an existing evaluation adit, an underground mine, a mill, three additional adits and portals, a tailings impoundment, access roads, a transmission line, and a rail loadout. Both DEQ and KNF are currently preparing responses to public comments and are preparing a Supplemental Draft EIS.

3.3.1.6 Rock Creek Mine

The 2001 Rock Creek Final EIS (KNF and DEQ 2001) describes the proposed Rock Creek Project as an underground copper and silver mine in northwestern Montana under the Cabinet Mountain Wilderness, located in Sanders County near Noxon, Montana. The project would be operated by Revett Mining Company (Revett), and the purpose of the proposed action is to develop the mineral interest. The project would include building a mill for ore processing and associated mine development rock disposal facilities. Both a rail loadout for transportation of concentrate and appropriate water treatment facilities are also proposed. DEQ and KNF approved the project. The USFS is currently preparing a Supplemental EIS to address the May 4, 2010, U.S. District Court ruling on the Final EIS and 2003 Record of Decision for the project.

3.3.2 Private and State Lands

The Montana Department of Transportation (MDT) has not allocated any funding for highway projects on MT 56 in its 2010-2014 Statewide Transportation Improvements Program (STIP).

Private development within the Lake Creek watershed is expected to continue. Development is expected to include, but is not limited to, septic and community water system permits, subdivision of land, home construction, land clearing, and commercial timber harvest.

3.4 Air Quality

3.4.1 Introduction

Air quality refers to the condition of the air and includes levels of pollutants measured over a period of time in the surrounding environment. This section reviews operational air quality conditions in both the Troy and general northwest Montana areas and discusses monitor locations and data.

3.4.2 Regulatory Framework

The Clean Air Act (CAA), as amended (42 USC 7401), is intended to achieve and maintain levels of air quality that will protect human health and safety. The U.S. Environmental Protection Agency (EPA) has established maximum concentrations for pollutants that are referred to as the National Ambient Air Quality Standards (NAAQS). Six “criteria pollutants” are used as indicators of air quality: ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. EPA has designated areas around the country that do not meet these standards as “nonattainment areas.”

The CAA is a federal law that DEQ enforces. The Clean Air Act of Montana (72-2-101 *et seq*., MCA) allows development of local air pollution control programs to develop control strategies for nonattainment areas. Agencies develop and maintain air pollution control plans, which are frequently referred to as State Implementation Plans (SIPs). These control plans explain how an agency will protect against air pollution under the CAA. Montana allows any city or county to establish its own local air pollution control program. Seven counties currently operate local air pollution control programs that encompass the following communities: Billings, Butte, Great Falls, Helena, the northern Flathead Valley, Libby, and Missoula.

The area around Libby, nine miles east of the permit area, is in nonattainment (*i.e.* it does not meet the standards) for particulate matter (PM) less than 2.5 micrometers in diameter (PM2.5) and less than 10 micrometers in diameter (PM10). Although the Libby loadout facility is within this nonattainment area, the remainder of the county, including the Troy Mine Permit Area, is in compliance with the NAAQS.

The 1987 KNF Forest Plan includes air quality goals for activities on KNF lands. The 1987 Forest Plan serves as the guiding management document until a new Forest Plan is completed. The 1987 Plan's goal is to maintain the existing excellent air quality on KNF lands and to cooperate with DEQ to protect local and regional air quality through DEQ programs.

The 1977 amendments of the Clean Air Act established the Prevention of Significant Deterioration (PSD) Program to prevent stationary industrial sources from causing a significant deterioration of air quality in areas that meet present air quality standards or NAAQS (attainment areas). Areas of the country were designated as belonging in Class I, II, or III airsheds for PSD purposes. Class I areas are all international parks, national parks greater than 6,000 acres, and national wilderness areas greater than 5,000 acres which existed on August 7, 1977. This class provides the most protection to pristine lands by severely limiting the amount of human-induced air pollution that can be added to these areas. Class II areas are currently all other areas of the country that are not Class I. Class III areas are areas that states may designate for development and new sources of air pollution. However, none have been designated to date. Under the PSD program, the Cabinet Mountain Wilderness is a Class I Federal Area where visibility is an important value (40 CFR 81.417). The remainder of the KNF is a Class II Federal Area.

3.4.3 Analysis Area

The analysis area for air quality is Idaho Airshed 11 and Montana Airsheds 1 and 2. The area outside the operating permit boundary in the general vicinity of the tailings impoundment is also included, because it could be affected by blowing dust during reclamation of the impoundment. The Libby loadout facility (located in Libby, Montana) is included in this analysis due to its relation to the Troy Mine mining activities. Public comments were received during the scoping process on potential effects of blowing dust.

3.4.4 Affected Environment

An air quality monitoring station, located in Libby at the Courthouse Annex, monitors for PM-2.5 and PM-10. According to 40 CFR 81.327 (Designation of Areas for Air Quality Planning Purposes), parts of Lincoln County are in nonattainment for particulate matter. The Libby loadout facility is located within the Libby PM-10 and PM-2.5 nonattainment area boundaries (Thunstrom 2006). The remainder of the county, including the Troy Mine Permit Area and general tailings impoundment vicinity outside the permit boundary, meet the NAAQS.

Based on a 14-month observation and complaints received regarding potential fugitive emissions, DEQ required Troy Mine to install, operate, and maintain at least one continuous particulate monitor to measure ambient air beyond Troy Mine, Inc.'s property boundary in the area of the tailings impoundment. On January 19, 2010, a PM-10 Ambient Air Monitoring Station was installed north of the permit boundary in the prevailing wind corridor. Monitoring began the same day (Genesis 2010).

The Spar Lake EIS discussed air quality within the area (KNF 2001). In forested areas, road dust is a source for particulates during dry periods in summer and fall, and it is a year-round source of particulates in the town of Troy due to the winter sanding of roads. Air pollution from this source is generally localized, as dust usually settles within close proximity of the road itself except on windy days. Outside influences on the local airshed include dust and smoke from areas to the west. Much of the impact comes from dust off the Palouse prairie and smoke from industrial grass burning which takes place in eastern Washington and northern Idaho. Forest fire smoke can also be a source of air pollution. Asbestiform minerals in particulate matter are also an issue in the Libby-Troy area from historic vermiculite mining.

The Troy Mine has a paved road to the mine to control road dust during operations from mine traffic. The Troy Mine has had a sprinkler system available to control dust operationally, but sometimes it has been disassembled or shut down due to cold weather. Windstorms in the impoundment area result in tailings blowing from the impoundment surface. Due to complaints from neighbors downwind, Genesis (now Troy Mine, Inc.) began several activities to control fugitive emissions from the tailings impoundment in the summer of 2008. Activities included applying chemical dust suppression to roads and berms and applying more water to the tailings impoundment.

The Troy Mine is currently covered by Montana Air Quality Permit #1690-02 – Genesis – Troy Mine. Within the last five years, EPA's Enforcement and Compliance History Online resource notes there has been one formal enforcement action related to violation of the CAA. A state Administrative Order was issued to the Troy Mine on July 25, 2010, and a $6,431 penalty was issued for this violation.

Air quality is generally considered an operational issue, because emissions regulated by EPA and DEQ typically occur only during mining operations. However, disturbed areas such as the tailings areas can also be a source of air pollutants post-closure until reclamation measures such as plantings are established. The 1978 EIS predicted that the most significant overall impact to air quality from the proposed facilities would come from increased population and traffic in the area. Mine and mill site pollutants were expected to be minimal due to the confined nature of the mining process. An active tailings impoundment was expected to have little effect on air quality due to the high precipitation rate of the area (DSL and KNF 1978, page 299). However, blowing dust has been a problem operationally when the irrigation system is down. Cell 2 of the tailings impoundment was reclaimed as part of a reclamation test that controlled blowing dust from the revegetated areas. This test has not been accepted by the Agencies as the final reclamation for Cell 2. In 2010, approximately half of tailings impoundment Cell 3 was covered with borrow material to control blowing dust.

3.4.5 Environmental Consequences

Methods for assessing potential air quality impacts generally include analyzing each alternative's potential (basically its location or associated activities) to introduce new or increased air pollution to an area above the levels experienced during operation.

In general, all three alternatives would cause air quality to return to pre-operational levels as mill emissions cease. Reclamation of the impoundment would provide a short-term negative air quality

impact, largely due to heavy equipment use during grading and covering with growth medium. Reclamation would establish vegetation on the tailings surface, and air quality would return to pre-operational levels as blowing dust from the tailings impoundment ceases. Specific potential impacts of each alternative are discussed in further detail below.

Upon mine closure and commencement of reclamation, impacts to air quality may occur from disturbed ground and windborne dust resulting from earthmoving activities. Reclamation areas that would incorporate earthmoving activities would include the tailings impoundment, borrow areas, roads that would be removed, buildings or other infrastructure that would be removed, and areas where the ground would be regraded, such as the mill site.

3.4.5.1 No Action Alternative

Under the No Action Alternative, impacts of reclamation activities on air quality would occur according to the specifications of the 1978 Reclamation Plan. The No Action Alternative also includes reclamation activities completed through 2010. Completed reclamation activities include using several activities to control fugitive emissions from the tailings impoundment by means of applying chemical dust suppression to roads and berms and applying more water to the tailings impoundment. During operations, the mining company has reclaimed soil stockpiles and the tailings embankment. The tailings impoundment Cell 2 was reclaimed as a reclamation test plot, but this has not been accepted by the Agencies as the final cover for Cell 2. In 2010, one-half of Cell 3 in the tailings impoundment was covered with borrow material to control blowing dust.

During reclamation activities, the existing mine infrastructure would be demolished and removed, adits would be sealed, and disturbed areas would be regraded and revegetated. **Sections 3.9**, **3.15**, and **3.16** describe how roads would be regraded and revegetated. The Libby loadout facility is not addressed in the No Action Alternative. In general, the KNF portion of the Troy Mine Permit Area would be returned to a revegetated state that would be visited only intermittently, largely by foot or single vehicle traffic for recreational purposes. The private portion of the Troy Mine would be revegetated, and if the reclamation bond was released, the site could be used for whatever purpose the landowner wanted so long as that use complied with existing statutes.

During reclamation, a negative air quality impact would be expected because of blowing dust from the use of heavy equipment for activities such as regrading and covering the area with soil and other growth media. In addition to these temporary effects from reclamation activities, the potential for wind erosion and dust pollution would remain until vegetation is established. Also, potential negative air quality impacts may occur during revegetation periods (1-3 years) in addition to those occurring during reclamation activities (1-2 years). The tailings embankment slopes and benches have been reclaimed and would not need to be irrigated to control dust.

After reclamation, heavy equipment would be removed from the site, and human-related activities on the site would drop both in scope and frequency. The permit area, especially the KNF portion, would primarily return to recreational use, with related air quality impacts occurring at reduced levels. After reclamation, air quality would largely return to pre-operational conditions within the Troy Mine Permit

Area. Over time, the air pollutant levels of the mine permit area would be indistinguishable from the surrounding forest lands. Potential impacts on air quality from the No Action Alternative would not be adverse if dust is controlled during reclamation activities.

3.4.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented and on-going, and future reclamation activities on the Troy Mine Permit Area would follow the specifications of the updated plan. At the mill site, the domestic water well would be used for irrigation during the first growing season after reclamation, if needed. BMPs and irrigation using mine water would be used at the tailings facility to suppress dust until vegetation is established.

The Proposed Action is similar to the No Action Alternative in that after reclamation activities, the permit area would revert to a revegetated area primarily used for recreation and wildlife habitat purposes. The potential impact of both the Proposed Action and the No Action Alternative reclamation plans would largely be the same. The Proposed Action would lengthen the time required for reclamation activities because facilities and access would be needed for long-term mine water management. Similar to the No Action Alternative, the Proposed Action would result in a short-term negative impact during reclamation-related earth-moving activities. Long-term, however, air quality would largely return to pre-operational levels due to reduced motorized and human-related activities. Likewise, fewer haul truck trips to the Libby loadout facility would decrease diesel emissions in the nonattainment area. Over time, the air pollutant levels of the Troy Mine Permit Area should be indistinguishable from the surrounding forest lands. Like the No Action Alternative, potential impacts on air quality from the Proposed Action would not be adverse since dust would be controlled through BMPs during reclamation activities.

3.4.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and the proposed mitigations expanded to address issues identified during the public scoping and agency review processes. Under the Agency-Mitigated Alternative, reclamation activities would be conducted, and the Troy Mine Permit Area would revert to a revegetated area primarily used for recreation and wildlife habitat purposes. The temporary, open-air Libby loadout facility was used until a new covered facility was constructed in 2011. The covered loadout facility would decrease the potential for fugitive emissions. Construction and use of a new covered facility is an operational issue and is not part of the proposed reclamation plan.

While there are differences in the details of the reclamation plan of the Agency-Mitigated Alternative when compared to the Proposed Action and the No Action Alternative, the potential effects on air quality would largely be the same. The irrigation system at the tailings impoundment would be used to irrigate the reclaimed tailings surface. BMPs for dust control, such as dampening disturbed areas, would be used to minimize the potential for air quality related impacts on surrounding areas and people (*e.g.,* neighbors, recreationists) during reclamation activities.

3.4.6 Resource Impact Summary

All three alternatives would largely cause air quality in the Troy Mine Permit Area and generally in the region to return to pre-operational levels. While a minor negative air quality impact is anticipated during reclamation activities, potential air pollution is not expected to be greater in duration, frequency, or intensity than historical levels during mining activities. After reclamation, air quality is expected to return to pre-operational levels over the long term. The overall, potential air quality impact of all three alternatives is generally neutral, due to a reduction in operational human use in the Troy Mine Permit Area and the resulting reduction in air pollutant levels to the pre-operational levels of the surrounding forest land and the Libby loadout facility.

3.4.7 Effectiveness of Mitigation Measures

Revegetating surface disturbed areas is an effective method to control dust and, therefore, to improve air quality. This is accomplished by stabilizing the surface and creating a root mass and plant cover which minimizes wind velocities across the surface and thus reduces the potential for blowing dust. In addition to the reclamation activities described above, BMPs for dust control, such as dampening disturbed areas, would be used to minimize potential air quality impacts on surrounding areas and people (*e.g.,* neighbors, recreationists) during reclamation activities.

3.4.8 Cumulative Effects

Past actions in the analysis area have had little effect on ambient air quality. The potential increase of highway-legal vehicles traveling to dispersed camping locations within the Lake Creek watershed would be minimal in comparison to overall annual traffic traversing MT 56. Of the reasonably foreseeable future actions described in **Section 3.3**, the prescribed burns proposed in the Sparring Bulls Draft EIS would have the potential to add smoke emissions to the area. The USFS receives an annual permit to burn from the Montana Air Resources Management Bureau. This issuance is based on participation in and compliance with burning restrictions issued by the Montana Airshed Group (KNF 2010, page 232). The Rock Creek Mine and Montanore Mine would add operational air emissions during mining activities if permitted. The Montana Air Quality Bureau would issue permits for both past and reasonably foreseeable future actions to ensure that each project does not diminish air quality within the airshed. All three alternatives would have the same cumulative effects in consideration with past, present, and reasonably foreseeable future actions. Cumulative and additive air quality effects would be minimal for all three alternatives. A net neutral effect would occur from all three alternatives because all would return air emission loads to pre-operational levels.

3.4.9 Regulatory Compliance

All three alternatives would comply with the Clean Air Act, the Clean Air Act of Montana, and the 1987 KNF Forest Plan because air emission loads would return to pre-operational levels after reclamation. Reclamation activities would not exceed the NAAQS and would not cause the Troy Mine Permit Area to become a nonattainment area.

3.5 American Indian Consultation

3.5.1 Introduction

Federal agencies are required to consult with American Indian tribes when an agency undertaking may have the potential to affect historic properties affiliated with their American Indian past. The 1987 Kootenai Forest Plan recognizes American Indian cultural integrity and political status and recognizes USFS's responsibility for government-to-government consultation with all federally-recognized tribes. As provided by tribes, traditional and cultural use issues are integrated into federal resource management decisions. Thus, American Indian interests are fully considered in planning proposed actions on National Forests. The KNF provides sustainable natural resources that may contribute to a way of life, cultural integrity, social cohesion, and to the economic well-being of treaty tribes.

3.5.2 Regulatory Framework

The National Historic Preservation Act (NHPA), as amended in 1992 (16 United States Code (USC) 470), establishes the federal government's policy to protect and preserve significant cultural resources. Section 106 of the NHPA requires federal agencies to take into account the effects of their undertakings on historic properties, which are defined to include cultural resources affiliated (culturally affiliated) with American Indian use and traditional cultural properties (TCP). If cultural resources might be affected by a proposed project, then consultation is required to identify appropriate avoidance and mitigation measures. The NHPA is discussed in more detail in **Section 3.6**.

The American Indian Religious Freedom Act (AIRFA) of 1978 (42 USC 1996) affirms the right of American Indians to access their traditional sacred places. If a place of religious importance to American Indians may be affected by an undertaking, AIRFA requires a consultation with Indian religious practitioners, which may be coordinated with the Section 106 consultation.

The Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 (25 USC 3001) addresses the rights of lineal descendants and members of Indian tribes, Alaska Native, and native Hawaiian organizations to certain human remains and precisely defined cultural items. It covers items currently in federal repositories as well as future discoveries. The law requires federal agencies and museums to provide an inventory and summary of human remains and associated funerary objects. The law also provides for criminal penalties in the illegal trafficking in Native American human remains and cultural items.

The Montana Human Skeletal Remains and Burial Site Protection Act (22-3-802 *et. seq.* MCA) provides legal protection to all unmarked burial sites regardless of age, ethnic origin, or religious affiliation by prohibiting unnecessary disturbance and unregulated display of human skeletal remains.

The Archaeological Resources Protection Act of 1979 (ARPA) (Public Law (P.L.) 96-95) and Regulations 43 CFR Part 7 establish a permit process for extending permits for work on cultural sites on federal lands. When those sites are culturally affiliated, consultation with affected tribal governments must occur.

The Religious Freedom Restoration Act of 1993 (P.L. 103-141) establishes a higher standard for justifying government actions that may impact religious liberties.

The Indian Sacred Sites Executive Order 13007 of June 1996 directs federal land managers to "(1) accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and (2) avoid adversely affecting the physical integrity of such sacred sites," and to "maintain the confidentiality of sacred sites" where appropriate.

DEQ considers impacts to cultural resources in all of its environmental documents.

3.5.3 Analysis Area

In October of 2007, KNF sent scoping letters to the Confederated Salish and Kootenai Tribes, Kalispel Tribe, Kootenai Tribe of Idaho, and Coeur d'Alene Tribe notifying them of the upcoming analysis for the Troy Mine Revised Reclamation Plan. No responses have yet been received from the tribes.

The analysis area is located within lands encompassed by the Hellgate Treaty of 1855. The Hellgate Treaty was signed between the United States and the Flathead, Upper Pend d'Oreilles, and Kootenai Tribes to ensure that the Tribes' reserved rights were protected. These rights include the "right of taking fish at all usual and accustomed places, in common with citizens of the Territory, and of erecting temporary buildings for curing; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed land." The federal government has trust responsibilities to Tribes under a government-to-government relationship to ensure that the Tribes' reserved rights are protected. Consultation with the Tribes in early phases of project planning assures that USFS meets its trust responsibilities.

3.5.4 Affected Environment

The affected environment typically includes traditional use areas that could be impacted by any new surface disturbance required for reclamation activities, such as religious practices, other traditional cultural uses, and cultural resource sites and remains associated with American Indian ancestors. The analysis area includes the Troy Mine Permit Area.

3.5.5 Environmental Consequences

The aforementioned tribes were afforded an opportunity to provide comments and concerns regarding the analysis for the Troy Mine Revised Reclamation Plan and the 1978 Reclamation Plan. Since the tribes have not yet provided traditional and cultural use data required to set a threshold for determining the effect on American Indian resources, it is not possible to analyze potential direct, indirect, and cumulative effects. All three alternatives would result in eventual reclamation of the disturbed areas after mine closure.

Reclamation and closure activities would primarily occur on or within areas that were previously disturbed during mining activities. If additional growth medium is needed for reclamation under either the Proposed Action or the Agency-Mitigated Alternative, the borrow site on private land east of the impoundment would be expanded by as much as 16 acres. The Forest Plan states that cultural resources

would be inventoried and evaluated before ground disturbing activities take place and that all significant resources identified would be protected or mitigation actions would be taken. Until a cultural resource survey of previously undisturbed areas is performed, it is assumed that all three alternatives would have minimal direct and indirect effects on cultural resources affiliated with tribal groups or traditional cultural properties.

3.6 Cultural Resources

3.6.1 Introduction

Cultural resources consist of a wide range of resources and places having historic, cultural, archaeological, or architectural significance and places from the past having important public and scientific uses. Cultural resources result from human activity and are typically unique, fragile, and nonrenewable.

3.6.2 Regulatory Framework

NEPA requires that federal agencies analyze the impacts of their activities on the environment, which includes cultural resources. To an extent, NEPA addresses some of the same concerns as the NHPA such as identification of irreversible effects. NEPA and the Section 106 processes can be synchronized.

The NHPA established the federal government's policy on protection and preservation of significant historic properties, which are cultural resources that are eligible for the National Register of Historic Places. The NHPA authorized the creation of the National Register of Historic Places (NRHP), which is an inventory of cultural resources that meet the National Register Criteria. The NRHP is maintained by the Secretary of the Interior and contains a broad range of property types. NHPA also created an Advisory Council on Historic Preservation (ACHP), which serves the public's interest by curtailing unnecessary government sponsored destruction of important cultural properties. ACHP works closely with State Historic Preservation Offices (SHPOs) to advise agencies on how to mitigate the effects of federal undertakings upon significant cultural features and landscapes.

36 CFR 800 reflects Section 106 of the NHPA and requires federal agencies to take into account the effects of their undertakings on historic properties (see Glossary) and to afford the SHPO and ACHP a reasonable opportunity to comment.

36 CFR 79 establishes standards, procedures, and guidelines to be followed by federal agencies to preserve collections of prehistoric and historic material, remains, and associated records that are recovered in conjunction with federal projects and programs under certain federal statutes. Proposed actions should ensure that federally-owned and administered collections of prehistoric and historic materials, remains, and associated records are deposited in repositories that have the capability to provide adequate long-term curatorial services.

Executive Order 11593 of 1971, Protection and Enhancement of the Cultural Environment, states that the federal government will provide leadership on preserving, restoring, and maintaining the historic and cultural environment of the Nation. The Executive Order directs federal agencies, through federal

plans and programs, to preserve cultural resources and to contribute to the preservation and enhancement of non-federally owned sites, structures, and objects of historic, architectural, or archaeological significance. It orders federal agencies to locate, inventory, and nominate to the National Register all properties under their control or jurisdiction that meet the criteria for nomination. It also directs federal agencies to exercise caution during the interim period so that cultural resources under their control are not inadvertently damaged, destroyed, or transferred.

ARPA and 36 CFR Part 7 Sec 2a provide protection for those archaeological resources found on public lands and Indian lands of the United States. This legislation provides civil and criminal penalties for those who remove or damage archaeological resources in violation of the prohibitions contained in the bill. The bill prohibits removing of archaeological resources from either public lands or Indian lands without first obtaining a permit from the affected federal land manager or Indian Tribe.

Executive Order 13287 of 2000, Preserve America, reinforces the federal government policy for "protection and enhancement of America's historic treasures, and to recognize and treat cultural resources as assets. Federal agencies shall advance this policy through the protection of, continued use of, and reinvestment in, the Federal government's historic buildings and sites and by conforming to the highest standards of care for, and consideration of, the unique cultural heritage of communities, and of the Nation."

In addition, the 1987 KNF Forest Plan states that cultural resource management shall be integrated into the overall National Forest multiple resource management effort and that cultural resources should be inventoried and evaluated before any activities disturb the ground. All significant resources identified would be protected or else mitigation actions would be taken. Appendix 19 of the Forest Plan summarizes the policy for managing and protecting cultural resources on KNF lands.

3.6.3 Analysis Area

The analysis area for cultural resources includes the area within the Troy Mine Permit Area and includes any borrow sources proposed to be used for reclamation materials. Borrow areas proposed for use include the East Borrow Pit. Other borrow areas cited in the Revised Reclamation Plan are located within the permit area or consist of lacustrine and volcanic ash-derived soil materials stockpiled during construction of the tailings impoundment. Areas within the permit boundary are subject to federal laws protecting cultural resources.

3.6.4 Affected Environment

According to the 1978 Draft EIS prepared for the Troy Mine project, an archaeological reconnaissance was made of KNF lands in the Troy Mine Permit Area. A previous survey of the area that included private land was done in 1975. None of these studies identified cultural resources in the area proposed for disturbance. The area of the tailings impoundment was noted to have been extensively disturbed by the landowner during management of the area for timber production (DSL and KNF 1978).

No cultural resources were discovered during construction of the tailings embankment or the operation of the mine. Additionally, the 1978 Draft EIS states that there are no known historic sites within the area

proposed to be disturbed by mining development. There are no built environment elements that are older than 50 years within the project area (built prior to 1960).

3.6.5 Environmental Consequences

No historic properties were identified prior to mine development, and no historic or archeological resources have been identified during mine operation. As discussed in **Section 3.5**, tribal consultation did not identify any potential cultural resources within the project area. There are no structures that would be old enough to warrant evaluation as potential historic properties. Additionally, reclamation and closure activities would occur primarily on or within areas that were previously disturbed during mining activities. If additional cover materials are needed for reclamation, the borrow site east of the impoundment on private land would be expanded. The Forest Plan states that cultural resources would be inventoried and evaluated before ground disturbing activities take place. All significant resources identified would be protected, or else mitigation actions would be taken. There are no known environmental direct, indirect, or cumulative effects related to cultural resources under any of the alternatives.

3.6.6 Regulatory Compliance

All three alternatives would be in compliance with the NHPA, Executive Order 11593, ARPA, Executive Order 13287, and the 1987 KNF Forest Plan because no cultural resources would be affected by the proposed activities.

3.7 Fish Habitat

3.7.1 Introduction

This section reviews fisheries and aquatic habitat and species population status by subwatershed within the analysis area that could be affected by reclamation activities or long-term adit and tailings water quality. This section also discusses the population status of threatened, endangered, and sensitive fish species within the analysis area. Potential impacts to these resources under each of the reclamation alternatives are identified. Additional information relevant to fish habitat conditions and water quality is found in **Section 3.9**.

3.7.2 Regulatory Framework

The regulatory framework for this section includes:

- Endangered Species Act (ESA) of 1973
- The National Forest Management Act (NFMA) (36 CFR 219.19)
- The KNF Forest Plan of 1987

The Endangered Species Act (ESA) of 1973 declares that "...all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act." Under ESA, federal agencies must consult with the Secretary of

the Interior whenever an action authorized by such agency is likely to affect a species listed as threatened or endangered. Bull trout and white sturgeon are currently listed as threatened and endangered, respectively, under the ESA. Effective September 30, 2010, the USFWS designated critical habitat for bull trout throughout their U.S. range (USFWS 2010). Under the ESA, critical habitat identifies geographic areas that contain features essential to conservation of a listed species. Critical habitat designations provide extra regulatory protection that may require special management considerations. Habitats are then prioritized for recovery actions. In addition, agencies are required to analyze effects of proposed actions on primary constituent elements (PCEs) for bull trout critical habitat. The Troy Mine Permit Area is included in Critical Habitat Unit 30, Kootenai River Basin. Specific water bodies with critical habitat designation within the analysis area include Bull Lake and Lake Creek.

Sensitive species are managed under the authority of NFMA and are administratively designated by the Regional Forester (FSM 2670.5). FSM 2670.22 requires the maintenance of viable populations of native and desired non-native species and the avoidance of actions that may cause a species to become threatened or endangered. NFMA directs the USFS to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives" (16 USC 1604(g)(3)(B)). Providing ecological conditions to support a diversity of native plant and animal species in the planning area satisfies the statutory requirements. To meet the requirements of NFMA and its implementing regulations, USFS assesses habitat for its ability to provide for a diversity of species.

FSM 2672.42 directs USFS to conduct a biological assessment (BA) to analyze impacts on sensitive species. If any unmitigated, significant effects are identified in the BA, the Forest Supervisor must make a decision to allow or disallow the impact. If the significant effects would result in a trend toward federal listing, the Forest Supervisor cannot allow the project to proceed. The sensitive species analysis in this document meets the requirements for a BA as outlined in FSM 2672.42. The westslope cutthroat trout (*Oncorhynchus clarki lewisi*) is the only sensitive fish species identified within the analysis area.

The Forest Plan establishes forest-wide objectives, standards, guidelines, and monitoring requirements for KNF sensitive species. Forest Plan direction for sensitive species includes both determining the status of sensitive species and providing for their environmental needs as necessary to prevent a trend toward federal listing.

The 1987 Forest Plan established management areas within the forest with different goals and objectives based on the capabilities of lands within this area (USFS 1987). The Inland Native Fish Strategy (INFISH) amended the Forest Plan in 1995 (USFS 1995). INFISH established standards and guidelines to protect riparian and aquatic resources on NFSL. As part of this strategy, the Regional Forester designated a network of priority watersheds which includes Lake Creek and all of its tributaries with surface water connections.

INFISH established stream, wetland, and landslide-prone-area protection zones called Riparian Habitat Conservation Areas (RHCAs) on NFSL. RHCAs are broken into four categories (**Table 3-2**).

Table 3-2. RHCA Categories and Standard Widths.

Stream or Waterbody Category	Standard Width
Fish-bearing streams	Minimum 300 feet each side of the stream
Perennial, non-fish bearing streams	Minimum 150 feet each side of stream
Ponds, lakes, and wetlands greater than 1 acre	Minimum 150 feet from maximum pool elevation
Intermittent and seasonally flowing streams, wetlands less than 1 acre, landslides, and landslide prone areas	Minimum 50 feet from edge (except in priority watersheds such as Lake Creek, where the minimum is 100 feet)

Source: USFS 1995

INFISH also identifies riparian management objectives (RMOs) for forested systems that include pool frequency, large woody debris (LWD) frequency, width/ mean depth ratio, and water temperature (**Table 3-3**). Bank Stability is also addressed but is not a required RMO for forested systems. Actions that retard attainment of these RMOs, whether existing conditions are better or worse than objective values, are considered to be inconsistent with the Forest Plan.

Table 3-3. Interim Riparian Management Objective Standards by Stream Width.

Wetted Width	Pools/mile	LWD/mile	Bank Stability %	Width/Mean Depth Ratio (Pools)	Water Temperature
< 10 feet	96	20 pieces > 12-inch diameter and 35-foot length.	> 80	< 10	No increase, < 59 ° F
10-20 feet	56				
21-25 feet	47				
26-50 feet	26				

Source: USFS 1995.

3.7.3 Analysis Area

The analysis area for evaluating direct, indirect, and cumulative effects includes the Stanley Creek, Ross Creek, and upper Lake Creek sub-watersheds within the Lake Creek watershed (as shown on **Figure 3-2** in **Section 3.9**). The extent of the analysis area was determined by the expected extent of hydrologic (water quantity and quality) influence related to the reclamation alternatives and associated activities.

3.7.4 Affected Environment

3.7.4.1 Fish Population Status

The Lake Creek Dam near the confluence of Lake Creek with the Kootenai River prevents fish from migrating upstream from the Kootenai River. Falls at the dam site were potentially a natural barrier to upstream fish passage prior to dam construction. Currently, a viable, disjunct population of bull trout (*Salvelinus confluentus*) exists in the Lake Creek drainage as well as kokanee salmon (*Oncorhynchus nerka*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), longnose dace (*Rhinichthys cataractae*), pygmy whitefish (*Prosopium coulteri*), slimy sculpin (*Cottus cognatus*), lake trout (*S. namaycush*), westlope cutthroat trout (*O. clarkii lewisi*), brook trout (*S. fontinalis*), and possibly torrent sculpin (*C. rhotheus*). Brook trout were introduced into the region in lower Lake Creek and Bull Lake and are currently distributed throughout much of the area. Hybridization between brook trout and bull trout has occurred (KNF 2001).

Threatened, endangered, and proposed species are those federally listed species which are either protected or proposed for protection under the ESA. Sensitive species are those species identified on the Regional Forester's Sensitive Species List.

3.7.4.2 Threatened, Endangered, and Proposed Species

White Sturgeon

The white sturgeon (*Acipenser transmontanus*), endangered, is a slow growing, late maturing, long-lived anadromous fish that relies upon large, fast-moving rivers with large cobble for spawning. Although this species occurs in the vicinity, no suitable white sturgeon habitat occurs within the analysis area. As such, the white sturgeon would not be affected by the Troy Mine reclamation activities and will not be discussed further in the analysis.

Bull Trout

Bull trout, threatened, are native to the upper Columbia River basin in northwestern Montana. This species requires clean, cold, complex, and connected habitat. Bull trout populations have declined because of land management practices, expansion of introduced fish populations, non-sustainable recreational harvest, and loss of habitat connectivity. Forest management activities, mining, and dam operations have also negatively impacted spawning and rearing habitat conditions in the lower Kootenai River metapopulation. Additionally, non-native brook trout threaten bull trout populations due to hybridization and interspecific competition. This bull trout population was listed as threatened in the conterminous U.S. in June of 1998.

Historically, bull trout likely occurred throughout the analysis area including Stanley Creek, Lake Creek, and Bull Lake. However, the current bull trout population in the analysis area is adfluvial, rearing in Bull Lake and in lower Lake Creek. These fish spawn in the Keeler Creek drainage. Currently, there is no evidence of a resident bull trout population in other tributaries of Lake Creek, nor is there evidence of recent use of Stanley Creek (KNF 2001).

3.7.4.3 Sensitive Species

Westslope Cutthroat Trout

The historic range of westslope cutthroat trout once included western Montana, central and northern Idaho, extreme northwestern Wyoming, and the southern portions of British Columbia, Alberta, and Saskatchewan (Liknes and Graham 1988). The distribution and abundance of westslope cutthroat trout have declined across their original range due primarily to hybridization with rainbow trout and displacement by brook trout (Behnke 1992; Rieman and Apperson 1989). In streams where brook trout and westslope cutthroat trout coexist, westslope cutthroat trout are typically confined to higher gradient reaches. Whereas, brook trout predominate in lower gradient reaches that were historically occupied by westslope cutthroat trout (Griffith 1988). This spatial segregation further isolates westslope cutthroat trout populations and can increase the risk of local extinctions due to genetic and stochastic factors (McIntyre and Rieman 1995).

Within the analysis area, genetically pure populations of westslope cutthroat trout persist in Ross Creek (Ross Creek sub-watershed) as well as in Spring Creek, Dry Creek, Camp Creek, Madge Creek, and in Porcupine Creek (upper Lake Creek sub-watershed) (KNF 1994; KNF 2010). Some of these remaining genetically pure populations of westslope cutthroat trout are found above fish passage barriers that protect them from hybridization but isolate them from other populations. Habitat quality and the proximity to other populations are also critical factors in the persistence of local populations (Rieman and McIntyre 1993). Habitat fragmentation and subsequent isolation of conspecific populations may increase the risk of local extinctions. Conversely, this spatial isolation also protects their genetic integrity.

Westslope cutthroat trout were historically present in Stanley Creek (USFS 1977), but appear to have been displaced or replaced by brook trout in association with habitat degradation (Carlson 2010). Several other small, isolated populations remaining in the Lake Creek drainage are at moderate risk of local extirpation due to disturbance events.

Interior Redband Trout

The interior redband trout (*Oncorhynchus mykiss gairdneri*), a subspecies of rainbow trout, is not present within the analysis area; therefore, it would not be affected by the Troy Mine reclamation activities and will not be discussed further in the analysis.

3.7.5 Environmental Consequences

Potential impacts to fisheries resources from mine closure and reclamation activities would include modifications to existing water quality (*e.g.*, sedimentation, erosion, or metal contamination) or to water quantity *(e.g.*, streamflow). Water quality and quantity issues are further discussed in **Section 3.9**.

In general, the proposed reclamation activities under any alternative would have no effect on habitat fragmentation. Increased sedimentation due to regrading roads and other disturbed areas and subsequent erosion of applied growth media could decrease suitable spawning substrate and reduce overwintering habitat for juvenile fish. This in turn could reduce spawning success and overwinter

survival. The presence of roads can also increase peak flows by altering the drainage network within a watershed. These increased peak flows can decrease channel stability and accelerate erosion and result in habitat degradation. However, there would be no new roads proposed under any of the alternatives.

The greatest risks to fisheries from the Troy Mine reclamation alternatives would be potential water quality impacts from sedimentation and from mine adit water discharge that contains copper and other metals. Sedimentation impacts would come from regrading, placement, and erosion of reclamation materials, and from reclaiming roads if BMPs are not properly implemented. Toxicity from metals such as cadmium and copper can decrease growth and survival of trout and has been identified as a potential contributor to bull trout declines (Hansen *et al.* 2002; 63 FR 31647). Heavy metals can also be toxic to some macroinvertebrate taxa (Kiffney and Clements 1994), thereby decreasing forage availability for fish. The following analysis will focus on anticipated effects of reclamation and associated activities on sediment and water quality.

3.7.5.1 No Action Alternative

Under the No Action Alternative, mine closure and reclamation would be conducted according to the 1978 Reclamation Plan. Potential short-term sedimentation and erosion associated with the removal and reclamation of mine facilities (including some roads, buildings, development rock fill, portal patios, and tailings and reclaim water pipelines) could impact fisheries. These activities could result in entrainment of fine sediment in pools and channel margins in lower gradient reaches of Stanley Creek and Lake Creek (see **Section 3.9**). Application of BMPs (*e.g.*, erosion control) would be assumed as part of Montana's legal requirements for storm water pollution prevention planning and permitting. To maintain compliance with Montana pollution prevention laws, a Storm Water Pollution Prevention Plan (SWPPP), which includes BMPs for use during ground disturbing activities, would also be required during reclamation. Because maintenance and/or modification of the existing storm water collection and diversion system at closure was not addressed in the 1978 Plan, lack of maintenance of this system could result in long-term erosion potential associated with these structures.

Mine adit water at closure would contain elevated levels of metals (primarily copper and antimony) and, initially, nitrates (**Section 3.9**). Post-closure water routing as proposed in the 1978 EIS would allow mine water flowing out of adit portals to naturally infiltrate through the development rock adjacent to the mine portals or to be discharged directly into Stanley Creek. This discharge could exceed current surface water quality standards and could potentially impact macroinvertebrate, tailed frog, and brook trout abundance in Stanley Creek. Bull trout and westslope cutthroat trout are not known to be present in the Stanley Creek drainage and would not be affected. However, as a result of dilution, dissolved copper levels in Lake Creek where bull trout and cutthroat trout are present would be at sublethal levels for those species and would meet water quality standards under typical streamflow and mine discharge conditions.

Table 3-4 compares potential copper concentrations in Lake Creek with no discharge of mine water and with a discharge of mine water under the No Action Alternative. These predicted values are estimated for the lowest annual flow period which is in August. The predicted values are compared to the chronic aquatic life criterion for copper.

Table 3-4. Potential Copper Concentrations in Lake Creek Under the No Action Alternative

Monitoring Site	Cu mg/L No Mine Discharge	Cu mg/L Mine Discharge	Cu mg/L Chronic Aquatic Life Criterion
LC-01	0.0010	0.0018	0.0030
LC-02	0.0010	0.0018	0.0030
LC-04	0.0010	0.0016	0.0030

Source: Data from Troy Mine, Inc. Water Quality Data Base.
Note: Cu = copper

Bull Trout Critical Habitat

The No Action Alternative would minimally affect primary constituent elements (PCE) and associated habitat indicators for bull trout critical habitat. Minimally affected PCE would include migration habitats with minimal physical, biological, or water quality impediments among spawning, rearing, overwintering, and freshwater and marine foraging habitats. These impediments include but are not limited to permanent, partial intermittent, or seasonal barriers. The associated habitat indicators would consist of chemical contamination and nutrient concentrations.

Sediment quantities generated from reclamation activities and delivered to Lake Creek under the No Action Alternative would be small and of short duration. Sediment inputs of a more chronic nature could be generated from the existing storm water collection and diversion system. These increases would be expected to be small relative to the existing sediment load in Lake Creek, and measurable impacts to spawning and rearing habitat or macroinvertebrate food sources would not be anticipated. Presently, bull trout are thought to spawn exclusively in the Keeler Creek drainage. Spawning in Lake Creek has not been confirmed. Therefore, it is unlikely that spawning habitat would be affected. The potentially affected reach in Lake Creek is known to be utilized primarily as a migratory corridor, and there is no evidence of bull trout spawning there. Increases in metal concentrations in Lake Creek under typical flow conditions would not be sufficient to pose a chemical migration barrier, or to affect reproduction, growth, or survival (**Table 3-4**).

The overall effects to threatened and sensitive fish species habitat under the No Action Alternative would be minimal because of the absence of bull trout and cutthroat trout in Stanley Creek, the dilution of contaminants in Lake Creek, and the relatively small anticipated increases in fine sediment to Lake Creek.

3.7.5.2 Proposed Action

Potential fisheries impacts resulting from implementation of the Proposed Action would include the potential for temporary erosion and sediment delivery to area streams near facilities to be removed or reclaimed, as well as from borrow areas. However, implementation of BMPs would reduce or eliminate this potential effect.

Disposal of post-closure mine water via pipeline to the tailings facility for infiltration would limit the potential for water quality impacts to Stanley and Lake creeks, unless the pipelines fail over time due to wear or vandalism. Potential erosion issues could occur in the vicinity of the mill site, office area, and

areas associated with the storm water collection and diversion system. These potential issues would be minimized by reconstructing stream channels, armoring them with coarse rock, revegetating stream banks, and including velocity control structures where needed along the storm water collection and diversion system (Genesis 2006).

Under the Proposed Action, unneeded roads that pose a resource risk would not be treated, and restoration work on needed roads would not be implemented. Any additional sediment from these sources would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact water quality for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment.

In the event of a break in the pipeline carrying mine water to the tailings impoundment, a large volume of adit water and sediment could reach Stanley Creek and/or Lake Creek until the pipeline could be shut off and repaired. Water would be rerouted from the old tailings lines to the reclaim water pipeline while the old tailings pipeline is repaired. Under the Proposed Action, these spills would potentially impact fisheries in Stanley and Lake creeks until the water is re-routed and the pipelines repaired. Potential impacts to fisheries and habitat under the Proposed Action would be expected to be minimized by proposed erosion control, revegetation, and by water management activities during and after reclamation.

Bull Trout Critical Habitat

The Proposed Action has the potential to affect PCE and associated habitat indicators. Affected PCE would include an abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish. The associated habitat indicators would be sediment and substrate embeddedness.

Reclamation activities under the Proposed Action may result in a temporary increase in sediment delivered to Lake Creek, but would decrease sediment contributions over the long-term. These temporary sediment increases would be expected to be small relative to the existing sediment load in Lake Creek, and measurable impacts to spawning and rearing habitat or macroinvertebrate food sources would not be anticipated. Bull trout are thought to spawn exclusively in the Keeler Creek drainage. Spawning in Lake Creek has not been confirmed. Therefore, it is unlikely that spawning habitat would be affected. Moreover, the potentially affected reach is utilized primarily as a migratory corridor, and there has been no confirmation of bull trout spawning there. Therefore, it is unlikely that spawning habitat would be affected.

Due to the absence of bull trout and cutthroat trout in Stanley Creek and the relatively small potential increases in fine sediment in Lake and Ross creeks, measurable effects to occupied bull trout and westslope cutthroat trout habitat under the Proposed Action would not be anticipated.

3.7.5.3 Agency-Mitigated Alternative

Potential impacts to fisheries resources from implementation of the Agency-Mitigated Alternative would be similar to those discussed for the Proposed Action, but the potential for pipeline failure and mine

water discharge would be minimized by building a new buried water pipeline to the decant ponds. Both this new buried pipeline and the old reclaim water pipeline would be equipped with automated sensors to reduce potential pipeline spills that could impact water quality in Stanley and Lake creeks. This alternative would also include retaining the buried reclaim water line as a backup pipeline to handle flows in situations when the new pipeline is down for repairs or to handle flows over the capacity of the new pipeline.

Maintenance of long-term water management facilities would be required as part of the Agency-Mitigated Alternative. The Agency-Mitigated Alternative also includes water quality monitoring of springs in the analysis area to validate the prediction that water quality standards would be met post-closure.

The Agency-Mitigated Alternative provides for more diligence in avoiding surface water impacts by proposing to use only rock with little or no potential for near-neutral metal leaching in reconstructed stream channels and by providing more engineering in final design of the post-closure storm water collection and diversion system. These approaches would minimize potential erosion (see Appendix E). To protect spawning and incubating westslope cutthroat trout, sediment-generating activities within RHCAs in the Ross Creek drainage would occur after July 15th or when intermittent channels are dry, whichever comes first. To protect bull trout rearing habitat in Lake Creek, sediment-generating activities occurring within RHCAs in Ross and Stanley creeks, and the upper Lake Creek subwatershed would not occur before July 15th or after October 15th unless activities are separated from lower Stanley Creek and Lake Creek by segments of dry channel. Regrading work at the tailings impoundment area would be exempt from this timing restriction because appropriate BMPs would be installed to prevent sediment delivery to Lake Creek (see **Section 3.18.5.10**). Sediment-generating activities would be subject to state and federal permits that may include additional timing restrictions for protection of water quality.

Potential short-term water quality impacts to fisheries and/or aquatic habitat in Stanley and Lake creeks under the Agency-Mitigated Alternative would be minimized by implementing BMPs, revegetating, and managing water to control erosion both during and after reclamation. Adding a new buried pipeline and automated controls on both the new and old reclaim water pipelines would limit the potential for metals toxicity impacts to the creeks in the event of a pipeline break as compared to the Proposed Action.

The Agency-Mitigated Alternative would reduce sediment loading both by implementing reclamation actions and by treating mining road-related sediment sources. Thus, sediment levels in Stanley and Lake creeks would be expected to decline over time.

Bull Trout Critical Habitat

The Agency-Mitigated Alternative has the potential to minimally affect PCE and associated habitat indicators. Affected PCE include an abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish. The associated habitat indicators would be sediment and substrate embeddedness.

Reclamation activities may result in a temporary increase in sediment delivered to Lake Creek, but would decrease sediment contributions over the long-term. These temporary sediment increases would be expected to be unmeasurable relative to the existing sediment load in Lake Creek. Measurable impacts to spawning and rearing habitat or macroinvertebrate food sources would not be anticipated. Bull trout are thought to spawn exclusively in the Keeler Creek drainage. Since there would be no effect to Keeler Creek associated with this alternative, it would be unlikely that spawning habitat would be affected. Moreover, the potentially affected reach in Lake Creek is used primarily as a migratory corridor, and there has been no confirmation of bull trout spawning there. Therefore, it is unlikely that spawning habitat would be affected.

Due to the absence of bull trout and cutthroat trout in Stanley Creek and the relatively small anticipated increases in fine sediment in Lake and Ross creeks, measurable effects to occupied bull trout and westslope cutthroat trout habitat under the Agency-Mitigated Alternative would not be anticipated.

3.7.6 Resource Impact Summary

The No Action Alternative would potentially impact water quality in Stanley Creek and Lake Creek from mine water discharging into Stanley Creek. Dissolved metals in Stanley Creek would exceed aquatic life criteria but would meet water quality standards in Lake Creek due to dilution. Because westslope cutthroat and bull trout are not known to be present in Stanley Creek, there would be no effect to occupied habitat or populations. The Proposed Action would reduce the potential for water quality impacts to Stanley and Lake creeks by routing mine water via pipelines to the impoundment decant ponds. Pipeline leaks could result in temporary exceedance of aquatic life criteria for heavy metals in Stanley and Lake creeks. The Agency-Mitigated Alternative would further reduce potential effects by adding a new buried mine water pipeline and automated controls on both the new and old reclaim water pipelines. These pipelines would reduce the potential for toxic metals to impact Stanley or Lake creeks in the event of a pipeline break as compared to the Proposed Action. Under the Agency-Mitigated Alternative, implementing water quality protection measures, including the use of non-metal-leaching rock in stream channels, would further reduce the potential for water quality impacts to fisheries.

The Proposed Action would increase sediment delivery in the short-term through reclamation activities and would not reduce road-related sediment loading because roads would not be treated under this alternative. The No Action Alternative and the Agency-Mitigated Alternative would temporarily increase sediment delivery to Stanley, Ross, and Lake creeks during reclamation activities but would reduce sediment loads and improve fish habitat over the long-term through road treatment. Sediment increases in Ross and Lake creeks would be small relative to existing sediment loads and would not result in measurable effects to cutthroat or bull trout habitat or populations**.** The Agency-Mitigated Alternative would introduce the smallest amount of sediment to stream channels due to design features and mitigation measures such as timing restrictions within RHCAs.

3.7.7 Effectiveness of Mitigation Measures

The No Action Alternative does not include mitigation measures to address the potential for discharged mine water to impact water quality in Stanley and Lake creeks. The Proposed Action would protect Stanley and Lake creeks by discharging mine water to the decant ponds where metals would be attenuated prior to reaching surface water. This approach would protect fisheries from metals toxicity. The long-term effectiveness of this mitigation is dependent on the integrity of the discharge pipeline. The Agency-Mitigated Alternative would address this concern by requiring a new buried pipeline which is sized to meet anticipated flows from the mine. In addition, the pipelines would include automated leak detection mitigation systems. These measures would reduce the chance of mine water discharging into surface water, and therefore, would reduce the potential for metals toxicity to fish.

Under the Agency-Mitigated Alternative, construction timing restrictions in RHCAs would reduce the potential for sediment delivery to stream channels, thus minimizing potential impacts to fish spawning and rearing habitat.

3.7.8 Cumulative Effects

Except for potential pipeline spills, cumulative effects from past, present, and reasonably foreseeable future actions in the watershed would be minimal with regard to fisheries and fishery habitat from the Proposed Action. Mitigation measures associated with the Agency-Mitigated Alternative would address the potential for mine water pipeline leaks and the potential for issues associated with water quality degradation from discharged mine water. Cumulative effects associated with the Agency-Mitigated Alternative would be minimal. The Agency-Mitigated Alternative would not result in degradation of fish habitat and associated RMOs for Ross, Stanley, and Lake creeks.

3.7.9 Regulatory Compliance

The No Action Alternative is consistent with INFISH, as it would not retard the attainment of RMOs. Effects associated with culvert failure and sediment delivery to streams would need to be addressed in the future to promote long-term recovery of the watersheds.

Both the Proposed Action and the Agency-Mitigated Alternative would be consistent with the Forest Plan as amended by INFISH because they would design and implement reclamation activities to promote the long-term ecological integrity of ecosystems, conserve the genetic integrity of native species, and contribute to attainment of Riparian Management Objectives.

3.7.10 Statement of Findings

3.7.10.1 Threatened and Endangered Species

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Affect, but is Not Likely to Adversely Affect*" bull trout. This determination is based on the lack of potential for take (harm or harassment of individual fish) and the lack of effects on occupied habitat. More specifically it is based on the following considerations: 1) Bull trout are not present in Stanley Creek where sediment inputs would occur; 2) BMPs and other mitigation measures,

coupled with the distance to occupied bull trout habitat in Lake Creek, would prevent measurable increases in sediment in rearing habitats; and 3) Bull trout are not known to spawn in Lake Creek. A stand alone biological assessment will be submitted to the USFWS to be consistent with the requirements of the ESA.

3.7.10.2 Critical Habitat

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "May Affect, but is Not Likely to Adversely Affect" bull trout critical habitat. This determination is based on the limited potential for reclamation activities to generate sufficient amounts of sediment to measurably affect rearing habitat in Lake Creek.

3.7.10.3 Sensitive Species

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in *No Impact* for the westslope cutthroat trout. This determination is based on the lack of potential effects to individual fish, populations, and habitat. Because westslope cutthroat trout are not present in Stanley Creek, potential effects would be limited to relatively small temporary increases in fine sediment in Ross Creek. Mitigation measures would reduce the potential for measurable amounts of fine sediment to enter Stanley and Ross creeks during reclamation activities. Fine sediment would not limit fish habitat quality or populations in Ross Creek, and the small temporary fine sediment increases would be negligible. This evaluation constitutes the biological assessment for westslope cutthroat trout.

3.8 Geology

3.8.1 Introduction

This section characterizes the geology in the vicinity of the Troy Mine Permit Area and identifies the potential impacts related to geology for each of the reclamation alternatives. Slope stability of the tailings embankment was eliminated from further consideration in Chapter 2 (**Section 2.3.2**). The geochemical composition of bedrock, surficial deposits, and reclamation materials could affect post-closure water quality and quantity. Water quality issues are further discussed in **Section 3.9**.

3.8.2 Regulatory Framework

The Montana Metal Mine Reclamation Act (MMRA) and the USFS mineral regulations at 36 CFR 228.8 (g) are intended to prevent land and surface water degradation by requiring lands disturbed by mining, whether they are federal, state, or private, to be reclaimed to comparable stability and utility. DEQ and USFS interpret comparable stability and utility to include both geochemical conditions and physical stability.

3.8.3 Analysis Area

The analysis area for this section considers the geologic conditions and surface topography found within the Lake Creek watershed with an emphasis on the vicinity of the Troy Mine Permit Area. The analysis area for mining-induced subsidence is within the perimeter of the mine workings (**Figure 2-3**).

3.8.4 Affected Environment

3.8.4.1 Regional Geology

The Cabinet Mountains and surrounding areas are composed of a thick series of metasedimentary rocks referred to as the Belt Supergroup. These Belt rocks were deposited in a basin about 1,450 to 850 million years ago (Harrison 1972). Originally deposited as a series of muds, silts, and sands, the deposits were metamorphosed to argillites, siltites, and quartzites, respectively.

The Belt Supergroup can be divided into four major groups (**Figure 3-1**). In ascending order, these are the Lower Belt, Ravalli Group, Middle Belt carbonate, and the Missoula Group. Regionally, the Lower Belt is represented by the Prichard Formation which consists mostly of argilites, with some interbedded siltite and quartzite units. It is the lowest formation within the Belt supergroup in this area and is mapped as the thickest at 25,000 feet. The Ravalli Group in this part of the Belt basin consists of, from oldest to youngest, the Burke, Revett, and St. Regis Formations. The Burke is composed primarily of siltites. Its contact with the underlying Prichard Formation is gradational. The Revett Formation is a north- and east-thinning wedge of quartzite, siltite, and argillite. In the Cabinet Mountains area, the Revett is informally divided into lower, middle, and upper members. The lower and upper members are dominated by quartzites with interbedded siltite and argillite; the middle member is mostly siltite with interbedded argillite and quartzite. Facies changes, from coarse to finer sediments, are well documented. The St. Regis Formation is dominantly silty argillite and argillitic siltite.

Regionally, the bedrock has been extensively folded and faulted along generally north to northwest trends. Most of this structural activity was related to complex plate interactions which occurred between 24 and 200 million years ago and which resulted in the rocks being thrust eastward along shallow dipping faults for up to 100 miles (Harrison *et al.* 1983). These faults were superimposed on the existing compressional structures.

Quaternary age deposits are reflected in Pleistocene glacial erosion and deposition of stratified and unstratified sediments. Large areas are covered by glaciofluvial and glaciolacustrine sediments to depths up to several hundred feet. Near Libby, Montana, bluffs of lacustrine silts stand up to 200 feet above the recent flood plain. During recent times these and older materials have been eroded and reworked by stream activity.

There appear to be three ages of events for mineralization for the Belt rocks in this area. Only one is found near the Troy Mine Permit Area, the Precambrian age mineralization event. Potentially the oldest mineralizing event, the Precambrian age migration of solutions through selected formations within the Belt Supergroup (Einaudi 1986), especially the Revett Formation (Sherry 1983), occurred prior to or during lithification (Hayes 1983, Hayes and Clark 1971, Lange and Balla 1993).

Harrison (1972) described this extensive mineralization as the Western Montana Copper-sulfide Belt. Harrison observed that disseminated copper had been found in every formation in the Belt Supergroup, with the exception of the Prichard Formation. He also noted that “ore grade” copper mineralization had been found only in the Revett Formation. Additional studies by Hayes and Einaudi (1986), Hayes (1990),

and Balla (2000) generalized the regional migration of fluids and mineral zoning model for comparison of the Troy Mine deposit and the Rock Creek deposit. Hayes (1983), Lange and Sherry (1983), Clark (1971), Harrison (1972) and Bennett (1984) also concur that the Revett was mineralized on a regional scale. A similar model to Balla's is used by Clark (1971) to explain the consistent mineral zonation of the various stratabound copper and silver deposits on a worldwide basis and within the Belt rocks.

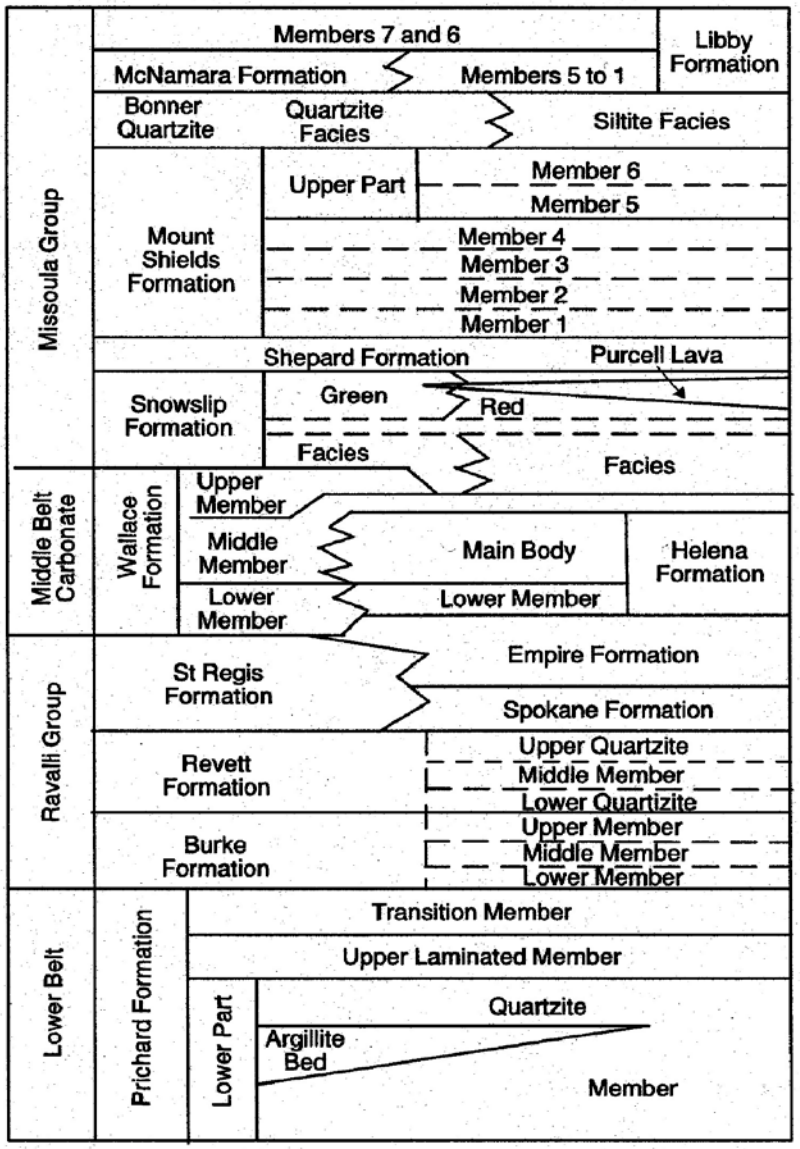
3.8.4.1 Troy Mine Area Geology

Three main items are critical in discussing the current geological make-up of the stratabound copper deposits found in the Revett Formation for this part of Montana, including the Troy Mine: 1) the paleo-environment, which includes the mineralogical make-up and permeability prior to diagenesis; 2) the diagenetic process, which includes burial depth and timing of burial, lithification, silicification and possible faulting creating conduits for remobilization of metals; and 3) the Cretaceous-age thrusting and faulting that fragmented the Revett, creating allochthonous blocks containing these isolated deposits.

Hayes (1983) and Balla (2000) describe the paleo-environment for the Revett within the Troy and Rock Creek deposits as either being a fluvial distributary channel or subtidal system or being a shoreline and barrier bar, upward fining sequence of quartz sands and silts. Hayes (1983) goes on further to describe that the sand, silt, and argillaceous silt bodies of the Revett Formation have apparent sheet geometry. This type of setting is conducive in providing longitudinal high porosity and permeable pathways that existed prior to diagenesis. The zonation (halos) is due in part to the host rock's permeability and porosity prior to or during diagenesis. The mechanism and source of mineralizing fluids is debated among the various authors, but what is noted is that it occurs on a regional scale. Balla (2000) gives a detailed comparison of the Troy deposit to the Rock Creek deposit to demonstrate the regional similarity and consistency over a large area. **Table 3-5** lists various geologic parameters of the ore bodies of both ore bodies.

The following discussion is taken, in part, from Balla (2000) where Balla describes geologic structure and the different mineral zones in the Troy Mine area in the following manner:

The Troy deposit is allocthonous. It originally formed some distance to the west of its present location. Underneath the Troy deposit at some depth is the Moyie thrust fault, which has had at least 1.53-3.08 miles of horizontal shortening (Harrison and Cressman 1993). The eastward thrusting of the Troy deposit occurred between 200 million years and 60 million years ago (Harrison and Cressman 1993). Since 60 million years ago, the deposit has been in its present geographical position. The Troy ore body occurs in the form of a very shallow syncline, with the axis of the syncline plunging gently approximately seven degrees to the south. The syncline formed sometime during the period of the eastward thrusting of the Belt sedimentary rocks (Balla 2000, p. 42).



Modified from Harrison & Cressman 1983
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Figure 3-1. Regional Geology

Table 3-5. Comparison of Troy and Rock Creek Deposits

Geological Feature	Troy Deposit	Rock Creek Deposit
Sedimentary Formation	Upper Revett	Lower Revett
Grade of Ore Body Copper (%)	0.76	0.68
Grade of Ore Body Silver (oz/ton)	1.58	1.65
Ore Zone Thickness (feet) Ore Zone Amount* (% by volume)	**0 – 80** **0.3 – 1.0**	4 – 285 1.0 – 3.0
Mineral Zones Pyrite (FeS_2) Halo Zone Thickness Amount (% by volume)	Regional 0.1 – 0.3	Regional (Variable 10 – 200+) 0.0 – 0.8
Pyrrhotite ($Fe_{1-x}S$)	Locally trace, in pyrite halo zone	Locally trace, in pyrite halo zone only
Galena (PbS) Halo Zone Thickness (feet) Amount (% by volume)	60 – 1,100 0.0 – 0.3	20 – 200 0.04 – 0.08
Chalcopyrite ($CuFeS_2$) Halo Zone Thickness (feet) Amount (% by volume)	0 – very thin 0.3	0 – 50 0.3

Source: Balla 2000

*Includes Bornite (Cu_5FeS_4), Digenite ($Cu_{2-x}S$), Chalcocite (Cu_2S), and Native Silver (Ag). Other minerals are very minor and do not affect this quantity.

Two major faults have affected the Troy ore body, the East Fault and the Cross Fault. In addition, several more faults were encountered underground during mining. The copper-silver mineralization was introduced into the Revett sands prior to lithification and hence prior to the development of joints and fractures. Thus, all joints and fractures are post-copper-silver mineralization in age. Hayes (1983) studied the joints and veinlet mineralization. Observations underground showed that the joint surfaces were all perpendicular to the bedding and all were coated with ore minerals consistent with the adjacent mineralized zone. In many instances, it was possible to see a slight depletion zone immediately adjacent to the mineralized joint surface. Close observation of the mineralized joint surface indicated that the mineralization had only migrated a few inches, at most. These observations were confirmed by Hayes (1983) who also confirmed the post-disseminated age of the mineralization on the joints and fractures. Quartz-sulfide veinlets also occur, generally along the vertical joint planes. The sulfides are the same as

the adjacent disseminated mineral zone. As with the mineralization on the joint surfaces, the sulfides in the veinlets were derived from the adjacent wall rock (Balla 2000, pp 42-43).

Pyrite Halo Zone

The pyrite halo zone extends far beyond the limits of drilling and mapping. Within the quartzite units of the upper Revett, the pyrite content averages less than 0.3 percent by volume. The pyrrhotite occurs only in the pyrite halo zone, and does not occur in the ore body. In the siltite units, the pyrite content averages less than 0.1 percent (Hayes, 1983, p. 105). Because it extends far beyond the Troy ore body, it is suspected that it pre-dates the ore-forming mineralizing event. It may represent the initial mineralizing event on a regional scale and was subsequently followed by the main ore-forming event. The pyrite occurs as disseminated, euhedral grains located in the former pore spaces between the original quartz and feldspar grains of the sand, now quartzite deposit. The size of the pyrite is from a few microns to more than 3 mm in size (Hayes, 1983, p. 105). Quoting from Hayes, 1983, p. 106:

> Minor pyrrhotite has been identified locally within rocks bearing only pyrite as another sulfide. Pyrrhotite occurrence is spotty. Its distribution appears to bear no relation to other ore-stage mineral zone boundaries (Balla 2000, p. 21, p. 26).

Galena Halo Zone

Galena occurs as a much better defined mineral zone near the bornite-digenite ore zone. Galena, similar to the pyrite, occurs in the pore space between the individual sand grains, prior to the lithification and cementing of the sand into a quartzite. The coarser the size of the sand grains and the larger the volume of the pore space between the sand grains, the larger the size of the galena. Hayes (1983) states that the galena content of the quartzites is between 0.1 - 0.3 percent by volume. In the siltites, which had much less permeability and porosity, the galena content is less, and occurs with chlorite. There is no silver associated with the galena zone (Balla 2000, p. 26).

Chalcopyrite Halo Zone

A thin zone of chalcopyrite occurs between the galena zone and the bornite-digenite ore zone. The chalcopyrite may be replacing the original pyrite. Similar to the galena, the chalcopyrite occurs as interclastic grains in between the original sand grains. Hayes (1983) estimates the chalcopyrite content as less than 0.3 percent by volume. There is no silver in the chalcopyrite zone (Balla 2000, p. 28).

Bornite-Digenite-Chalcocite-Native Silver Zone

The bornite-digenite-chalcocite-native silver zone is the ore zone, and constitutes the Troy ore body. The three copper minerals, bornite, digenite, and chalcocite, occur together along with native silver. The bornite-digenite-chalcocite-native silver zone is also the most sulfide rich part of the entire sulfide system. Within the zone of disseminated bornite-digenite-chalcocite-native silver mineralization, the sulfide content increases from about 0.3 percent by volume to almost 1.0 percent by volume (Hayes 1983). The bornite, digenite, and chalcocite minerals occur as intergranular grains adjacent to the detrital quartz and feldspar grains of the original sand. Bornite is the more common mineral. The minerals also occur as clots (balls) within the quartzite and as “ore rods” (water release features), indicating that the mineralization was emplaced into the sands prior to the dewatering and diagenesis of

the sediments. The bornite and digenite minerals that occur between the individual sand grains and that comprise the main ore zone are not leached, as they are encapsulated by the quartz overgrowths that occurred during diagenesis and burial metamorphism. The bornite and digenite ore minerals occur in-between the original sand grains that comprise the Troy ore body. The bornite and digenite minerals were emplaced in-between the sand grains, prior to the Revett formation becoming a rock. Through the geological processes of diagenesis and burial metamorphism, the sands that now comprise the Revett formation were converted to a rock. As diagenesis, lithification, and burial metamorphism continued, quartz overgrowth surrounded the individual ore minerals, sealing the individual bornite and digenite ore minerals (Hayes 1983, Balla 2000, p. 28).

Once the Revett formation had been converted from a sand deposit to a quartzite, subsequent tectonic events slightly remobilized the sulfide grains. This remobilization of the sulfide minerals occurred only near fracture and joint surfaces and consisted of the sulfide minerals adjacent to the fractures migrating into and onto the fracture and joint surfaces. The total movement is minor and is measured as a few centimeters. Various studies at the Troy Mine have shown that about 90 percent of the total metal content of the Troy ore body is disseminated in the quartzite and perhaps as much as 10 percent has remobilized onto fracture and joint surfaces.

Chalcopyrite-Ankerite Zone

There is an unusual zone composed of chalcopyrite and ankerite that appears to be the relatively barren zone that is "behind" the bornite-digenite-chalcocite-native silver zone in the southeastern part of the Spar Lake deposit. The bornite-digenite-chalcocite-native silver zone diminishes, and only chalcopyrite and ankerite with minor bornite occur. The sulfide content has decreased and no silver is present. The chalcopyrite-ankerite zone is not part of the ore zone (Balla 2000, p. 35).

Balla (2000, p. 35) describes the post-sulfide cementation of the ore body in the following manner:

> Diagenesis and lithification continued after the sulfide mineralization was emplaced into the sands of the Revett Formation. Hayes (1983) has documented the successive filling of the pore spaces that remained after the sulfide mineralization was emplaced. The lowest temperature cement was ferroan calcite. This was followed, through an orderly transition, into cementation by magnesium carbonate. It is an image that shows a pore space in the bornite-digenite-chalcocite-native silver ore zone being filled by calcite and then magnesium carbonate. The most important cementation was the development of quartz overgrowths on all of the mineral grains. This process, which volumetrically is the most important, was the result of pressure solution as lithification continued. Pressure solution in a sedimentary rock occurs when the external pressure (lithostatic loads) exceeds the hydraulic pressure of the interstitial fluid. When this occurs, the contact surfaces between the mineral grains increase, thereby reducing the pore space (and permeability) of the sediment, and effectively welding the individual grains together. The result is an impermeable rock with no porosity.

3.8.4.2 Geochemical Composition

Two geochemical processes that should be considered during mine development and reclamation are: 1) acid rock drainage (ARD) and 2) metal leaching (ML) in near-neutral pH environments. Both ARD and ML have the potential to cause serious environmental problems to water quality and aquatic life through the release of acids and metals.

Acid Rock Drainage

ARD is the product formed by oxidation of iron-sulfur minerals such as pyrite and pyrrhotite. The chemical and biological reactions involved in ARD generation are complex. Sulfide minerals are unstable at oxidizing surface environments where they are far from their kinetic equilibrium (the environment from which they were formed). Exposure to air and moisture causes mineral oxidation. Acid generation occurs from the oxidation of iron sulfide minerals to ferrous iron (Fe II), sulfate (SO_4^{2-}), and to sulfuric acid (H_2SO_4). If not neutralized, sulfuric acid will decrease the pH. Complex iron interactions increase the amount of acid that can be generated. Available water transport for the oxidized ingredients and insufficient neutralizing capacity (buffering) of the solution can suppress pH values.

Net acid production results from the relationship between the rates of time dependent reactions of acid-generating minerals and acid-consuming minerals (Saskatchewan Environment and Public Safety 1992). The net generation of acid from a rock or waste rock facility is directly related to the availability of neutralizing minerals. The pH decrease associated with ARD occurs when neutralizing minerals are consumed or become unavailable by secondary mineralization or coatings. A pH decrease will also occur if acidity is produced at a faster rate than alkalinity.

Acid production depends on the amount, type, and depositional environment of sulfides present, on the amount of neutralizing (acid-consuming) minerals available in the rock, on the degree of exposure of these minerals to oxygen, water, and to carbon dioxide, on site conditions, and on other factors. Development of acid drainage is time dependent and, at some sites, may evolve over a period of many years (British Columbia Acid Mine Drainage Task Force 1989, Saskatchewan Environment and Public Safety 1992). Drainage from acid producing rocks typically contains elevated metals that can adversely affect water quality and aquatic life. Bacterial processes are also an important factor in the rate of acid generation. The type of bacteria that participates in sulfide oxidation is dependent on the pH environment which affects the extent of these bacterial processes and the oxidation reaction kinetic rate. At near-neutral pH, acid generation occurs primarily from chemical oxidation of pyrite (or iron sulfide). A minor amount of biological oxidation of these components to sulfuric acid also occurs from sulfur oxidizing bacteria. Near-neutral pH oxidation rates are much slower than reactions that occur at lower pH due to the dominant chemical oxidation reaction. If the neutralizing potential of a rock material is exhausted and pH values are depressed below 4, strongly oxidizing sulfur bacteria will grow and oxidize ferrous iron (Fe II) of pyrite directly to ferric iron (Fe III). Bacterial interactions can accelerate sulfide oxidation and thus increase the rate of acid generation. *Thiobacillus ferrooxidans* is a widely recognized species of sulfur/compound oxidizing bacteria that will grow in low pH environments (below pH 4).

Metal Leaching (ML)

Traditionally, mine waste characterization and management has focused on metal and sulfate release under acidic conditions. While acidic effluents present the greatest potential for environmental damage, there are also cases where elevated metal concentrations have occurred in neutral seepage from "non-acid generating" mine wastes. Certain elements remain relatively soluble at neutral pH and can occur in concentrations above water quality standards. Sulfide oxidation, in combination with neutralization by associated buffering minerals such as carbonates and to a lesser extent feldspars**,** can produce elevated concentrations of metals without a depression of pH. Elevated concentrations of metals can also be a result of the dissolution of secondary, non-oxidative, metal-bearing minerals such as salts, oxides, and sulfates.

Factors Influencing Acid Production, Acid Consumption, and Metal Release Rates

Mineralogic texture and chemistry must be evaluated in testing for ARD and ML potential. For example, sulfides cemented in a silica matrix, or that are large grained and have lower surface area, have slower oxidation rates than a small, high surface area sulfide mineral that is in a porous matrix such as sandstone. Decreased contact with oxygen and water due to cementation results in slower oxidation rates. Temperature, pH, and availability of water and oxygen also greatly affect the ARD and ML potential from a sulfide containing deposit or sulfide waste.

Impurities in a sulfide crystal structure or oxidative differences between iron sulfides (as compared to copper, zinc, or lead sulfides) also will determine oxidation rates. For example, in the absence of ferric iron (Fe III) at pH 2.5-3.0, sulphuric acid will dissolve some heavy metal carbonate and oxide minerals, but has little reactive effect on heavy metal sulfides. However, ferric iron ion is capable of dissolving many heavy metal sulfide minerals, including those of lead, copper, zinc, and cadmium (GARD guide 2008). Iron sulfide, particularly pyrite (FeS_2) and pyrrhotite ($Fe_{1-x}S^4$) are the most common sulfide minerals, and much research is available on the oxidation reaction of these minerals. Pyrite and pyrrhotite are the most common acid-producing sulfide minerals because of their high degree of instability in oxidizing conditions.

Sulfide mineral oxidation is a process that may occur in pH-neutral conditions and is probably the source of the elevated copper in the water that is found in the underground workings in the Troy Mine, which has developed and exposed the bornite-digenite-native silver ore zone. Bornite is a copper-iron-sulfur mineral, and digenite is a copper-sulfur mineral. The underground pillars that support the overlying sedimentary rocks are composed of ore grade bornite-digenite-native silver. In a pH-neutral oxidizing environment, the bornite-digenite-native silver minerals found on fracture and joint surfaces in the rock are oxidized in place to a mixture of various copper oxide minerals. These copper oxide minerals are exposed in the outcrops of the Troy ore body on the south side of Mt. Vernon and underground in the mine workings. The oxide minerals include tenorite, chrysocolla, brochantite, malachite, and cupriferous goethite (Hayes and Balla 1986). These are all secondary copper oxide minerals which occur in areas of low acidity. The bornite and digenite minerals that occur between the individual sand grains and that comprise the main ore zone are not leached, as they were originally encapsulated by the quartz overgrowths that occurred during diagenesis and burial metamorphism.

Subsequent melting snow water, percolating down through the various sedimentary rocks along these same fracture and joint surfaces, partially dissolved the oxidized copper oxide minerals, producing the dissolved copper detected in the underground mine waters. However, it should be noted that in the Troy Mine neither the overlying galena halo zone nor the pyrite halo zone were ever mined and are not exposed.

Moreover, the melting snow water, percolating down through the overlying galena and pyrite halo zones, is not creating acid rock conditions, for sampling of the underground mine waters consistently shows that the pH of the mine waters is 7.2 to 7.4, a near-neutral to alkaline condition.

Kirk (2003) provides a complete discussion of potential ARD and ML for the rock types described in this section.

3.8.4.3 Subsidence

The Troy Mine is a room and pillar mine with overburden thickness ranging from a few feet at the portals to over 1,200 feet. The height of the mine workings varies from about 20 feet to as much as 70 feet. Kenncott Copper Corporation (1970) conducted an evaluation to determine the appropriate room and pillar sizing for the Troy Mine. This evaluation included laboratory tests of rock samples, field tests of scaled room and pillar system, theoretical estimates of stress, and field mapping of structures.

Mining-induced surface subsidence is the lowering of the ground surface as a result of underground mine failure. The potential for surface subsidence depends on a number of factors including overburden thickness; height of the underground excavation; physical properties of the ore and overburden rock masses; and span, or width, of the mined-out area. The Troy Mine uses room and pillar mining, a method in which pillars of ore are left after mining as the primary form of ground support. The mine openings disrupt the established stress field and change the magnitude and direction of the stresses in the surrounding rocks, resulting in permanent stress redistribution. If the redistributed stresses caused a failure in the mine workings, the resulting void would have the potential to propagate to the surface, resulting in subsidence. Surface subsidence would impact vegetation, soil, surface water and groundwater, and slope stability. Subsidence could also impact human safety.

The type of subsidence most likely to occur at the Troy Mine is chimney subsidence. These chimney-shaped failures can be caused by several different mechanisms. At the Troy Mine, two different mechanisms are likely to cause chimney subsidence:

- Plug subsidence: Plug subsidence occurs when there are structural features near a mine opening which create a shear zone that enables the undercut rock to slide downwards under the influence of gravity. Plug subsidence would occur where faults or other large-scale geologic structures are present. This type of subsidence generally propagates upward almost instantaneously. If the mine workings are close enough to the surface, surface expression would occur soon after the initial cave-in of the mine workings.
- Progressive failure in a discontinuous rock mass: In areas where the rock mass is highly jointed and weak, like the rock around the East Fault, the rock above an underground opening can begin

> to unravel. The opening propagates upward as the rock mass unravels over time. Eventually, if the workings are close enough to the surface, subsidence would occur.

Subsidence at the Troy Mine was not addressed as part of the 1978 reclamation plan. At the Troy Mine, there have been two occurrences of surface subsidence, which have been referred to colloquially as "sinkholes" (Call and Nicholas, Inc. 2005 and 2006, Tetra Tech 2006) (**Figure 2-3**). Rock mass rating (RMR) is a method used to determine the overall integrity of the rock mass and to provide guidelines for engineering design and ground support. RMR is based on several parameters which can be categorized as rock strength, jointing, and groundwater inflow. RMR can range from 0 to 100, with a rating between 80 and 100 indicating a rock mass which requires little support.

Both surface subsidence occurrences are located in the rock mass associated with the East Fault, a highly fractured area with an estimated RMR of approximately 20 (Tetra Tech 2006). An RMR of 20 puts the rock mass along the East Fault in the "very poor" class, which is the lowest of five classes. The mine rock mass not associated with the East Fault, in general, has an RMR of 50 to 90. This range spans the top three of the five classes, from "fair" to "very good."

The existing subsidence at the Troy Mine occurred in the weak rock mass along the East Fault. Given the RMR values of this area, it would be reasonable to expect that the East Fault rock mass would be the most likely area to encounter future subsidence.

After the 1978 EIS, numerous subsidence studies on projects in the same geologic units have used the Troy Mine as an analog (Redpath (1991); Agapito (1991); Camp, Dresser and McKee, Inc. (1989); and ASARCO (1994). These reports support the conclusion that a properly designed room and pillar mine has a low likelihood of causing subsidence. A report by Tetra Tech (2006) states:

> At hard rock room and pillar mines… surface subsidence is not an inevitable consequence of mining. Provided that the mine is properly designed to prevent subsidence, the potential for subsidence to occur is minimal. This view is shared by many experts in the field of subsidence, including Peng (1992), Whitaker and Reddish (1989), Agapito (1991), Golder Associates (1989), and Cullen and others (2002). Room and pillar mining is well established as a means to significantly reduce or prevent surface subsidence.

3.8.5 Environmental Consequences

Numerous reclamation alternatives were reviewed and evaluated to determine geologic impacts and to ensure reclamation success within the analysis area.

Methods for assessing geologic impacts to reclamation success generally include analyzing how each alternative addresses the effects of the following issues:

- Geochemical composition limits on plant growth due to sulphur content, metal concentrations, or other parameters in the development rock, tailings, or reclamation materials;
- Mining-induced subsidence; or
- Altered local topography.

Information used for this analysis is taken from the various studies, reports, and reviews of environmental documents on the Troy Mine and on other mine projects in the area.

The geologic materials at the Troy Mine have little or no potential for ARD but have some potential for near-neutral metal mobility (BC Research 1976, Kirk 2003). Previous studies have shown that the infiltration of water through waste rock fill found at the Troy Mine and other mine sites with similar geology in the area does not degrade groundwater or surface water. Oxidation of the mineral pyrite is the main reaction which is responsible for acid production and metals leaching at mine sites. The Troy Mine ore body is composed of non-acid producing copper sulfide minerals (digenite, bornite, and chalcocite) and has a low pyrite content (Balla 2000). The total sulfur content of the ore body is low, ranging from 0.3 percent to 1.0 percent by volume. In addition, iron and magnesium carbonates present within the ore body act to neutralize any acid that may be generated.

The potential environmental consequences from surface subsidence event include: slope instability; loss of vegetation; erosion and soil loss; changes in the groundwater regime; increased sediment loading in adjacent streams; and changes in surface water drainage.

Proposed reclamation of subsidence features was reviewed and evaluated in order to ensure reclamation success within the analysis area by alternative. The following parameters were used to assess reclamation success:

- Post-reclamation stability of steep slopes;
- Erosion control during establishment of vegetation;
- Success of revegetation;
- Mitigation of impacts to ground and surface water; and
- Mitigation of impacts to human safety.

3.8.5.1 No Action Alternative

Geochemical Composition

Development rock, ore, and tailings have a low acid-producing potential but have some residual metal content. Under the No Action Alternative, reclamation of the patios would include some regrading to achieve the final contours needed for drainage and then covering the areas with 12 inches of stockpiled lacustrine and volcanic ash-derived soil material hauled from the tailings impoundment area or borrow from the USFS borrow site. Revegetation would include seeding a mixture of herbaceous plants. Over time, trees and shrubs would be expected to volunteer from the surrounding slopes. This type of reclamation activity would minimize the risk of near-neutral metal mobility and erosion from the development rock.

Potential issues related to nitrates from blasting residues in waste rock or tailings are discussed in **Section 3.9**.

Subsidence

In hard rock mines, it is difficult to estimate how far subsidence would propagate toward the surface, but a conservative estimate is that the maximum height would be approximately 10 times the height of the excavation (Tetra Tech 2006). The two subsidence features at the Troy Mine are located where the overburden thickness is between 270 feet and 320 feet (Tetra Tech 2006). Based on these reports, the Agencies conclude that any future subsidence would be most likely to occur along the East Fault zone under similar conditions.

Genesis (now Troy Mine, Inc.) made efforts to reclaim the existing subsidence features in 2005 and 2006. In 2007, Genesis applied for Minor Revision 07-001 to Operating Permit 00093 to address one future subsidence occurrence. In this minor revision application, Genesis concluded that "the only area with any potential for a similar sinkhole event to occur is between the two reclaimed sinkholes on private land," (letter from Genesis to DEQ dated February 14, 2007). The reclamation bond was increased to include the cost of reclaiming one additional subsidence feature. None of the parameters used to assess reclamation success were adequately addressed in Minor Revision 07-001.

The first feature was about 50 feet in diameter, 20 feet deep, about 0.1 acre in size (Tetra Tech 2006), and located on a moderate slope. Genesis (now Troy Mine, Inc.) backfilled the depression with borrow material to blend with the surrounding slopes, covered the disturbance with growth medium, and seeded in 2006 with the approved mix. During the Agencies' inspection in September of 2010, the site appeared to be stable, showed no evidence of erosion, and had established vegetation (DEQ 2010). The Agencies concluded that the reclamation has minimized impacts to surface and groundwater and has minimized impacts to human safety.

The second subsidence feature was oblong in shape, approximately 100 by 135 feet, 20 to 30 feet deep (Tetra Tech 2006), and located on a steep slope. Genesis (now Troy Mine, Inc.) did not backfill the depression, but used an excavator to push the sides into the depression in an attempt to blend with the surrounding slopes. The headwall remained. No growth medium was applied, and the area was seeded in 2006 with the approved mix. During the September 2010 inspection, the existing slope did not appear stable, material continued to slough, erosion was apparent over most of the disturbance (including continued erosion up the slope), and the top of the slope was eroded and undercut. Vegetation had not established enough to prevent erosion; moreover, sediment had washed downslope into the drainage ditch along the road and through the culvert to the other side of the road (DEQ 2010). The Agencies concluded that Troy Mine, Inc. has not minimized impacts to surface and groundwater or to human safety and has not returned the area to comparable stability and utility. Overall, reclamation methods previously used by Troy Mine, Inc. proved insufficient for larger subsidence features and steeper slopes.

Topography

Under the No Action Alternative, reclamation activities for the final mine closure would continue under the specifications of the 1978 Reclamation Plan. Mine adits would be plugged with concrete. Under the 1978 Reclamation Plan, regrading of the mine and mill area would promote storm water drainage and revegetation efforts. Regrading in the No Action Alternative would not remove the man-made appearance of the portal patios and mill area.

Reclamation of the tailings impoundment surface would start with regrading to the final contours needed for drainage to the northeast corner of the impoundment surface. Then the area would be covered with 18 inches of salvaged lacustrine and volcanic ash-derived soil material from the soil stockpile between the tailings impoundment and Lake Creek. Because the embankment has already been reclaimed, it would not be regraded at closure. Regrading of the surface would direct runoff away from the embankment but would not return the tailings impoundment area to pre-mine conditions. Revegetation would soften the man-made appearance, but the tailings impoundment would always resemble a terrace above Lake Creek.

3.8.5.2 Proposed Action

Under the Proposed Action, reclamation activities on the Troy Mine Permit Area would follow the specifications of the revised plan (Genesis 2006) (**Table 2-1**). Development rock would be used to backfill from portals 30 feet into the adit and would be placed as tightly as possible against the roof. Rock remaining after adit plugging would be graded against the sides of the slopes to form a wedge. The portal patios would be regraded to slope away from the mine. Two concrete, non-hydraulic plugs are proposed for the Service and Conveyor adits. Under the *2006 Revised Reclamation Plan*, regrading activities proposed in the mine and mill areas as part of the No Action Alternative would be included within the Proposed Action. Additional grading of the portal patios, drainages, and borrow sites would promote better slope stability, storm water drainage, erosion resistance, and better revegetation potential.

Geochemical Composition

The development rock, ore, and tailings all have low acid producing potential but have some residual metal content. Regrading and revegetation would be similar to the No Action Alternative and would minimize the risk of near-neutral metal mobility and erosion from the development rock.

Subsidence

Mining-induced subsidence would be dealt with as in the No Action Alternative. The effects of the Proposed Action would be the same as the No Action Alternative.

Topography

The Troy Mine Revised Reclamation Plan (Genesis 2006) summarizes reclamation work completed on the impoundment to date and provides figures associated with soil stockpile locations and volumes for use at final reclamation.

Under the Proposed Action, the tailings impoundment surface as deposited during operations would remain largely unchanged (Genesis 2006, Exhibit E). Minor regrading may be needed to relocate the final decant ponds. Storm water could still run off the tailings surface into the decant ponds, which may decrease the permeability of the decant ponds over time.

The topographic effects of the Proposed Action would be similar to the No Action Alternative.

Reclamation of the tailings impoundment surface would include minimal regrading to achieve the final contours needed for drainage to the decant ponds and then covering with 18 inches of glacial outwash from the borrow sites east of the impoundment. Because the embankment has already been reclaimed, it would not be regraded at closure. Regrading of the surface would direct runoff away from the embankment. Regrading would not return the tailings impoundment area to pre-mine conditions; however, revegetation would soften the man-made appearance of the impoundment. The tailings impoundment would resemble a terrace above Lake Creek.

3.8.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and further amended to address issues identified during the public scoping and agency review processes (**Table 2-1**).

Geochemical Composition

The effects of regrading and revegation under the Agency-Mitigated Alternative would be similar to the other alternatives as far as reducing the risk of near-neutral metal mobility and erosion from the development rock. In addition, under the Agency-Mitigated Alternative, all drainage channels would be built from imported rock rather than from mine development rock. This approach would further minimize the potential for near-neutral metal mobility.

Subsidence

As discussed under the No Action Alternative, efforts to date to reclaim the second subsidence feature have not been adequate. Based on the 2010 inspection, the Agencies would require Troy Mine, Inc. to properly reclaim the second subsidence feature to meet the parameters for reclamation success under this section of the EIS.

Minor Revision 07-001 is inadequate to address reclamation of future subsidence events, particularly those occurring on steep slopes. Under the Agency-Mitigated Alternative, the following mitigations would be required, as appropriate, to address parameters used to assess reclamation success:

- Post-reclamation stability of steep slopes;
    - Excavate the upslope end of the disturbed area to lay the slope back to a grade mild enough to minimize erosion. This would create further disturbance, but would stabilize the slope and prevent headward erosion.
    - Recontour the disturbed area by using a combination of grading and backfilling to blend into the adjacent undisturbed area. The recontoured area would be free-draining, prevent ponding, and minimize infiltration.
    - Terrace across the slope to key in the fill material.
    - Recontour or back fill additional disturbed areas related to accessing the site.
- Control erosion during establishment of vegetation;
    - Erosion control would include BMPs on the subsidence features, and any additional disturbance necessary to reclaim the feature, as approved by the Agencies.

- On steep slopes or drainageways, an erosion control mat would be keyed in on the upslope end to discourage water flow beneath the mat. The mat would provide stability and help control erosion while the vegetation has time to establish.

- Success of revegetation;
  - Use rocky growth medium with wood-based organic amendment and soil testing to determine needs for fertilizer and mulch.
  - Use an aggressive cover crop to help control erosion until perennial plants are established.
- Mitigation of impacts to ground and surface water; and
  - Install a drainage ditch above the subsidence feature to divert surface runoff.
  - The mitigations listed above would limit surface and groundwater impacts.
- Mitigation of impacts to human safety.
  - Signs and fences would be used, as necessary, until reclamation is complete.
  - The mitigations listed above would limit impacts to human safety.

Topography

The Agency-Mitigated Alternative contains alterations to the mine and mill area regrading plan to safely pass storm water or any potential mine water discharge in the future through the mill pad area to Stanley Creek (see **Appendix E**). The additional grading of the mine and mill areas under the Agency-Mitigated Alternative would achieve a higher level of erosion resistance, storm water control, and revegetation potential to promote soil stability than would the Proposed Action.

Grading of the impoundment surface would be similar to the Proposed Action. The surface would slope towards the relocated decant ponds. A berm would be built to prevent storm water and sediment from entering the decant ponds (see **Appendix C**). Effects would be similar to the Proposed Action.

Effects of the Agency-Mitigated Alternative on topography would essentially be the same as the other alternatives.

3.8.6 Resource Impact Summary

In all three reclamation alternatives, the geology and geochemical composition would have minimal impact on revegetation success. In general, the effects of geologic materials on reclamation in the three alternatives would be minor.

Under all three reclamation alternatives, another subsidence event could occur.

Similarly, all three alternatives would provide a net positive effect to local topography through increased soil stability, erosion resistance, and storm water control. Regrading would not return the mine area or the tailings impoundment area to pre-mine conditions, but revegetation would soften the man-made appearance. The portal patio slopes would resemble talus slopes, and the tailings impoundment would resemble a terrace above Lake Creek.

3.8.7 Effectiveness of Mitigation Measures

Under the Agency-Mitigated Alternative, no additional measures would be required to mitigate geochemical impacts to reclamation success. The use of rocky glacial and lacustrine and volcanic ash-derived soils as growth media would minimize root contact with mined materials. This would effectively minimize the potential effects of plant uptake of metals from the development rock and tailings.

The Agency-Mitigated Alternative would use the most appropriate technology currently available. Such technology would include engineering and reclamation practices that have been proven effective to stabilize soils, minimize erosion, and to limit infiltration into mined-materials containing metals.

3.8.8 Cumulative Effects

Cumulative indirect and direct effects are anticipated to be minimal with regard to geologic materials. There would be few anticipated geologic impacts associated with any of the alternatives when combined with potential effects from past, present, or reasonably foreseeable future actions in the Lake Creek watershed.

3.8.9 Regulatory Compliance

The No Action Alternative does not meet the requirements of the MMRA and the USFS mineral regulations because it does not address past or future subsidence. Efforts by Troy Mine, Inc. to date have not adequately mitigated impacts from subsidence.

The Proposed Action would not be consistent with MMRA and the USFS mineral regulations in that it does not provide additional mitigations for management of subsidence.

The Agency-Mitigated Alternative would be consistent with MMRA and the USFS mineral regulations because it provides appropriate mitigations for subsidence. It also minimizes potential impacts from use of development rock in channel construction by using imported rock instead of development rock.

3.9 Hydrology

3.9.1 Introduction

Hydrology is the description of the water resources of an area, including groundwater, surface water, the interaction between them, and overall water quality. This section characterizes the existing hydrology within the three sub-watersheds that surround the Troy Mine Permit Area. Hydrology could be affected by reclamation activities or long-term water quality of mine discharges. Discharges could arise from the mine adits and workings or seepage from the tailings impoundment. This section identifies potential impacts to these resources under each of the reclamation alternatives.

3.9.2 Regulatory Framework

The regulatory framework for this section includes:

- The Federal Clean Water Act.

- The Montana Water Quality Act (75-5-101, *et seq*., MCA).
- Forest Service Manual 2532 and FSH 2509.22 R1/R4 Amendment, including Manual and policy updates (USFS 2009a).
- The Kootenai National Forest Plan - 1987.
- Executive Order 11990.

The Federal Clean Water Act provides for the restoration of the Nation's water (33 USC 1251 *et seq.*). The U.S. Environmental Protection Agency (EPA) delegated most of the implementation of the Clean Water Act (CWA) to the State of Montana. Designated beneficial uses of Montana's state waters include recreation, water supply, fisheries, aquatic life, and wildlife. The CWA requires that the State of Montana establish priority ranking for waters on the Section 303(d) List of impaired waters and to develop Total Maximum Daily Loads (TMDLs) for these waters. TMDLs are one of many tools in the CWA to help achieve the Act's main objective to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (CWA section 101(a)). A federal judicial order and Montana Law (MCA 75-5-703(3)) both require that "all necessary TMDLs" be completed by May 5, 2012, for water bodies on the 1996 303(d) List.

Section 303(d) of the CWA requires the listing of water bodies and outlines a program for addressing water body segments with impairments that preclude them from meeting standards designated for beneficial uses. These impairments to water quality include both point and non-point sources. Under United States Department of Agriculture (USDA) Non-point Source Water Quality Policy Directive 9500-007, the USFS agreed to become a Designated Management Agency for NFSL in Montana. The USFS, as a Designated Management Agency, is responsible for conducting land management activities that maintain or enhance the water quality within NFSL (USDA 1986).

Section 313 of the CWA requires the USFS to adhere to the goals set forth in the state surface water quality laws and regulations. Section 319(k) of the CWA, in conjunction with Executive Order 12372, state that federal agencies shall accommodate state concerns regarding the consistency of agency projects with the state non-point source pollution management program. DEQ is the lead agency for development of Water Quality Plans/TMDLs for 303(d)-listed water bodies.

The Clean Water Act regulates discharge of dredged or fill material into any water of the U.S., including wetlands (33 USC 1344) and provides the regulatory framework for assessing impacts to water quality. Section 404(b)(1) guidelines prohibit discharges of dredged or fill material into waters of the United States, including wetlands, if a practicable alternative to the proposed discharge exists that would have less adverse impacts on the aquatic ecosystem (provided that the alternative does not cause other significant adverse environmental impacts) (40 CFR 230(a)).

DEQ administers the **Metal Mine Reclamation Act** (MMRA) under which the Troy Mine has applied for amendments and revisions to its Operating Permit #00093. One of the MMRA's purposes is to ensure that the usefulness, productivity, and scenic values of all lands and surface waters affected by mining and exploration receive the greatest reasonable degree of protection and that the lands are reclaimed to beneficial uses. The act and its rules define the steps to be taken in issuing an operating permit or

revising an approved operating plan for reclamation of an applicant's proposed or modified mine operation. Pursuant to Section 82-4-336(10), MCA, DEQ may not issue a permit or approve an amendment to a permit unless the reclamation plan prevents the pollution of air or water. In addition, the reclamation bond that a mine operation must submit before DEQ issues a permit or approves a permit amendment must be sufficient to ensure compliance with the Montana Water Quality Act (WQA).

The WQA provides a regulatory framework for protecting, maintaining, and improving the quality of water for beneficial uses. Pursuant to the WQA, DEQ has developed water quality classifications and standards, as well as a permit system to control discharges into state waters. Mining operations must comply with Montana's regulations and standards for surface water and groundwater.

All federal agencies are obliged to meet state water quality standards that protect the beneficial uses of lakes, rivers, streams, and wetlands.

The Forest Service Manual. The basis of the USFS's non-point source pollution control strategy stems from the USFS's non-point source policy (USDA 1986). In implementing non-point source pollution controls, the USFS will apply its non-point source strategy to all activities on NFSL that may impair water quality. USFS's non-point source strategy includes integrated project planning that considers temporal and spatial distribution of impacts, identification of priority restoration needs, implementing restoration, implementing best management practices (BMPs) on all ground disturbing activities, monitoring, and adjusting BMPs, or mitigating actions as needed to ensure that Montana Water Quality standards are met and designated beneficial uses of water are protected (DEQ and USFS 2008).

Executive Order 11990 requires that federal agencies ensure that their actions minimize the destruction, loss, or degradation of wetlands. It also assures the protection, preservation, and enhancement of the nation's wetlands to the fullest extent practicable during the planning, construction, funding, and operation of transportation facilities and projects.

3.9.3 Analysis Area

The project area lies within the KNF immediately west and north of Bull Lake and encompasses a major portion of the Stanley Creek drainage and a portion of the Lake Creek drainage. The analysis areas for this section are the sub-watersheds of the Lake Creek watershed that include the following mine facilities: Stanley Creek (mine and mill facilities and mine-related roads), Ross Creek (South Adit and mine-related roads), upper Lake Creek (tailings impoundment), and lower Lake Creek (monitoring site) (**Figure 3-2**). No mine facilities are located in the Keeler Creek sub-watershed, so it will not be discussed further.

The analysis area for cumulative effects is the Lake Creek watershed, which is the extent of potential water-related effects.

3.9.4 Affected Environment

3.9.4.1 Surface Water

The 1978 EIS for the Proposed Plan of Mining and Reclamation contains general baseline information on the entire Lake Creek watershed. This section focuses on the surface waters affected by reclamation actions identified in the analysis area, namely the mine and mill facilities, the tailings impoundment, and the waters potentially affected by seeps and springs in the mine workings area.

Ross Creek

Ross Creek is a cobble/boulder stream with naturally high peak flows due to precipitation intensity, steep topography, and rocky slopes. Natural debris flows occasionally occur above tree line or in burned areas and contribute to high sediment loads in Ross Creek during flood events. Large debris jams are common and cause relatively frequent channel adjustment and migration. However, the lowest reach of Ross Creek has intermittent streamflow and is usually dry for part of the year.

Elevated peak streamflows from timber management is not generally measurable in streams the size of Ross Creek (Grant *et al.* 2008). The Ross Creek watershed also has a high proportion of roadless areas, which have never been timber harvested and which make management-related peak flow increases highly unlikely (KNF 2010).

During the 1960s, numerous roads were built on Mt. Vernon in the lower Ross Creek watershed for exploratory drilling and development of the South Adit. Portions of National Forest land on Mt. Vernon were patented in 1978 and subsequently the timber was harvested. Evidence from historic aerial photos indicates that road development, timber harvest, and mine development work increased the frequency of slope failures on Mt. Vernon. At least five slope failures have occurred since the 1960s, with three resulting in debris torrents. The most recent event was in November of 2006 when a slope failure caused a debris torrent that delivered considerable fine sediment to Ross Creek. Overall, these events have scoured two tributary streams to bedrock and left extensive bedload deposits along the channels.

The effects of these events on the mainstem of Ross Creek appear to be fairly minor because the alluvial fans at the bases of these drainages prevented most of the larger material from reaching Ross Creek. Most of the fine sediment that reached Ross Creek probably has been transported down to the south end of Bull Lake. The lake acts as a settling basin and substantially reduces the sediment load that Ross Creek contributes to Lake Creek.

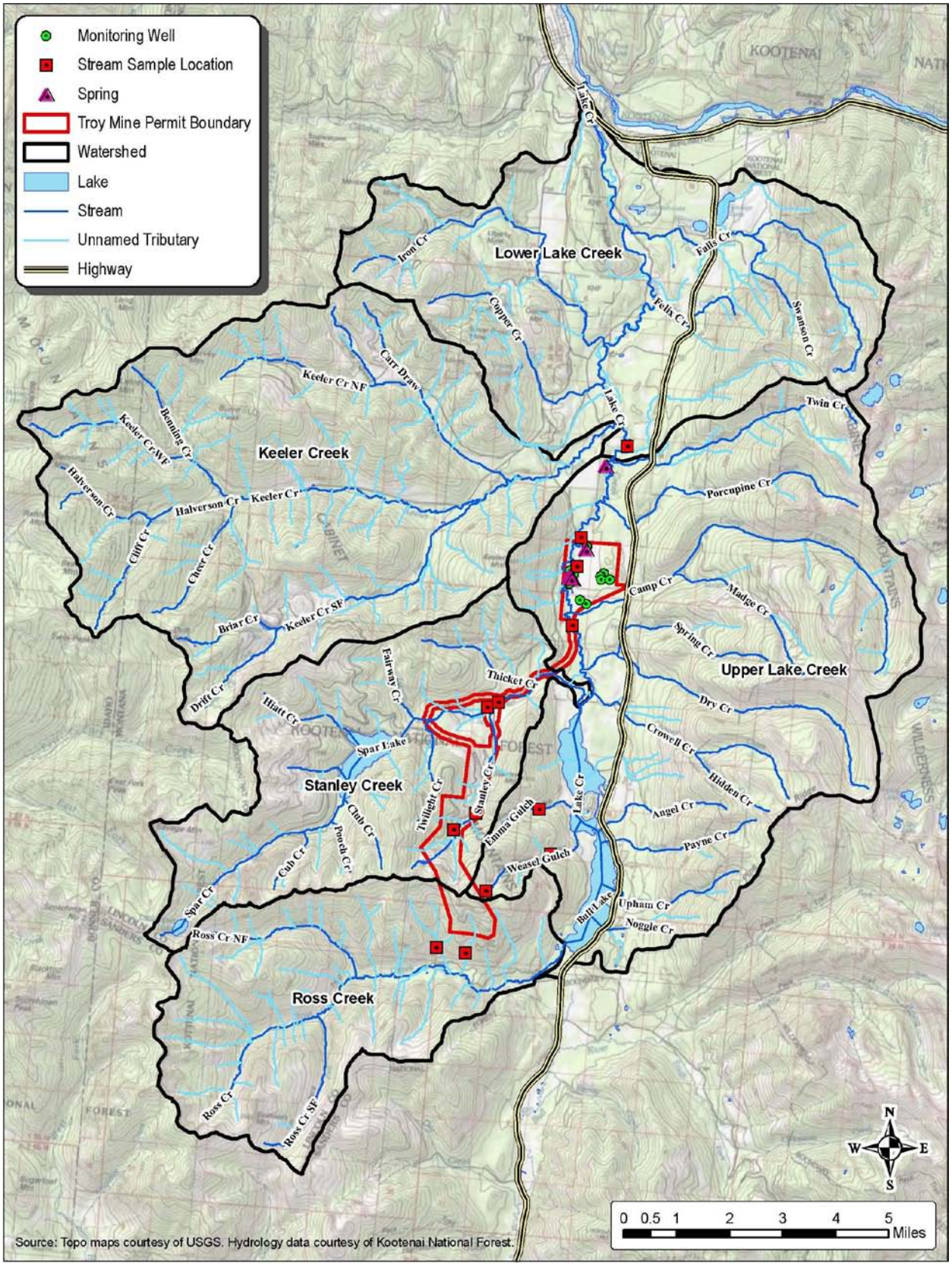


Figure 3-2. Surface Water

Development rock from construction of the South Adit was sidecast along an approximately 200 foot length of a tributary of Ross Creek. The sidecast material has forced the stream into the opposite bank, resulting in erosion at high flows. However, this site contributes little sediment to Ross Creek because of the large depositional area in the Ross Creek valley bottom.

Stanley Creek

For purposes of this analysis, Stanley Creek is divided into two segments: upper Stanley Creek is defined as the reach of Stanley Creek above its confluence with Fairway Creek; and lower Stanley Creek refers to the stream below the confluence. Upper Stanley Creek is a steep cobble/boulder stream that readily transports sediment downstream. It is perennial in the upper reaches and intermittent in the lower reaches. Flow is largely snowmelt-driven, and flow along the intermittent reach down to lower Stanley Creek generally occurs only for two to three months in April, May, and June. Flows in upper Stanley Creek are quite responsive to large rain or rain-on-snow events.

Natural peak flows in upper Stanley Creek have been increased by additional runoff from timber harvest, road construction, and from paving of the mill site. Higher peak flows generally result in more sediment transport. The maximum peak flows resulting from logging and mining activities probably occurred in the early 1980s when the mill site storm drainage system was connected to Stanley Creek. Since then, peak flows have dropped because the mill site drainage is no longer connected to Stanley Creek, and headwater areas have gradually reforested.

The increases in peak streamflow from more recent timber harvest (KNF 2001), planned timber harvest, and from ecosystem burning (KNF 2010) have and would remain below Forest Plan guidelines. This means that the range of peak streamflow expected is acceptable on the basis of channel conditions and would not impair beneficial uses.

Streamflow in lower Stanley Creek comes primarily from Fairway Creek, which emanates from Spar Springs. The flow from the springs is not subject to the typical high peaks associated with storms and spring runoff. As a result, lower Stanley Creek has a particularly stable channel condition. Trees remain where they fall into the stream, and bedload sediment migrates downstream slowly. The substrate is dominated by sands and small gravels rather than by coarse gravels and cobbles. Water clarity is exceptional most of the year.

The upper Stanley Creek watershed has three tributary streams. Below the west ventilation adit, the middle tributary of Stanley Creek was partially buried by coarse rock, which was sidecast during the initial mine development. The stream discharges through a culvert onto the talus slope and flows about 200 feet down to the original stream channel. The stream channel area is unvegetated for approximately another 200 feet below the toe of the sidecast material. While some erosion may be occurring along the unvegetated steep slope adjacent to the sidecast area, this site overall is probably a minor source of sediment to Stanley Creek.

Management activities that have increased sediment supply to upper Stanley Creek include road construction and timber harvest in the 1960s and 1970s, adit development in the 1970s, a tailings spill

from the pipeline below the mill site in 1981, sediment washing from the mill pad area during the 1980s, on-going erosion from NFSR 4626 above the mill site, and erosion below the two 48-inch culvert outlets located below the mill site. Most of this sediment is probably transported fairly rapidly down to lower Stanley Creek and to Lake Creek. Implementation of BMPs has reduced sediment contributions from the mill site and from NFSR 4626. Sidecasting of snow containing sand from road plowing operations continues to contribute fine sediment to lower Stanley Creek where NFSR 4626 is close to the stream.

In 1996, a slump occurred in the fill slope on NFSR 4626 between the mill site and the North Portal area resulting in a debris avalanche that buried approximately 200 feet of upper Stanley Creek with landslide debris. After reaching Stanley Creek, the slide became a debris torrent that caused major scour and sediment deposition down to the creek's confluence with Fairway Creek. Sediment deposited during this event is still evident throughout upper Stanley Creek and is a chronic source of sediment during peak flow events. It is likely that much of the sediment resulting from the 1996 slope failure is now deposited in lower Stanley Creek.

Heavy equipment was used to do channelization work in upper Stanley Creek following flood events in 1980 and in 1996. This work left an unnaturally incised channel that was vulnerable to erosion in subsequent high runoff events.

In October of 2009, a leak in a tailings pipeline spilled tailings into Thicket Creek (a tributary to Stanley Creek) about 150 feet above its confluence with lower Stanley Creek. Approximately 40 tons of tailings solids flowed out of the pipeline during the course of the spill and much of this material settled in Thicket and Stanley creeks as a layer of cohesive silt. Some of the material was suspended in the stream and carried down to Lake Creek. Cleanup operations removed most of the tailings from Thicket Creek. Difficult access and high water velocities made it impossible to remove most of the tailings that had reached Stanley Creek. Tailings are presently visible in the slower water areas downstream from the confluence with Thicket Creek.

Lake Creek

Lake Creek is a meandering, low-gradient stream with a wide floodplain. It flows through deep deposits of fine-grained soil. Trees and other woody debris frequently form jams that cause secondary channels and main channel migration. This on-going channel adjustment is the initiating process that causes adjacent bank and slope erosion. Tributary streams also contribute sediment from natural processes. The dominant substrate size on the bars is gravel and cobble. Lake Creek is perennial for its entire length.

Elevated peak flows from management activities are not generally measurable in streams the size of Lake Creek (Grant *et al.* 2008). Upper Lake Creek watershed also has a high proportion of roadless and wilderness areas that make management-related peak flow increases highly unlikely.

In upper Lake Creek, human-caused sediment sources appear to be primarily from road failures from timber harvest-related slope failures in the Camp Creek watershed and from various activities related to timber harvest and mine operations in the Stanley Creek watershed as discussed above. In 1984, a tailings spill released an unknown quantity of tailings into Lake Creek (EPA 1992). After 26 years, it is likely that most of these tailings have been flushed from Lake Creek into the Kootenai River and are no longer impacting the substrate of Lake Creek.

The tailings spill into Thicket Creek on October 1, 2009, resulted in short-term turbidity from a plume of suspended tailings flowing down to Lake Creek. "Copper and lead exceeded chronic water quality criteria for a short period (not more than two or three days) while the total suspended sediment values were high, but quickly returned to baseline conditions as tailings materials settled out and were back to baseline conditions in Lake Creek by October 3rd. There likely were no toxic effects due to the short duration at chronic levels" (Hydrometrics 2009). Concentrated deposits of material from this spill were not apparent on the stream bottom, and there appear to have been no long-term sediment effects to Lake Creek.

Some of the sediment entering Lake Creek is deposited on the channel bottom and gradually works its way downstream. There has been no systematic stream channel morphology monitoring in Lake Creek, so it is unknown whether there have been recent changes in channel conditions due to sediment deposition. The proportion of human-caused sediment to natural sediment is unknown.

Water Quality Sampling

A sampling program was implemented to determine baseline conditions for surface waters (DSL and KNF 1978, page 107) for analysis in the 1978 Draft EIS. Appendix G of the 1978 Draft EIS (Volume 2) presents the surface water quality data collected. Typical water quality data were extracted from these files and presented in the Draft EIS as Table II-8 (DSL and KNF 1978, page 111). These data indicate that baseline water quality met water quality standards applicable at that time.

The investigation was rigorous in areas of most probable impact (*i.e.*, Stanley and upper Lake creeks) and cursory for other water bodies (DSL and KNF 1978, page 110). Water quality parameters evaluated included specific conductance, nutrients, temperature, metals (iron, zinc, and copper), and turbidity. Water quality was reported in the Draft EIS as being:

> …very similar in all surface waters in the drainage with only small areal or seasonal variations. Water quality is a direct result of the quality of precipitation with some addition of ions from rock/water interactions. Water quality in the Belt Series Precambrian rocks usually is excellent and quality in this drainage is exceptionally high. Biological productivity is generally low in these cold and pure waters and the systems are poorly buffered. This means that small inputs of acid or alkaline wastes can alter pH. Similarly, wastes added to these streams usually have a greater impact than in streams with higher concentrations of dissolved minerals. These streams, thus, are sensitive to changes, and can easily be impacted (DSL and KNF 1978, page 110).

Stanley and Lake creeks are on the list of impaired waters for the State of Montana (**Table 3-6**).

Table 3-6. Water Quality Impaired Streams (2008 Water Quality Integrated Report, DEQ)

Stream	Aquatic Life	Probable Cause	Probable Source
Lake	Partial support	Physical substrate	Natural, mine tailings
		Nitrate/nitrites	Natural
		Sediment, siltation	Forest roads
Stanley	Partial support	Copper	Mine tailings
		Nutrient/Eutrophication Biological Indicators	Streambank Modifications/Destabilization

Copper and antimony are constituents of concern because they have exceeded water quality standards for surface water in the mine water (**Table 3-7**). TMDLs are scheduled to be completed for all impaired water bodies in Montana by 2012. Stream conditions in Stanley and Lake creeks will be evaluated for water quality impairments. If one or both streams are impaired, TMDLs will be developed for the constituents of concern. Nutrients, including ammonia and nitrate plus nitrite, are also a concern because they are present in mine water from blasting residue. Surface water quality has been monitored at Stanley and Lake creeks since 1975 (SRK 2005). Additional water quality monitoring sites were added in 1986, as was an aquatic biological monitoring program. The program included macroinvertebrate monitoring and water quality and flow monitoring three times per year (Parametrix 2009).

Manganese and iron have also been sampled and often exceed the secondary drinking water guidelines in monitoring wells near the tailings impoundment and in the toe ponds. This is regarded as the natural condition for this aquifer because similar levels of iron and manganese were documented in monitoring wells installed in 1980, prior to construction of the tailings impoundment. The probable source is dissolution of these metals from glacial lake silts and from other sediments that comprise the aquifer. Moreover, natural springs containing high levels of iron are observed throughout the Lake Creek valley.

Nitrates are elevated in mine water due to residues from blasting compounds. During mine shutdown nitrate plus nitrite levels have ranged from 0.3 to 1.1 mg/L as nitrogen (**Table 3-7**). The mine was shut down from 1993-2004 as described in Section 1.4.1. Based on the limited interim shutdown data collected between 2000 and 2003, nitrate levels averaged 0.91 mg/L as nitrogen, less than the operational average of 4.88 mg/L (**Table 3-7**).

Table 3-7. Dissolved Water Quality Concentrations for Mine Discharge Water

		Antimony mg/L	Copper mg/L	Zinc mg/L	Ammonia (NH_3) mg/L	Nitrate + Nitrite mg/L	TDS mg/L
WQ Standard		0.006	0.00285	0.037	3.58	Narrative	NA
During Shutdown (2000-2003) Metals measured as dissolved.							
	Max	0.016	0.079	0.015	0.13	1.1	181
	Min	0.007	0.044	<0.001	<0.05	0.3	102
	Mean	0.011	0.059	0.013	0.087	0.91	132
	n	4	7	4	4	7	8
Operation (2004-2009) Metals measured as dissolved.							
	Max	0.015	0.042	0.01	2.39	13.6	199
	Min	0.006	0.041	<0.01	<0.05	0.7	111
	Mean	0.010	0.041	<0.01	1.64	4.88	144
	n	3	3	3	9	9	9

Notes: Data from Troy Mine, Inc. Water Quality Data Base.
TDS – Total Dissolved Solids
n – sample size
Note: although shutdown did not end until 2004, the data were collected between 2000 and 2003.
Water quality standards shown are the lowest applicable standard from Montana Numeric Water Quality Standards from Circular WQB-7 (February 2008). Zinc and copper standards based on chronic aquatic life criterion at hardness = 25 mg/L. Ammonia standard based on temperature of 0° C and pH of 7.7. Nitrate-nitrite standard is a narrative standard to prevent nuisance algal growth.
Shading indicates exceedance of standard.

Dissolved metals concentrations (primarily copper and antimony) increase in groundwater that moves through the mine workings. During mine operations, copper concentrations have averaged 0.041 mg/L, and antimony concentrations have averaged 0.010 mg/L (**Table 3-7**). Interim shutdown data indicate similar metals concentrations: copper concentrations were somewhat higher, averaging 0.059 mg/L, and antimony concentrations averaged 0.011 mg/L (**Table 3-7**). During both shutdown and operations, copper in mine water has exceeded the chronic aquatic life standard. Because this copper standard is hardness-dependent and the hardness in upper Stanley Creek is generally less than 25 mg/L, the aquatic life standard is quite low at 0.003 mg/L.

Mine and Mill Site Facilities

The mill and office facilities would be reclaimed after mine closure. The mill facility platform was built of development rock and rocky glacial fill. This material fills portions of two ephemeral drainages (**Figure 3-3**). Runoff from both drainages is currently combined and routed through two long, four-foot diameter culverts beneath the fill and eventually discharges to Stanley Creek. The high velocity of water discharging from the culverts has scoured an area below the fill, causing sediment to enter Stanley Creek.

Water quality for selected parameters in Stanley Creek is summarized in **Table 3-8**. Water Monitoring Station 17A is located below the mill and office sites, and Station SC02 is located below the confluence with Fairway Creek. Site SC-17A is sampled annually and has a small sample size. Stanley Creek is listed as an impaired stream for copper concentrations and nutrients/eutrophication. Three of the four samples taken at monitoring site SC-17A between 2005 and 2009 exceeded chronic aquatic life criteria

for copper. There are several possible sources of copper in this stream segment, including natural constituents.

Table 3-8. Recent Surface Water Quality Data for Stanley Creek, 2005 – 2009.

Site		Antimony (TR) mg/L	Copper (TR) mg/L	Zinc (TR) mg/L	Ammonia (NH_3) mg/L	Nitrate + Nitrite mg/L	TDS mg/L
WQ Standards		0.006	0.00285	0.037	3.58	Narrative	NA
SC17A	Max	<0.003	0.011	0.04	<0.05	0.13	29
	Min	<0.003	0.002	<0.01	<0.05	0.08	10
	Mean	<0.003	0.005	0.012	<0.05	0.10	19
	n	4	4	4	4	4	4
SC02	Max	<0.003	<0.001	<0.01	<0.05	0.13	44
	Min	<0.003	<0.001	<0.01	<0.05	0.07	20
	Mean	<0.003	<0.001	<0.01	<0.05	0.10	31.4
	n	15	15	15	15	15	15

Notes: Data from Troy Mine, Inc. Water Quality Data Base
TR – Total recoverable
TDS – Total Dissolved Solids
n – sample size

Water quality standards shown are the lowest applicable standard from Montana Numeric Water Quality Standards from Circular WQB-7 (February 2008). Zinc and copper standards based on chronic aquatic life criterion at hardness = 25 mg/L. Ammonia standard based on temperature of 0° C and pH of 7.7. Nitrate-nitrite standard is a narrative standard to prevent nuisance algal growth. Shading indicates exceedance of standard.

Tailings Impoundment Area

The tailings impoundment would be reclaimed after mine closure, but the decant ponds would remain to treat and to dispose of mine discharge water. The tailings impoundment is located about 500 to 1,000 feet east of Lake Creek, and many studies have investigated the potential for water infiltrating through the tailings impoundment to influence water quality in Lake Creek (DSL and KNF 1978, SRK 2005, Summit Envirosolutions 1996, and Summit Envirosolutions 1999) (see also Appendices C, D, and I). Water containing tailings that is routed to the impoundment during operations plus all precipitation that falls on the impoundment surface either infiltrates through the tailings mass or is collected in the decant pond and pumped back to the mine for reuse.

In addition to operational monitoring conducted under the operating permit, the water quality and health of the aquatic ecosystem in Lake Creek adjacent to the impoundment has been monitored since 1986. Water quality data at surface water stations upstream (LC-1) and downstream (LC-2 and LC-4) of the impoundment are shown in **Table 3-9**. There is one exceedance of the chronic aquatic life criterion for copper at site LC-01 and one at LC-02. The latter sample was collected in October of 2008 and contained 0.049 mg/L copper (Parametrix 2009). Surface water samples collected both upstream and

downstream of LC-2 on the same date showed no detectable copper. It is not known if a field or laboratory error occurred, but a resample in November of 2008 showed copper below detection (Parametrix 2009, p. 3-15). No adverse impacts to the macroinvertebrate community have been observed at this site (Parametrix 2009).

Table 3-9 summarizes surface water quality in Lake Creek near the tailings impoundment for selected parameters. Monitoring stations are shown on **Figure 2-5**.

Table 3-9. Surface Water Quality Data for Lake Creek, 2005 – 2009.

Site		Antimony (TR) mg/L	Copper (TR) mg/L	Zinc (TR) mg/L	Ammonia (NH_3) mg/L	Nitrate + Nitrite mg/L	TDS mg/L
WQ Standards		**0.006**	**0.003**	**0.037**	**3.58**	**Narrative**	**NA**
	Max	**<0.003**	**0.006**	**<0.01**	**<0.05**	**0.08**	**46**
LC-1	**Min**	**<0.003**	**<0.001**	**<0.01**	**<0.05**	**0.04**	**25**
	Mean	**<0.003**	**0.001**	**<0.01**	**<0.05**	**0.059**	**36.2**
	n	**15**	**15**	**15**	**15**	**15**	**15**
	Max	**<0.003**	**0.049**	**<0.01**	**<0.05**	**0.09**	**45**
LC-2	**Min**	**<0.003**	**<0.001**	**<0.01**	**<0.05**	**0.03**	**32**
	Mean	**<0.003**	**<0.004**	**<0.01**	**<0.05**	**0.057**	**37.5**
	n	**14**	**14**	**14**	**14**	**14**	**14**
	Max	**<0.003**	**0.003**	**<0.01**	**<0.05**	**0.17**	**55**
LC-4	**Min**	**<0.003**	**<0.001**	**<0.01**	**<0.05**	**0.06**	**32**
	Mean	**<0.003**	**0.001**	**<0.01**	**<0.05**	**0.10**	**43.6**
	n	**15**	**15**	**15**	**15**	**15**	**15**

Notes: Data from Troy Mine, Inc. Water Quality Data Base
TR – Total recoverable
TDS – Total Dissolved Solids
n - Sample size

Water quality standards shown are the lowest applicable standard from Montana Numeric Water Quality Standards from Circular WQB-7 (February 2008). Zinc and copper standards based on chronic aquatic life criterion at hardness = 25 mg/L. Ammonia standard based on temperature of 0° C and pH of 7.7. Nitrate-nitrite standard is a narrative standard to prevent nuisance algal growth.. Shading indicates exceedance of standard.

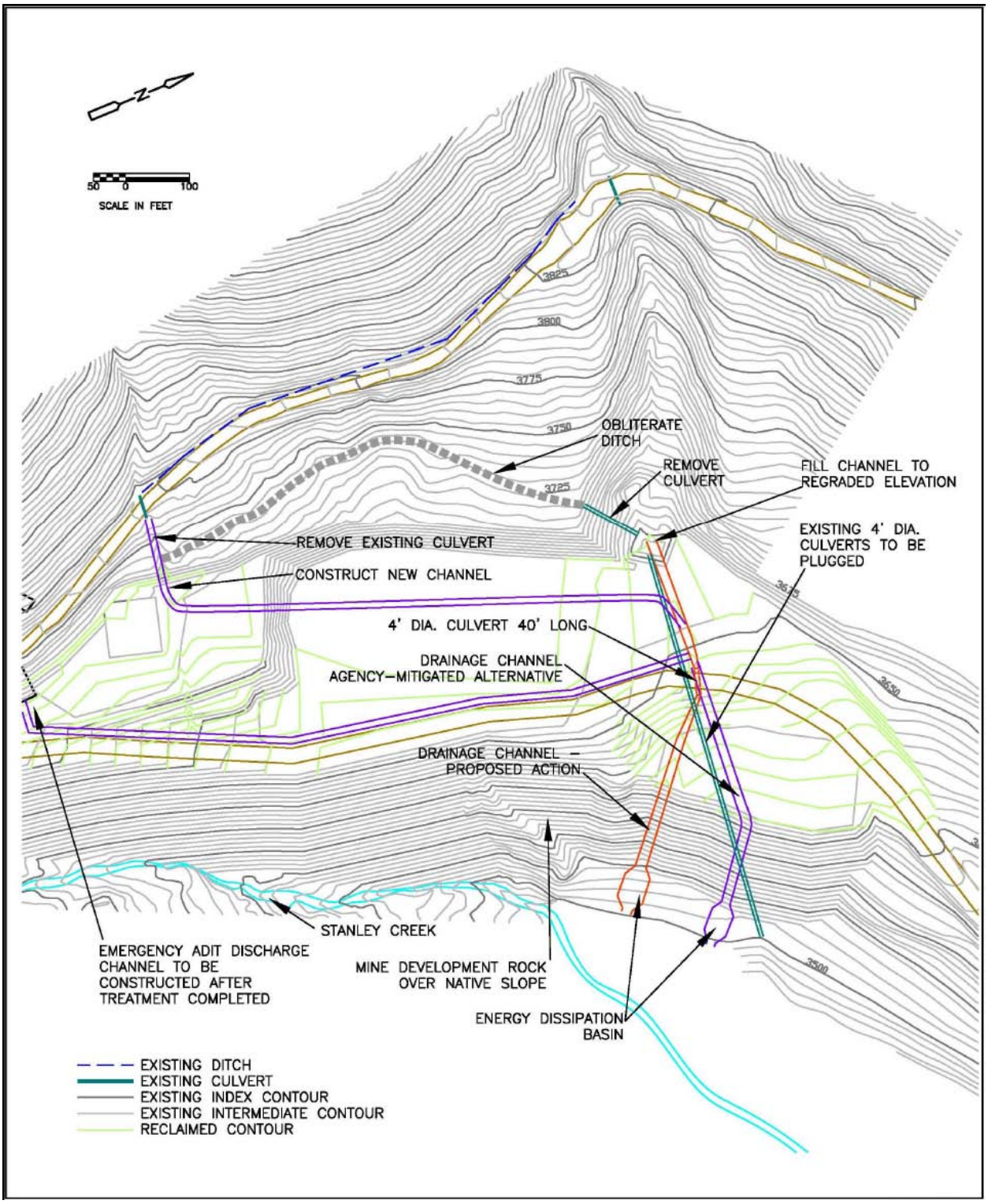


Figure 3-3. Mill Site Drainage Channel Alternatives

Mine Workings Area

The mine workings are located high in Mt. Vernon between Ross Creek on the south, Stanley Creek on the north, Bull Lake on the east, and a high ridge to the west. There is potential for water in the mine void to discharge through springs and seeps on the lower slopes of Mt. Vernon and thus affect the water quality of these surface waters.

Selection of the surface water monitoring sites was based on knowledge of the geology in the area**.** There are a number of seeps, springs, and small tributary streams surrounding the mine workings area (**Figure 3-4**). These surface water sources are located in tributaries to Ross and Stanley creeks, and to the Emma Gulch and Weasel Gulch drainages, both of which flow into Bull Lake. **Table 3-10** summarizes water quality at surface water sites, seeps, and at springs in the vicinity of the mine workings. Comparing the data to surface water quality standards, the total recoverable concentration of copper in a sample collected at SC-15A on April 4, 2005, exceeded the chronic aquatic life standard for copper; and the total recoverable copper concentration in a sample collected at SC-15C on August 12, 2010, was at the chronic aquatic life standard for copper. All other constituents were below water quality standards at all collection times. SC-17A is located below the mill site, and elevated copper levels at this sampling site are likely affected by water or sediment coming from the mill site itself.

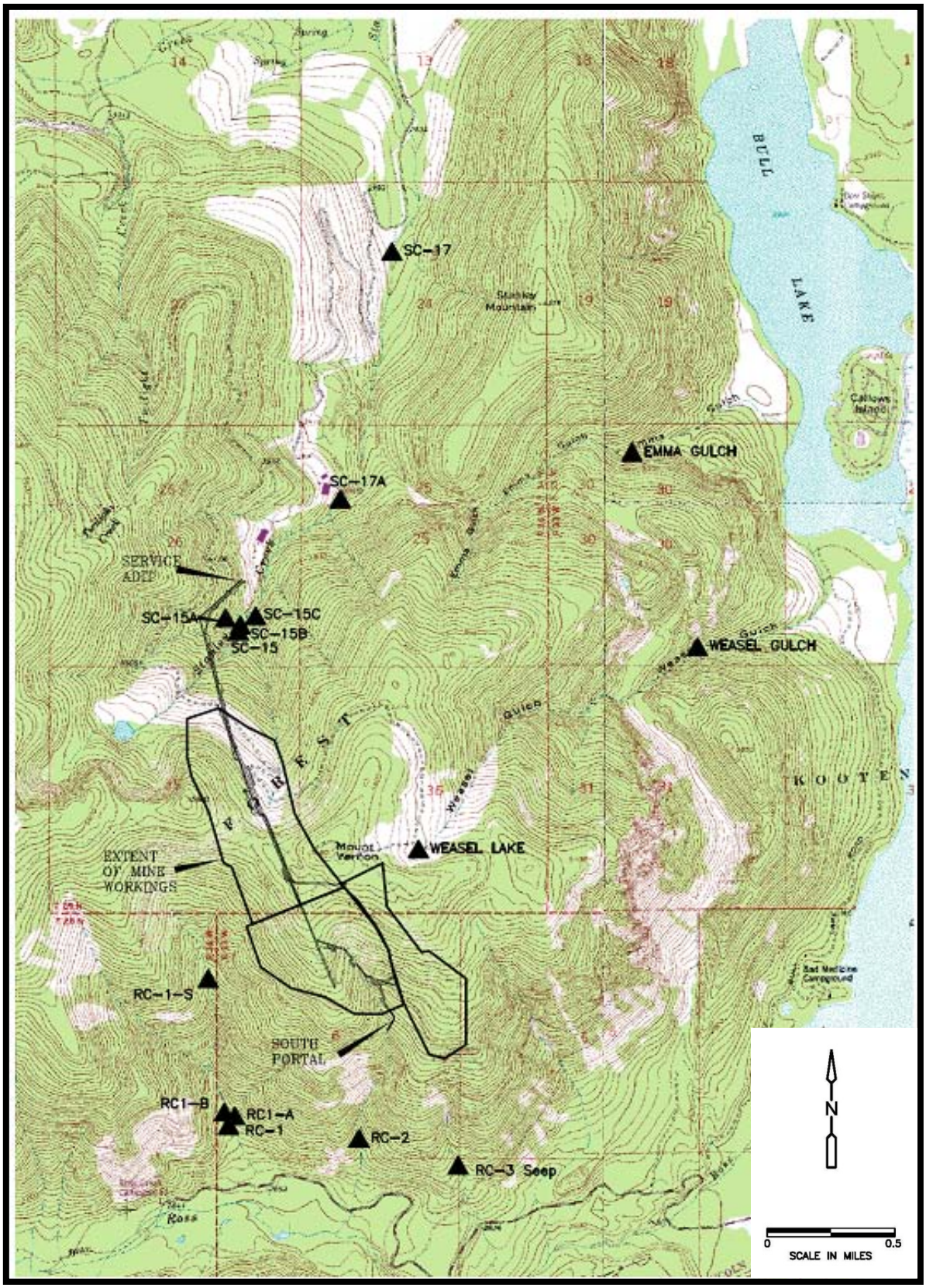


Figure 3-4. Seeps, Springs, and Surface Water Monitoring Sites in the Mine Workings Vicinity

Table 3-10. Surface Water Quality Data in Mine Workings Vicinity 2000 – 2010.

Site		Antimony mg/L	Copper mg/L	Zinc mg/L	Ammonia (NH_3) mg/L	Nitrate + Nitrite mg/L	TDS mg/L
WQ Standard		0.006	0.00285	0.037	3.58	Narrative	NA
Weasel	10/21/05	<0.003	<0.001	<0.10	<0.05	<0.01	<10
	Max	<0.003	<0.001	<0.010	0.23	0.079	62
Emma	Min	<0.003	<0.001	<0.010	<0.05	<0.01	21
	Mean	<0.003	<0.001	<0.010	<0.013	<0.047	44
Aug. 26, 2003		<0.003	<0.001	<0.010	0.23	<0.01	62
	n	6	6	6	7	8	10
	Max	<0.003	<0.001	0.003	0.69	2.74	111
RC1	Min	<0.001	<0.001	0.003	<0.05	0.69	80
	Mean	<0.003	<0.001	0.003	<0.28	1.40	91.3
Aug. 26, 2003		--	<0.001	<0.010	0.69	1.1	--
	n	3	3	2	3	4	3
	Max	--	0.001	0.003	--	--	--
RC3	Min	--	0.001	0.003	--	--	--
	Mean	--	0.001	0.003	--	--	--
	n		1	1			
	Max	<0.003	0.004	<0.010	<0.1	0.34	34
SC15A	Min	<0.001	<0.001	0.002	<0.05	<0.05	<10
	Mean	<0.003	0.002	<0.009	<0.06	0.13	21
	n	9	9	8	8	9	8
	Max	<0.003	<0.01	<0.001	<0.1	0.88	41
SC15C	Min	<0.001	0.003	<0.001	<0.1	0.27	41
	Mean	<0.003	<0.01	<0.001	<0.1	0.58	41
	n	2	2	1	2	2	1

Notes: Data from Troy Mine, Inc. Water Quality Data Base and DEQ August 2010 Sampling
Metals data from August 26, 2003 and site RC-3 are dissolved; other metals data are total recoverable or a combination of dissolved and total recoverable measurements.
TDS – Total Dissolved Solids
n - Sample size; small sample sizes are due to low or no flows at time of sampling.
Water quality standards shown are the lowest applicable standard from Montana Numeric Water Quality Standards from Circular WQB-7 (February 2008). Zinc and copper standards based on chronic aquatic life criterion at hardness = 25 mg/L. Ammonia standard based on temperature of 0° C and pH of 7.7. Nitrate-nitrite standard is a narrative standard to prevent nuisance algal growth.
Shading indicates exceedance of standard.

Roads and Other Facilities

Mt. Vernon has an extensive system of roads, which are in a variety of conditions. All the roads are unsurfaced except for NFSR 4626, which has been paved up to the mill site. Roads currently used for mining operations are minimally maintained, and roads that are not used are gradually revegetating. However, some of these roads adversely affect area water resources by intercepting and routing water directly to streams, thereby contributing sediment from chronic erosion of unvegetated surfaces and initiating debris events through failure of saturated road fills on steep slopes.

3.9.4.2 Groundwater

The study area lies within the Northern Rocky Mountains Intermontane Basins aquifer system. According to the USGS Ground Water Atlas of the United States, the groundwater of these basins generally occurs as follows:

> *Recharge to the aquifer system is by precipitation that falls directly on basin floors and by snowmelt that runs off the surrounding mountains and is transported into the basins by tributary streams. The streams lose much of their water by infiltration into the basin-fill deposits. The basin-fill aquifers discharge primarily to streams that flow parallel to the long axes of the basins; some discharge is to springs and by withdrawals from wells* (USGS 1996).

Tailings Impoundment Area

The tailings impoundment lies within the Lake Creek watershed. The Lake Creek valley is filled with unconsolidated to semi-consolidated deposits of silt, clay, and sand interbedded with gravel and cobble zones. Groundwater occurs in the Lake Creek valley in permeable sand, gravel, and cobble zones. Groundwater flow is presumed to be from the valley sides toward Lake Creek and to the north (Land and Water Consulting 2004).

Table 3-11 shows the typical water quality of wells installed in the tailings impoundment area. Wells MW-1 through MW-4 are completed in the deep aquifer, but wells MW 95-4 and MW 95-5 are shallow wells completed 10 to 15 feet below ground surface. The wells are located near the toe of the tailings dam, generally west and south of the impoundment (**Figure 2-5**). The monitoring shows no exceedance of groundwater standards. However, if nutrients in shallow groundwater, as measured in MW 95-4, discharge locally to surface water (as they may at the toe ponds) nuisance algal growth could occur. No numeric exceedances for the aquatic life standard for ammonia or for the human health standard for nitrate plus nitrite are observed in the toe pond water quality data. Nonetheless, nitrate plus nitrite levels may be high enough at times to promote nuisance algal growth in the toe ponds.

Mill Site Facilities

The office and mill site platform are built over glacial till overlying quartzite bedrock. This bedrock has enough secondary porosity (fractures) to transmit groundwater to unconsolidated deposits in the adjacent stream valley. With no groundwater monitoring at the mill site, it is not known if water flowing through mill site fill could potentially dissolve metals and discharge them to Stanley Creek. Groundwater beneath the mill site ultimately discharges to Stanley Creek.

Previous studies (Balla 2000, Kirk 2003) have shown that development rock fill found at the Troy Mine and at other mine sites in the area with similar geology is not generally acid-producing and is unlikely to degrade groundwater or surface water. In general, oxidation of the mineral pyrite is the main reaction that is responsible for acid production and for metals leaching at mine sites. The Troy Mine ore body is composed of non-acid producing copper sulfide minerals (digenite, bornite, and chalcocite) and has low pyrite content (Balla 2000). Kirk (2003) demonstrated that metals could be leached at neutral pH conditions.

Table 3-11. Groundwater Quality Data for Monitoring Wells at Tailings Impoundment 2000 – 2009

Site		Antimony mg/L	Copper mg/L	Zinc mg/L	Ammonia (NH_3) mg/L	Nitrate + Nitrite mg/L	TDS mg/L
WQ Standard		0.006	1.3	2	NA	10.0	NA
MW-1	Max	<0.005	0.002	0.011	0.015	0.32	171
	Min	<0.003	<0.001	<0.01	<0.05	0.05	142
	Mean	<0.003	<0.0011	<0.010	0.10	0.16	156
	n	7	7	7	7	7	7
MW-2	Max	<0.005	0.012	0.25	0.75	0.22	197
	Min	<0.003	<0.001	<0.01	0.082	<0.01	19
	Mean	<0.003	<0.0027	0.047	0.41	<0.075	115
	n	7	7	7	7	7	7
MW-3	Max	<0.005	0.002	0.024	0.51	0.15	178
	Min	<0.003	<0.001	<0.01	0.25	<0.01	122
	Mean	<0.003	<0.0013	<0.012	0.37	<0.05	147
	n	7	7	7	7	7	7
MW-4	Max	<0.005	<0.002	0.04	0.78	0.13	197
	Min	<0.003	<0.001	<0.01	<0.05	<0.01	30
	Mean	<0.003	<0.0012	0.019	0.31	<0.07	99
	n	7	7	7	6	6	7
MW95-4	Max	<0.005	0.038	0.028	4.2	1.19	460
	Min	<0.003	<0.001	<0.01	<0.05	<0.01	126
	Mean	<0.003	0.007	<0.012	2.12	0.19	284
	n	11	8	10	13	13	14
MW95-5	Max	<0.005	0.003	0.35	0.6	0.4	284
	Min	<0.003	<0.001	<0.01	<0.05	0.09	97
	Mean	<0.003	0.002	0.095	0.25	0.23	168
	n	4	4	4	3	3	4

Notes: Data from Troy Mine, Inc. Water Quality Data Base.
Metals data measured as dissolved for groundwater samples.
TDS – Total Dissolved Solids
n – sample size
Water quality standards are human health standards from Montana Numeric Water Quality Standards from Circular WQB-7 (February 2008). Shading indicates exceedance of standard.

The portal patios were constructed of development rock fill that may contain zones of higher pyrite concentrations. Balla (2000) found that most of the pyrite grains were not reactive because they were coated with a non-reactive oxidation rind and enclosed within the impermeable quartzite rock. The portal patios have not shown any evidence of acid generation in the past 30 years.

Mine Water Discharge

The Troy Mine underground workings are within the Stanley Creek and Ross Creek sub-watersheds. During operations, dewatering pumps in the underground mine route water to the mill and/or tailings

impoundment. After groundwater enters the mine workings, metals concentrations increase (**Table 3-7**). Although most water from the mine void is removed by pumping, some of it may re-enter the groundwater system, ultimately discharging to streams, seeps and springs, and to groundwater aquifers in the Stanley Creek and Ross Creek watersheds.

The total sulfur content of the ore body is0.3 to 1.0 percent (Hayes 1983). In addition, the ore body contains about 4 percent iron and magnesium carbonates that act to neutralize any acid that may be generated (Balla 2000). The dissolved copper in the mine void is associated with neutral metals leaching, and given the low acid-producing potential, metals concentrations are not expected to increase above currently observed concentrations in mine-affected waters (KNF and DEQ 2001, KNF and DEQ 2009).

Groundwater in the mine void was sampled in December of 2009 and had a dissolved copper concentration of 0.114 mg/L and a dissolved zinc concentration of 0.020 mg/L (**Appendix D**). Previous mine water chemistry data are summarized in **Table 3-7**. These levels do not exceed groundwater standards, but if mine water discharges to streams, seeps, or springs, metals could potentially exceed the surface water standards for aquatic life. The mine pool rate of rise was monitored during an 18-month period of mining inactivity from September of 2002 to February of 2004 as described in the Mine Flooding Report (Genesis 2006, Appendix A). Pumping was resumed prior to mine water reaching the 4,225-foot elevation spillover point within the mine. During this time, surface water sites surrounding the mine workings were monitored, and no changes in water quality were observed at these sites (Table 3-10 and Troy Mine Water Quality Data Base).

Mine Water Management

During active operation of the mine, Troy Mine, Inc. typically uses the tailings impoundment and decant ponds to settle out suspended sediment from the tailings slurry, which is piped from the mill. Decant water is then pumped to the mill circuit via a return line. Up to 1,170 gpm of the decant pond water seeps through the unlined bottom of the ponds into the underlying aquifer. The fate and transport of contaminants in mine waters downgradient of and beneath the tailings impoundment/decant pond area have been described in the following reports:

- Interim Report of Findings: Hydrologic and Hydrogeologic Assessment, ASARCO Troy Mine, Troy Montana. 1996. By Summit Envirosolutions;
- Site Instrumentation Status Report, Troy Tailings Facility. December 1999. By Summit Envirosolutions;
- Mine Water Plume Location and Identification Phase 1 Results and Phase 2 and 3 Workplan. October 2001. Prepared for Genesis Inc./Sterling Mining Company by Hydrometrics (see Appendix H);
- Assessment of Fate and Transport of Copper in Decant Pond Disposal System – Troy Mine. Lincoln County, Montana. January 2004. Prepared for Revett Mining Company by Land and Water Consulting, Inc.;
- Troy Mine Copper Attenuation Study – Secondary Processes (see Appendix D). May 2010. Prepared for DEQ and KNF by CDM; and

- Assessment of Natural Attenuation of Metals in a Decant Pond Disposal System, Troy Mine. May 2010. Prepared for Genesis Inc. by Hydrometrics, Inc. (see Appendix I).

Empirical evidence indicates that treatment of discharged mine waters occurs due to attenuation of metals as water percolates through glacial and stream sediments underlying the tailings impoundment.

Summit Envirosolutions (1996) evaluated the potential impacts of dissolved parameters from the tailings impoundment and concluded that groundwater from beneath the impoundment flows towards Lake Creek. In 2001, Hydrometrics conducted a tracer study in which sodium chloride (salt) was added to the decant ponds (Appendix H). The transport of salt from the decant ponds into the groundwater was tracked and monitored by measuring electrical conductivity within existing wells. (Water containing salt conducts electrical current, whereas pure water does not conduct electricity.) This report concluded that the deep wells and decant ponds appeared to be hydraulically connected; that is, some decant water did flow vertically downward to be intercepted by the deep wells, but the travel time was longer than the period of the test (80 days). To determine whether decant water was also transported within shallow sands and gravels above the zone of the deeper wells, shallow monitoring wells were installed. The 2001 Hydrometrics report (Appendix H) indicated that, while deep groundwater and the decant ponds system are hydraulically connected, most of the decant pond water is transported downgradient (towards Lake Creek) via the shallow alluvial aquifer (**Figure 2-1**).

Because decant pond water primarily traveled downgradient of the ponds in the shallow groundwater system, it was expected that copper concentrations should be higher in the shallow monitoring wells. However, copper concentrations in groundwater along the flow path were either much lower than the decant pond water or below the laboratory reporting limit. These data indicate that copper was being removed from the groundwater via some undefined geochemical process.

In 2004, a study was performed that focused on the fate (ultimate state) and transport (movement) of copper beneath the decant ponds (Land and Water 2004). Geologic material beneath the decant ponds was analyzed for total copper both by electron microprobe (to identify the composition of copper minerals) and by sequential extraction (to identify which mineral phases contain the most copper). Study results indicated that copper was attenuated (removed from the groundwater) within the upper foot of soil primarily through the precipitation of secondary copper minerals (carbonates, silicates, and oxides) and through the secondary adsorption of copper onto organic matter. Precipitation is the formation of a solid (mineral) from dissolved constituents in groundwater; and adsorption is a process where dissolved metal adheres to the surface of organic particles.

The Land and Water (2004) report did not evaluate the longevity of the attenuation processes and only evaluated the fate and transport of copper. Thus, the agencies required Revett (Troy Mine, Inc.) to expand the evaluation to include other metals (antimony, arsenic, cadmium, lead, mercury, and uranium) and to evaluate the duration of the natural attenuation mechanisms. This evaluation was to include the effects of changing redox (oxygenated vs. anaerobic environment) or pH (corrosive vs. neutral) conditions on the attenuation processes.

The final Hydrometrics (2010) report addressed the issues of other metals and the duration of natural attenuation mechanisms (Appendix I). Antimony, uranium, and cadmium were detected at low levels in well MW-01-15 adjacent to the decant ponds. Within 150 feet (downgradient) of the decant ponds, concentrations of metals were below the analytical reporting limit. These results indicated that natural attenuation effectively removes metals from groundwater within a relatively short flow path. Of particular note is the fact that mine-related water has been disposed of within the decant pond system for over 30 years. During this time, metals of concern have not been detected at levels that exceed applicable standards, either in groundwater at the edge of the tailings impoundment or in Lake Creek itself.

The agencies evaluated whether there are other secondary attenuation processes that would prevent migration of metals beyond the decant ponds. These secondary attenuation processes would occur when oxygen-rich mine water from the decant ponds mixes with groundwater. When the oxygen-poor groundwater contains iron, the dissolved iron precipitates from solution as iron hydroxide (a solid mineral). When the iron hydroxide precipitates, it would facilitate removal of other metals from water by co-precipitation. Specifically, the 2010 CDM study evaluated the following: whether dissolved iron in groundwater would precipitate as iron hydroxide; whether dissolved iron that precipitates would help remove copper and other metals (co-precipitation) from mine waters (**Appendix D**); and the quantity of other metals that would be removed with the iron. The evaluation consisted of: 1) computer geochemical modeling using the input parameters from mine waters and the groundwater under the tailings impoundment; and 2) bench-scale jar testing using varying proportions of mine waters and groundwater.

Study results showed that if the effectiveness of the primary metals attenuation mechanisms beneath the decant ponds decreases over time, there would be secondary attenuation mechanisms capable of removing at least 73 to 98 percent of the copper and 11 to 59 percent of the antimony from the groundwater. The range of the concentrations remaining in solution after bench scale testing was 0.002 to 0.012 mg/L copper and 0.002 to 0.046 mg/L antimony in groundwater (**Appendix D**).

In summary, water quality data and several studies on the fate and transport of metals of concern in the vicinity of the decant ponds and tailings impoundment show that natural attenuation mechanisms have been effective at removing metals from the Troy Mine decant pond water for the last 30 years.

3.9.5 Environmental Consequences

Potential impacts to hydrology resources from mine closure and from reclamation activities include effects on water quantity, water quality, and on stream channel morphology. Water quality concerns include nutrients, metals, and sediments. These issues are evaluated for each of the three alternatives. The issue of treatment of mine discharge water at the tailings impoundment is discussed under the tailings impoundment section of the Proposed Action.

3.9.5.1 No Action Alternative

Mine Water Discharge

Under the No Action Alternative, mine closure and reclamation would be conducted according to the Reclamation Plan analyzed in the 1978 Draft EIS. The mine workings would be allowed to fill to the elevation where water would naturally flow out the Service and Conveyor adits and down the slope to Stanley Creek. According to the 1978 Reclamation Plan, the water would be discharged "under applicable State and Federal permits." However, this discharge would not be permittable without treatment under MPDES regulations for reasons explained below. The water quality standards for surface water have become more stringent since the mine was originally permitted.

Water Quantity

Studies and data collected from the Troy Mine production years help describe the hydrologic cycle at the mine site and the expected long-term equilibrium water level when mining ends. Inflows to the underground workings consist of rainfall and snowmelt that infiltrate the area above the mine and then percolate into the underground workings. The rate at which the underground void space would be occupied by groundwater and whether the groundwater would rise to the point of spill-over have been studied by Klohn Crippen (2000), Genesis (2006), and by CDM in 2010 (Appendix B).

However, data collected during mining operations that could be used for prediction of hydrologic equilibrium at the Troy Mine are somewhat limited. Hydrologic equilibrium refers to a balance between mine inflows and outflows that results in a relatively constant water elevation in the mine workings. For the Troy Mine, this balance would be attained after closure when the water elevation reaches the height of the high points in the Service and Conveyor adits (4,225 feet) and flows down the adits, thus controlling the water elevation in the mine. In the 1978 Draft EIS, the mining company predicted that the maximum discharge from the mine would be 2,500 gpm (5.57 cfs). There was no estimate of minimum discharge (DSL and KNF 1978, page 305). Klohn Crippen (2000) states that peak inflow into the mine can approach 4,000 gpm (8.9 cfs) during spring snowmelt events. The mine pool rate of rise was monitored during an 18-month period of mining inactivity from September of 2002 to February of 2004 as reported in the Mine Flooding Report (Genesis 2006, Appendix A). In September of 2003 the mine water level reached 4,209 ft. before pumping resumed; therefore, outflow at the predicted 4,225 feet elevation from the mine was not observed.

A study on the mine water balance predicted that water would begin to flow from the mine at the 4,225 feet elevation approximately 21 months after pumping ceases (**Appendix B**). This water would exit the mine through the Service and Conveyor adits. However, the exact period before overflow is dependent on precipitation conditions preceding and after the termination of pumping. Mine water discharge rates would vary seasonally and are predicted to range from 300 to 3,100 gpm (0.67 to 6.9 cfs). The water balance estimates that flows would vary seasonally as shown in **Table 3-12**. June would be the month with the greatest discharge with an average monthly flow estimated at 4.9 cfs and peak discharge of 6.9 cfs. In drier years, it is expected that water, other than adit seepage water, would not discharge from the main mine workings in August and September (**Appendix C**).

Table 3-12. Estimated Monthly Mine Water Discharges (cubic feet per second)

Month	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Ave.
Oct	0.84	1.57	0.67	3.29	0.67	1.98	0.69	1.02	1.10	1.88	1.37
Nov	1.31	2.04	0.73	3.76	0.73	2.45	1.16	1.49	1.57	2.35	1.76
Dec	1.00	1.74	0.67	3.46	0.67	2.15	0.86	1.19	1.27	2.04	1.50
Jan	1.76	2.49	1.18	4.21	1.18	2.90	1.61	1.94	2.02	2.80	2.21
Feb	1.52	2.25	0.95	3.97	0.95	2.66	1.37	1.70	1.78	2.56	1.97
Mar	1.39	2.13	0.82	3.84	0.82	2.54	1.25	1.58	1.66	2.43	1.84
Apr	2.25	2.98	1.68	4.70	1.68	3.39	2.10	2.43	2.51	3.29	2.70
May	3.59	4.32	3.01	6.04	3.01	4.73	3.44	3.77	3.85	4.63	4.04
Jun	4.44	5.18	3.87	6.90	3.87	5.59	4.30	4.63	4.71	5.48	4.90
Jul	2.47	3.20	1.89	4.92	1.89	3.61	2.32	2.65	2.73	3.51	2.92
Aug	1.19	1.92	0.67	3.64	0.67	2.33	1.04	1.37	1.45	2.23	1.65
Sep	0.67	1.03	0.67	2.74	0.67	1.44	0.67	0.67	0.67	1.33	1.06

Water discharging from the Service and Conveyor adits would flow both overland and subsurface in the coarse development rock and glacial fill towards Stanley Creek. The slope distance between the adits and Stanley Creek is approximately 250 feet. The ratio of surface to subsurface flow between the portals and the toe of the portal patio fill would vary seasonally. At higher adit discharge rates, a greater proportion of water would remain as surface flow all the way to Stanley Creek. Most of the subsurface water would likely emerge at the toe of the portal patio fill and then flow into Stanley Creek.

The discharge of mine water directly to Stanley Creek would result in higher flows in upper Stanley Creek year-round. The highest flows would occur in late spring to early summer. Continually augmented flows in Stanley Creek would probably change the length and duration of perennial reaches. Because upper Stanley Creek typically has baseflows in the 1 to 3 cfs range (DSL and KNF1978, p. 305), the inflow of up to 6.9 cfs of additional water would result in a flow regime measurably different than those measured before mine development or during operation. This effect would diminish in the downstream direction and result in smaller flow alterations in lower Stanley Creek and much smaller effects in Lake Creek.

Water Quality

The discharge of relatively large quantities of water to upper Stanley Creek would alter the water quality of the stream because the mine water would contain elevated levels of nitrates and metals. Copper and antimony are expected to exceed water quality standards for an extended period of time, but nutrients would probably decrease to acceptable levels within several years of closure. At closure, copper and antimony in mine water infiltrating the coarse development rock that forms the mill patio would not be

sufficiently attenuated to meet water quality standards before reaching Stanley Creek. Once reaching upper Stanley Creek, the concentrations of copper and antimony would be diluted to some degree by the stream. Because the No Action Alternative does not include water treatment, copper and possibly antimony would potentially exceed water quality standards for upper Stanley Creek both in the short- and long-term. The metal concentrations would vary seasonally. Any mixing zone allowed would be insufficient to attain water quality standards under low flow conditions because of the high volume of mine water compared to the volume of receiving water.

At closure, the amount of nitrates in mine water infiltrating the coarse development rock that forms the mill pad below the Service and Conveyor adits would not be attenuated before reaching Stanley Creek. The Agencies concluded that nitrates may initially violate narrative water quality standards for upper Stanley Creek. However, the interim shutdown data demonstrated that nitrates would decline in mine water within several years; and, therefore, the Agencies concluded that nitrates would not violate water quality standards over the long-term.

Sediment and Stream Morphology

Sediment would be generated by the discharge of mine water on the mill patio. This sediment would have impacts on aquatic habitat in Stanley and Lake creeks, especially in the portions of those streams with lower gradients where the sediment would tend to deposit, potentially affecting channel morphology as well.

Mine Area Surface Water, Seeps, and Springs

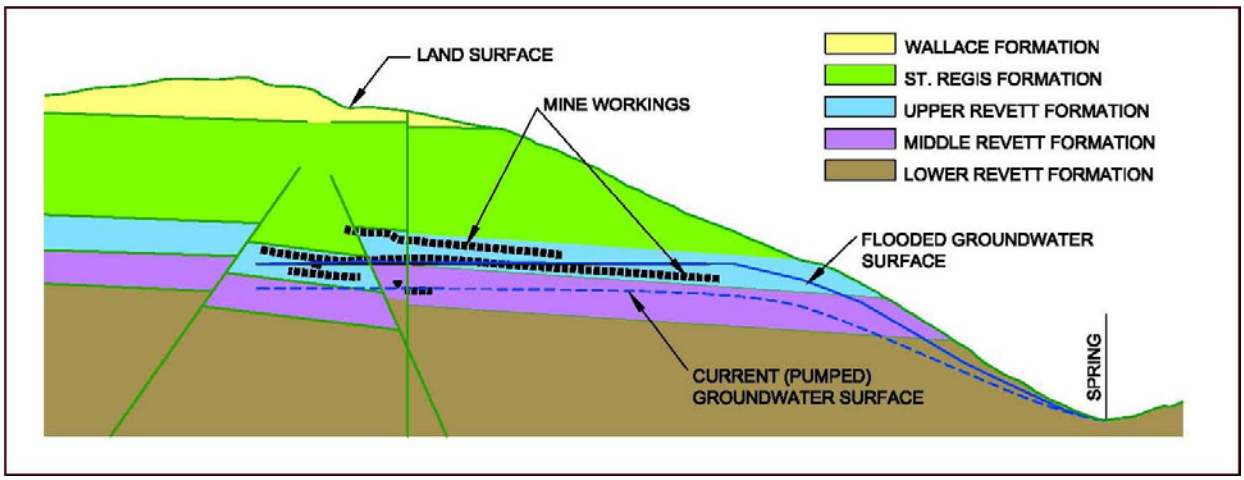
After mine closure, groundwater would rise in the mine to the predicted overflow elevations (4,225 feet) in the Service and Conveyor adits, as described in the previous section. A potential consequence of this rise is that water, contaminated with nutrients or metals, could move through bedrock formations and discharge at area seeps, springs, and streams in the headwaters of drainages surrounding the mine workings, namely, Stanley Creek, Weasel Gulch, and Emma Gulch drainages, and the northern tributaries of Ross Creek. Monitoring site locations for springs, seeps, and other surface water in these drainages are shown on **Figure 3-4**.

Water Quantity

One potential consequence of the increased hydraulic head from the rising level of water in the mine workings is that it could force mine water through fractures and other pathways in the vicinity of the mine, thus increasing flow to seeps, springs, or streams in the vicinity of the mine. To evaluate this potential, an investigation of the seeps, springs, and surface water was undertaken from both a hydrogeological and a geochemical perspective (Appendix F). The hydrogeologic evaluation superimposed a three-dimensional map of the mine workings on the map of surface water monitoring sites in the vicinity of the mine workings to show the three-dimensional relationship between projected water levels in the flooded mine to sites of known surface water flow. Cross-sections were cut through this mine model to show the expected groundwater conditions in the operational (dewatered) and post-

closure (flooded) mine conditions. **Figure 3-5** is a typical section showing the expected change in groundwater surfaces in relation to surface water.

The monitoring sites in Stanley Creek are 250 feet below the elevation of the operational (pumped) water level in the mine, and the monitoring sites in the Ross Creek drainage are at least 700 feet below the operational water level. The projected post-closure rise of water level would be relatively small compared to the hydraulic head difference between the operational (pumped) mine water level and most surface water measurement sites (**Figure 3-5**). By using the principles of groundwater flow, it is expected that this head difference would decrease in an outward direction from the mine to no more than a few tens of feet in the vicinity of the monitoring sites. This few tens of feet head difference would limit the potential for seeps and springs to migrate horizontally and vertically from their current locations. This head difference would also limit the potential increase in seep and spring flow rate to a small percentage of current flow.



Source: Genesis Inc., 2010.

Figure 3-5. Typical Section of Expected Groundwater Surfaces

Two tributaries of Stanley Creek have perennial flow above the elevation of the mine workings. These streams could potentially be augmented by groundwater as the mine workings flood. Other springs and seeps may become active in the 175 foot vertical interval between the current pumping level of 4,050 feet and the final pool elevation of 4,225 feet. Whether these springs would appear depends largely on whether the faults that intersect the workings and ground surface can transmit sufficient water to result in surface seeps. Known surface faults in the perimeter around the mine workings tend to be vertically oriented. It is likely that these fractures would already have associated springs prior to flooding, and mine flooding would slightly increase their flow and possibly cause their points of discharge to move upslope a few feet. This is because vertical fractures are currently likely to be discharging to springs at a lower elevation, and it is only the elevation of the discharge that would change. Horizontal joints, fractures, and faults that are currently above the flooded level would exhibit no discharge until they

become saturated by future mine flooding. This geological structure suggests limited potential for development of new springs in the 175 foot interval between current pumping level and final pool elevation.

An average of 2.3 cfs of water is displaced from the mine workings to areas (*e.g.*, the decant ponds) more distant from the mine (Appendix D). Changes in surface water flows and locations are expected to be minimal after mine closure because discharges are not expected to vary measurably at the surface water monitoring sites and because the potential for new, higher elevation springs to develop would be limited. Surface water flows after mine closure would likely remain less than pre-mining flows in the vicinity of the workings.

Water Quality

Recent water quality data for surface water in the vicinity of the mine are summarized in **Table 3-8** and **Table 3-10**. Currently, surface water generally meets human health standards and chronic aquatic life criteria. The exception is in upper Stanley Creek at SC-17A where mill site operations are likely a contributing factor to elevated copper levels in water samples. Such operations at the mill site would include past snow handling practices. Snow that was plowed from the mill and office yards was dumped over the face of the mill pad. Sediment from the mill area was deposited in the dirty snow where it could wash into Stanley Creek. During the ten years of surface water monitoring in the vicinity of the mine, effects of mine water on surface water in the immediate area are not clearly evident. It should be noted that, during the interim shutdown period from 1993 to 2004, mine water elevations varied. The hydraulic head increased within the mine void during periods when the pumps were shut off. In August of 1999 the water elevation was at 4,189 feet, and in August of 2003 the water level was at 4,209 feet. On August 26, 2003, some surface water sites in the vicinity of the mine workings were sampled (**Table 3-10**). Antimony and copper concentrations were below detection limits at these sites, and nitrates were within the range of observations made at other times when the mine pool was lower. Monitoring continued at some of these sites on an annual basis and no detections of metals were found. This suggests that mine water has not measurably affected these surface water sites.

A geochemical evaluation of surface water quality data compared with mine water quality data was undertaken for common ions, selected dissolved metals, and for nitrogen compounds (**Appendix F**). The analysis of common ions showed that the mine-related waters had higher total dissolved solids and a distinct calcium-magnesium bicarbonate composition, indicative of long-term contact with dolomitic aquifer materials. The surface waters in the vicinity of the mine are not calcium-magnesium bicarbonate waters and are low in dissolved solids, suggesting that the primary source of these waters is precipitation, runoff, and/or freshly recharged, near-surface groundwater. Typically, precipitation, runoff, and near-surface groundwater have not had enough residence time (contact) with dolomitic aquifer materials to become calcium-magnesium bicarbonate waters. The metals comparison shows that dissolved copper concentrations were nearly two orders of magnitude lower in these surface water locations than in the mine-related waters. These data suggest that the surface water in the vicinity of the mine is derived primarily from precipitation or freshly recharged near-surface aquifers.

After the mine is flooded, mine water quality would be expected to improve over time. Following closure of the mine, rebound of the water table would reduce oxidation in the workings by orders of magnitude, because the dissolved concentration of oxygen in the water is 10,000 times lower than in air. Construction of portal plugs and backfilling of the adits would further reduce available oxygen to water in the workings by reducing the rates of groundwater recharge with aerated surface water. However, flooding of the mine to the spill-over elevation (where the Service and Conveyor adits intersect the ore body) would not result in complete flooding of the underground workings. About half of the workings would still remain above the water table. Oxidation rates are projected to decrease primarily within the flooded portion of the mine void. Long-term metals concentrations in drainage from the mine are expected to be similar to concentrations observed near the end of interim shutdown in 2004 with potential decreases over an unknown period of time. A decrease in ammonia and nitrate plus nitrite concentrations is expected post-closure because this was observed during the temporary shutdown and in unused, flooded portions of the mine where blasting has ceased.

Because discharges are not expected to vary measurably at the surface water sites, and because no sediment is likely to be transmitted to the seeps and springs by groundwater flow, sediment and stream morphology impacts from mine flooding are not expected in mine area surface waters.

Mill Site and Portal Patios

As approved in the 1978 EIS, the Reclamation Plan states that the mill site patio would be left at its current elevation and that the cut and fill slopes, which are partially revegetated, would be left in the current configuration. However, it does not address how reclamation would treat runoff from the two ephemeral channels that currently cross the mill site in culverts. It is assumed that the culverts would remain in place and that the smaller drainage to the south would continue to drain to the entrance of these culverts. The 1978 Reclamation Plan also states that the mine patios would be regraded to drain and that the faces of the portal patios would be left at their current angle-of-repose slopes.

Sediment

Water flowing through the two long culverts at the mill site is causing erosion at their discharge point at the base of the patio fill. At some point in the future, it is expected that the culverts would plug or fail internally and discharge water across the fill and down its face to Stanley Creek. It is also likely that the ditch that diverts water from the smaller drainage across the regraded mill patio would fail and discharge water across the regraded patio and down its face to Stanley Creek. Fine-grained material currently on the face of the fill near the mine portals would eventually erode into Stanley Creek. All these sources would contribute sediment to Stanley Creek and impact aquatic habitat and stream morphology.

No mine water flows out of the North or South adits. Water seen near the portal outlets of the North and South adits during spring runoff is due to surface runoff in the vicinity of the adits. The west ventilation adit lies in the path of an ephemeral stream that originates farther upslope. No provision for restoration of this channel was provided in the 1978 Reclamation Plan. The 1978 EIS is unclear whether placement of soil on the faces of the portal patios was planned. If soil were placed on the steep slopes of

development rock below the adits, it would erode. Erosion of soil below the North Adit would contribute sediment to Stanley Creek. Below the South Adit, erosion of soil would contribute sediment to a Ross Creek tributary. However, delivery of sediment to the main stem of Ross Creek might not occur because the flows would cross a large alluvial fan, which would slow water flow and cause sediment to deposit prior to reaching the stream.

A mine subsidence area is located northeast of the South Adit. The headwall of this subsidence area is unstable and is a potential source of sediment to Ross Creek. This source of sediment is not addressed in the 1978 Reclamation Plan because it resulted from mining-related subsidence that occurred after mine development.

Channel Morphology

Sediment resulting from erosion at the mine site and North Adit area would be rapidly transported to lower Stanley Creek, where the low gradient and lack of flushing flows would result in a relatively long residence time. The sediment would accumulate in slower reaches such as pools, gradually reducing pool depth.

Roads and Other Facilities

Under the Reclamation Plan analyzed in the 1978 EIS, disposition of the mining-related roads was left up to the discretion of the USFS at time of closure. Consequently, the No Action Alternative with respect to roads is the same as the Agency-Mitigated Alternative (see Agency-Mitigated Alternative effects discussion for roads and **Table 2-1**). The tailings pipelines and the power line would be removed. Removal of miscellaneous facilities, including the water makeup pump station, reclaim pump station, and the maintenance sump, was not addressed.

Surface Water Quantity

Proposed road treatment (**Section 3.15**) would increase the infiltration of precipitation, reduce runoff, and route less water to stream channels. Road runoff can increase the volume of water delivered to stream channels, elevate the peak streamflow rate, and cause accelerated erosion in stream channels.

Surface Water Quality

Under the No Action Alternative, NFSR 4626 would retain a paved surface and would limit sediment delivery to Stanley Creek until such time as the pavement fails in the future. Treatment of other roads would result in minor short-term sediment delivery during the first year following treatment; but by the second year, revegetation would minimize sediment delivery. Over the long-term, there would be less sediment delivery from surface erosion and stream culvert failures to Ross and Stanley creeks from these roads. The risk of mass failures and the accompanying sediment delivery would also be reduced.

Disturbed ground associated with the removal of the power line and the tailings pipelines would be revegetated. Where these facilities are close to streams, short-term sediment delivery would be possible until vegetation is re-established.

Stream Channel Morphology

Short-term sediment delivery from reclamation activities associated with roads and other facilities would not be expected to have a measurable effect on stream channel morphology. Stabilization of roads would lessen the long-term risk of mass failures and would provide better protection for stream channel conditions in Stanley and Ross creeks.

Tailings Impoundment

According to the reclamation plan analyzed in the 1978 Draft EIS, the tailings impoundment would be reclaimed by regrading the surface to promote runoff and by excavating a channel from the low point of the final impoundment surface to an appropriate natural drainage. Eighteen inches of stockpiled soil would be spread over the surface, and vegetation would be re-established. This would eliminate the decant ponds and prevent accumulation of water on the surface of the impoundment. The toe ponds at the tailings impoundment were permitted in July 1983 but no reclamation plan was specified. The Agencies have assumed that the toe ponds would remain after mine closure under the No Action Alternative but that the tailings pipelines and other facilities would be removed.

Groundwater Quantity

Draft EIS estimated that up to 1,170 gpm of seepage could discharge from the impoundment to the underlying aquifers during operation of the mine. After reclamation under the No Action Alternative, no water would be routed to the impoundment. Revegetation would increase evapotranspiration and reduce infiltration of precipitation that falls on the tailings impoundment surface. No groundwater recharge from mine waters would occur. Reclamation of the tailings impoundment would approximately return the flux of groundwater through the area to pre-mining levels. The water table beneath the tailings impoundment would be lower compared with operational conditions.

Groundwater Quality/Nitrates/ Metals/Sediment

Nitrate is produced from the incomplete combustion of blasting agents used during underground mine development and is transported from the mine void either dissolved in mine water or as residue on rock sent to the mill. It is then transported to the impoundment within the tailings slurry. After cessation of mining, addition of nitrate to the tailings impoundment would cease. Residual nitrate would slowly be rinsed out of the tailings by precipitation and diluted in the groundwater. Concentrations of nitrate in the underlying aquifer would decline. Currently, nitrate concentrations in the tailings decant pond water range between 10 mg/L and 30 mg/L, and concentrations in monitoring wells located close to the decant ponds are similar. Monitoring wells and toe ponds downgradient of the tailings impoundment generally have nitrate concentrations of less than 1 mg/L (**Table 3-11)**. Nitrate concentrations are expected to decline rapidly after mining ends, as was observed during the interim mine shut-down between 1993 and 2004, because nitrate-rich mine water will no longer be discharged in the tailings impoundment.

Ambient groundwater beneath and downgradient of the tailings impoundment contains elevated concentrations of dissolved iron and manganese, which often exceed the guidelines for public water supplies (**Table 3-11**). In comparison, the mine's decant pond water generally contains much lower

concentrations of dissolved iron, but similar or greater concentrations of dissolved manganese. Consequently, it is expected that closure of the mine and cessation of discharge of water to the decant ponds under the No Action Alternative would slow down the operational diluting effect of the mine water on dissolved iron concentrations, potentially resulting in slightly higher iron concentrations in groundwater beneath the impoundment (similar to baseline conditions) and a possible slight reduction in manganese concentrations.

Concentrations of dissolved metals other than iron and manganese in groundwater beneath and downgradient of the tailings impoundment are generally at low to non-detectable concentrations. Copper and antimony concentrations are slightly elevated in monitoring wells completed near the decant ponds but are near or below detection limits in monitoring wells downgradient of the impoundment (**Table 3-11**). This reduction in metals concentrations is likely related to both dilution and attenuation of metals along the groundwater flow path. As noted in the Draft 1978 EIS on page 313:

> "The tailings pond water quality would be modified, however, by a number of processes including oxidation in the pond, percolation through tailings and percolation through the underlying silts and clays. These fine-grained materials beneath the pond would cause some sorption and ion exchange of metals. Metals removal by earth materials has been examined in a number of waste systems and generally fine-grained materials have significant capacity to remove metals".

Reclamation at closure of the tailings impoundment under the No Action Alternative would be expected to further reduce concentrations of these metals in groundwater beneath the impoundment because mine water would no longer be added to the impoundment.

Surface Water Quantity

Lake Creek flows from south to north along the western perimeter of the tailings impoundment and groundwater beneath the tailings impoundment flows generally westward toward Lake Creek. The 1978 Draft EIS estimated that up to 1,170 gpm of seepage from the tailings impoundment enters the underlying groundwater system and enters Lake Creek. A water balance developed by ASARCO in 1989 recalculated the rate of seepage from the impoundment into groundwater and estimated an average flow of 850 gpm. Construction of toe ponds between the tailings embankment and Lake Creek during 1983 intercepted some of this flow, thus reducing the flux of groundwater into Lake Creek. Closure of the Troy Mine under the No Action Alternative would end discharge of mine water to the impoundment and could slightly reduce the quantity of surface water in Lake Creek as a consequence of reduced groundwater flow into the creek. However, this reduction would be offset by increased flow from Stanley Creek into Lake Creek where water from the underground mine would be discharged after closure of the operation.

Surface Water Quality/Nitrate/Metals/Sediment

Concentrations of nitrate in Lake Creek adjacent to the tailings impoundment site ranged from 0.03 mg/L up to 0.5 mg/L as nitrogen during the baseline period (1977-1981) and prior to deposition of tailings in the impoundment. **Table 3-9** shows water quality for Lake Creek at three stations in the

vicinity of the impoundment. Nitrate concentrations in Lake Creek have remained within the range of baseline conditions and indicate that there is little, if any, effect on nutrient concentrations in the creek from tailings impoundment seepage. Consequently, no changes in nutrient concentrations in surface water are expected to result from reclamation of the impoundment under the No Action Alternative.

Metals from the tailings impoundment could reach Lake Creek either via transport of dissolved metals through groundwater or via overland flow into the creek. Runoff from the impoundment surface currently reports to the decant ponds area on the eastern edge of the impoundment, which is an internal basin from which no runoff is possible. Runoff from the tailings embankment generally enters the toe ponds along the western margin of the tailings impoundment. Some of this water is pumped back into the impoundment and helps prevent water from overflowing the toe ponds and reaching Lake Creek. Water quality data collected from Lake Creek at monitoring locations in the vicinity of the tailings impoundment show no exceedances of the chronic aquatic life standard at the site downstream of the impoundment (LC-4) although occasional exceedances of this standard are noted at upstream stations (**Table 3-9**). This suggests that there is no consistent source of copper loading, such as groundwater discharge from the tailings impoundment area, to Lake Creek. Antimony has not been detected at any of the monitoring sites in Lake Creek.

Under the No Action Alternative, impacts to Lake Creek from metals derived from the tailings impoundment are not anticipated. Flow of groundwater from beneath the impoundment into Lake Creek would be reduced because mine water would not be discharged to the impoundment. The No Action Alternative proposes regrading the impoundment surface to allow runoff to enter "an appropriate natural drainage." Thus, there is some increased potential for metals in storm water runoff from the impoundment surface to reach the creek until the reclaimed surface is revegetated.

Reclamation of the tailings impoundment under the No Action Alternative would result in temporary increases in sediment eroded from disturbed ground reaching Lake Creek. No BMPs for limiting sediment were listed in the 1978 Reclamation Plan. Sources would include redisturbed soil stockpiles, haul roads, and the surface of the tailings impoundment. Transport of sediment would return to background levels once revegetation of disturbed areas is complete.

Stream Channel Morphology

No effects to the morphology of the Lake Creek stream channel are anticipated to result from reclamation of the tailings impoundment under the No Action Alternative.

3.9.5.2 Proposed Action

Mine Water Discharge

In the Proposed Action, the decant ponds would be used post-closure to dispose of mine waters discharging from the Service and Conveyor adits until the quality of this water improves enough to be discharged directly to Stanley Creek. Such a change in future water management would require issuance of, and compliance with, an MPDES permit. Under the Proposed Plan, mine water would be captured at the Service and Conveyor adit portals and then transported through the existing tailings pipelines to the

tailings impoundment for disposal. Concrete adit plugs would be constructed to funnel mine water into the pipeline (Genesis 2006, pp. 7-6 to 7-7). The quantity of water discharged from the adit would be the same as discussed under the No Action Alternative.

Water Quantity

The continued disposal of mine water via the pipelines to the tailings facility would continue to reduce flows into upper Stanley Creek, which may have occurred as a result of mine development.

Water Quality/Nitrates/Metals/Sediment

Under the Proposed Action, seepage is expected around the adit plug and could increase over time due to lack of maintenance of the pipeline intake structure. This seepage water contains metals and poses a risk of contamination to surface water. Using the existing tailings transport lines could also cause impacts to Stanley and Lake creeks if pipelines leak or break as they have in the past. This concern is real because of the age of the tailings lines (30-plus years) and because they are above ground. Pipeline leaks could also occur as a result of vandalism. Because mine water would not be discharged to Stanley Creek, implementation of the Proposed Plan would not have the water quality, sediment, and channel morphology impacts on Stanley Creek described for the No Action Alternative. The Proposed Action includes the use of the buried reclaim water line as a backup to the existing tailings pipelines. The reclaim water line has less wear than tailings pipelines because it was used to transport reclaim water, not tailings. However, buried steel pipelines are subject to corrosion. A buried line would pose a somewhat lower risk of erosion than an above ground pipeline. The existing pipelines contain no automated controls to shut the systems down in case of a leak.

Failures in the above ground pipelines could occur, discharging metals to Stanley or Lake creeks and cause erosion. These impacts could result in exceedances of water quality standards. Troy Mine, Inc., has to complete a Supplemental Environmental Project as part of a settlement for a tailings line spill in 2009. As part of the settlement, the mining company would install some controls on the tailings lines to minimize potential spills for the rest of mine life.

Mine Area Surface Water, Seeps, and Springs

Both the Proposed Action and the No Action Alternative have the same potential environmental consequences for mine area seeps and springs because the mine would flood to the same elevation. (Refer to the discussion under the environmental consequences of the No Action Alternative.) The Proposed Action would continue monitoring of surface water for heavy metals, but no further actions are proposed to protect water resources in the future.

Mill Site and Portal Patios

The mill pad and office pad areas would not be recontoured back to the pre-mine natural topography, but would be outsloped to drain precipitation (Figures 4-2 and 4-3, Genesis 2006). The fill slopes along the outside perimeter of the mill pad area, which generally range from 30 to 60 feet in vertical depth, would be left at the current angle-of-repose (approximately 1.3H:1V). The regraded area would be

covered with rocky glacial growth media located within the mill and office site pad areas. Additional borrow material, if needed, would come from the existing USFS borrow site to the north of the mill/office site area. This glacial material contains coarse fragments similar to the soils that existed in the area before mining began.

The two drainages that currently are routed through the long twin culverts would be routed across the mill pad and down the face of the fill slope in separate locations (Genesis 2006, Figure 4-3). The new channels would be armored with coarse rock to prevent scour during the proposed design flow resulting from a 100-year, 24–hour design flow event. Rock energy dissipation basins would be constructed where the channels reach the base of the fill slope. The existing culverts would be sealed with concrete at their upper ends. **Figure 3-3** shows the existing drainage system and the planned system after reclamation under both the Proposed Action and the Agency-Mitigated Alternative.

According to the Revised Reclamation Plan, adits would be closed against entry by placing backfill into the adits 30 feet and tight to the back (roof) (Genesis 2006). The mine patios at the North and South adits would be regraded to create an out-sloped surface. Twelve inches of glacial material would be placed over the regraded surface and revegetated with a forest mix. The angle-of-repose rock slopes below the adit patios would not be regraded, and no growth medium would be placed on them. The plan does not address the stream channel at the West Adit.

Water Quality/Sediment/Other Contaminants

The Proposed Action would eliminate the risk of future failure of the long twin culverts by decommissioning the culverts. However, because the reconstructed stream channels would cross the mill pad on fill material, all or part of the streamflow is likely to go subsurface and not follow the constructed channels, emerging from the fill slope or the toe of the fill slope at unknown locations. Erosion and resulting sedimentation is likely to occur from the point where the water emerges from the fill to where it enters Stanley Creek.

Water that does remain in the channels could cause erosion where the drainage is routed down the steep face of the mill site fill slope. The Proposed Action would base the channel design on the peak flow resulting from a 100-year 24-hour flow event. This flow is less than the 100-year recurrence interval peak flow that is recommended for design of new structures under the Forest Plan. Furthermore, no provision was made to route the larger stream from the toe of the fill slope to Stanley Creek, which is approximately 200 feet away. Considerable erosion could be expected as a new channel would be eroded.

Revegetation of the disturbed ground would prevent sedimentation to Stanley Creek from most of the regraded office and mill site areas. The angle-of-repose fill slopes along the outside perimeter of the mill pad area might continue to be a source of sediment and contaminants for a period of time, particularly where the slopes are in close proximity to Stanley Creek. Portions of these slopes are currently unvegetated and contain fine grained material and spilled concentrate from past snow plowing and road grading operations. Eventually natural revegetation would stabilize these slopes and lessen the risk of sedimentation.

The USFS borrow site would be regraded at 2:1 slopes and revegetated. It is unlikely to be a sediment source because the topography allows for sediment to be easily trapped on site.

If demolished buildings are buried on site as proposed, water leaching through these buried materials at the site would eventually discharge to Stanley Creek and could potentially contaminate surface water.

Under the Proposed Action, the North and South portal patios would be revegetated except for the angle-of-repose slopes, which do not currently contribute sediment to area streams. However, during reclamation and before vegetation is re-established, the patios pose a short-term risk of sediment delivery to nearby drainages. If the regraded areas are successfully revegetated with forest cover, they would not be a source of long-term sediment delivery to area streams. The intermittent stream channel at the West Adit patio could be a longer-term sediment source to Stanley Creek.

Roads and Other Facilities

The Proposed Action would leave the existing roads in place per USFS requirements. Roads would be left in their existing condition, and maintenance responsibility would be turned over to the USFS. The segment of NFSR 4626 that accesses the mill site would be left in its current paved condition.

The tailings pipelines would be retained to convey water from the mine site to the decant ponds. Once the mine water is of sufficient quality for direct discharge to Stanley Creek, the tailings pipelines, portions of which are buried less than 3 feet, would be removed and the disturbed ground reclaimed (Genesis 2006, page 4-14). The power line would be removed once power is no longer needed at the mill site. The disturbed ground associated with removal of any of these facilities would then be revegetated.

All other facilities (makeup well pump station, water reclaim pump station, and maintenance sump) would be removed. The maintenance sump would be blended to existing topography. Disturbed ground would be revegetated.

Surface Water Quantity

Roads would continue to exacerbate peak flows by concentrating storm water runoff and delivering it to stream channels. Elevated peak flows increase the risk of stream channel erosion.

Surface Water Quality

NFSR 4626 to the mill site would present a low risk of sediment delivery because it would remain paved. The USFS would have to maintain the road surface into the future to prevent deterioration.

As a result of leaving all the mining-related roads in their current condition, there would continue to be sediment delivery at stream crossings at current levels. There would continue to be a moderately high risk of steep road fill failures during storm events in both the Stanley and Ross creek watersheds.

Disturbed ground associated with removing the power line and the tailings pipelines would be revegetated. Where facilities are close to streams, short-term sediment delivery is possible until vegetation is re-established.

There is a potential for sediment delivery after reclamation of the maintenance sump because it is within 200 feet of Lake Creek, but sediment erosion at this site would be reduced by revegetation. The Proposed Action, does not address removal of tailings material that may be within the sump, so there may be a risk of water quality contamination here. It is not clear if the Proposed Action would re-establish the original surface contours when the maintenance sump site is reclaimed.

Stream Channel Morphology

The Proposed Action does not reduce the existing risk of road-related mass failures on Mt. Vernon. Based on past failure history, this risk appears to be moderately high. These failures result in severely scoured stream channels and substantial in-channel sediment deposition.

Tailings Impoundment

Under the Proposed Action, the tailings impoundment would be reclaimed by covering the surface with 18 inches of rocky, glacial materials derived from borrow sources located east of the impoundment and then revegetating this surface. No major changes to the final topography of the impoundment are proposed. Any surface contouring would be localized. Storm water from the impoundment surface would continue to drain toward the decant pond area, where it would either infiltrate to groundwater or it would evaporate. Water from the underground mine workings would continue to be discharged to the decant ponds via the tailings pipelines from the mine site. The toe pond pumpback system would continue to operate until water quality meets applicable criteria.

Groundwater Quantity

Under the Proposed Action, all mine water draining from the underground workings via the Service Adit would continue to be discharged to the decant ponds at a rate predicted to range from 300 gpm up to 3,100 gpm (Appendix C). This is similar to the rate of discharge of water into the tailings impoundment during operation of the mine. The quantity of groundwater flowing beneath the tailings impoundment would remain similar to current operational conditions and would be greater than the pre-mining flux of groundwater.

Groundwater Quality/Nitrate

The discharge of nitrate-containing mine water to the decant ponds would result in continued input of nitrate into groundwater beneath the impoundment for several years after closure of the mine. Based upon data collected during the interim shut-down of the mine between 1993 and 2004, nitrate concentrations in the mine water are predicted to decline rapidly after blasting ceases (**Table 3-7**); consequently, this continued addition of water to the tailings impoundment would not be predicted to result in long-term loading of nitrate to the groundwater in this area. Nitrate levels in groundwater near the decant ponds would decline to a few parts per million within a few years and would reach

background levels within a decade or so. Nitrate concentrations in downgradient groundwater would remain below the groundwater quality standard of 10 mg/L.

Groundwater Water Quality/ Metals

Mine water is expected to discharge from the Service and Conveyor adits after mine closure. The No Action Alternative would allow this water to discharge directly to Stanley Creek. As discussed in **Section 3.9.4.1**, Affected Environment, Water Quality Sampling, the mine discharge is expected to have concentrations of copper and antimony that will exceed water quality standards for an unknown period of time (**Table 3-7**). Upper Stanley Creek, which already exceeds the aquatic water quality standard for copper during some sampling events at some monitoring locations (**Table 3-8**), would be further impacted if untreated mine water discharge enters it. To avoid further impacts to Stanley Creek, the Proposed Action would route mine water discharge through pipelines to the decant ponds at the tailings impoundment. Mine water would be treated through natural attenuation mechanisms as it infiltrates, allowing metals concentrations to attenuate within the soils (**Appendices C, D, and G**).

Groundwater beneath the tailings moves in a westerly direction and eventually discharges to Lake Creek (Summit Envirosolutions 1996). Mechanisms for attenuating metals (removing them from groundwater) below the impoundment include dilution, precipitation, adsorption, and co-precipitation. The effectiveness of these mechanisms in treating mine-related water has been substantiated through monitoring of water at the tailings impoundment for the past 30 years as well as studies directed at understanding the geochemical processes that occur in the underlying soils and groundwater system.

The 1978 Draft EIS for Troy Mine analyzed the dilution potential of Lake Creek on discharge of mine process water (DSL and KNF 1978). In the study, the discharge rate of process water into the aquifer was assumed to be 1,170 gpm and a conservative base flow of Lake Creek of 50 cfs (22,440 gpm) was used, which resulted in a 20:1 dilution ratio (*i.e.,* every gallon of tailings seepage water is diluted with 20 gallons of Lake Creek water). The quality of the process discharge water was taken from the maximum of two analyses of the water resulting from mill flotation/separation tests performed in 1976. These copper and antimony concentrations are much higher than those found in the discharge water expected from the closed mine. With this dilution ratio, the concentration of copper was less than the standard at that time (0.02 mg/L) but higher than the present chronic aquatic life standard (0.003 mg/L). Antimony was not considered a concern at the time of this analysis; however, this dilution ratio would allow compliance with the current standard for antimony in Lake Creek.

Data from monitoring of shallow wells near the tailings impoundment show that copper concentrations are much lower (often below laboratory detection limits) in groundwater than concentrations in the process water discharged to the decant ponds (Appendix H). This confirms that dilution and geochemical attenuation of metals are occurring below the impoundment. The primary geochemical attenuation processes, which are precipitation and adsorption of metals, were investigated by Land and Water (2004). Study results indicated that copper was attenuated within the upper foot of soil primarily through the precipitation of copper minerals (carbonates, silicates, and oxides) and through the adsorption of copper onto organic matter. Precipitation is the formation of a solid (mineral) from

dissolved constituents in groundwater, and adsorption is the dissolved metal adhering to the surface of particles. Hydrometrics (2010) conducted further studies to determine attenuation mechanisms for metals other than copper and including antimony to estimate the duration of the attenuation mechanisms (Appendix I). Metals concentrations were below the analytical reporting limit within 150 feet downgradient of the decant ponds. These results indicated that natural attenuation effectively removes metals from groundwater within a relatively short flow path. During 30 years of mine operation, copper and antimony have not been detected at levels that exceed applicable standards in groundwater at the edge of the tailings impoundment.

In regard to the duration of the primary attenuation processes, Hydrometrics states "The mineral precipitation and co-precipitation mechanisms are expected to last indefinitely or in perpetuity as long as geochemical conditions remain similar to current conditions. The geochemical conditions include soil composition and the pH and oxygen content of the discharge water and groundwater system. The adsorption mechanisms are conservatively estimated to last a minimum of 600 years" (Appendix I).

The 2004 Land and Water report focused on the current (primary) copper removal mechanisms within the decant pond sediments, while the CDM study (**Appendix D**) was designed to evaluate potential secondary removal mechanisms of copper and other metals that would occur in the event that the initial mechanisms become less effective. These additional, secondary processes would occur downgradient of the decant ponds in response to mixing the relatively oxygen-rich decant pond water with oxygen-poor and iron-rich natural groundwater. Theoretically, the mixing of the two waters would result in precipitation of iron minerals within the groundwater and concurrent removal of other metals such as copper and antimony. This process is known as co-precipitation of metals. To evaluate whether this mechanism was likely to occur, two processes had to be demonstrated: 1) that the mixing of the waters would result in the precipitation of iron, and 2) that other metals would be removed concurrently with the iron. The two processes were evaluated using geochemical computer modeling and laboratory testing, respectively. The computer modeling showed that between 98 and 100 percent of the iron would precipitate in response to mixing of the waters, while the laboratory tests showed that precipitation of the iron resulted in the removal of 73-98 percent of the copper and 11-59 percent of the antimony.

Taken together, the primary removal mechanisms (precipitation and adsorption) and the secondary co-precipitation processes that occur downgradient of the tailings impoundment ensure that copper and antimony would be removed from discharged mine water before groundwater reached Lake Creek. Numerous studies have been conducted to document that the possibility is remote for copper and other metals from mine water to reach Lake Creek at levels above the current regulatory limits. While the water from the decant ponds does move in the shallow groundwater toward Lake Creek, the effect of dilution alone would result in meeting human health criteria. Similarly, aquatic criteria are likely to be met due to the natural attenuation mechanisms that occur beneath the decant pond and in the groundwater system. Over 30 years of monitoring data have shown that copper and antimony do not migrate more than 150 feet downgradient of the decant pond at levels that exceed groundwater standards. Most of the copper and all measurable antimony are removed by primary attenuation processes occurring within the first foot of sediments below the decant pond. Additional secondary

attenuation mechanisms would result in further removal of copper. This becomes particularly important in the event that the primary attenuation mechanisms become less effective in the future. The precipitation attenuation mechanism is predicted to last indefinitely. The adsorption mechanism is predicted to last more than 600 years.

Proper functioning of the mine water disposal system could potentially be impacted if storm water transports fine sediment into the decant ponds at a rate that plugs the ponds with sediment and debris. This would prevent the infiltration of mine water through the decant ponds and limit the attenuation process beneath the tailings in the glaciofluvial materials.

Surface Water Quantity

Under the Proposed Action, mine water would continue to be discharged to the tailings impoundment decant ponds at a rate similar to current operational conditions. This water infiltrates through the tailings and into the aquifer, moves downgradient through the aquifer, and enters Lake Creek via groundwater flow paths. Mine water discharge and storm water runoff would be disposed of within the tailings impoundment area. There would be no overland flow from the tailings impoundment and no overall change to surface flow in Lake Creek.

Surface Water Quality/Nitrates

Nitrate concentrations in Lake Creek near the tailings impoundment are described in **Section 3.9.4**. There is no evidence of nitrate loading to Lake Creek as a result of operation of the tailings impoundment (see **Table 3-9**); consequently, no effects to nitrate levels in Lake Creek are predicted to result from reclamation of the tailings impoundment under the Proposed Action. Nitrate concentrations in mine water would decline after cessation of mining.

Surface Water Quality/Metals

As described for the No Action Alternative, operational water quality data from Lake Creek do not indicate that metals derived from the tailings impoundment reach Lake Creek (**Table 3-9**). Under the Proposed Action, continued discharge of mine water to the decant ponds would result in long-term addition of metals to the aquifer immediately beneath the tailings impoundment. As described in the groundwater quality section above, analysis of the Proposed Action indicates that attenuation of these metals is predicted to continue. Consequently, impacts to surface water from metals in water associated with the tailings impoundment are not anticipated.

Surface Water Quality/Sediment

As described above in the surface water quantity section, there would be no surface water runoff from the tailings impoundment area. The Proposed Action would use the borrow areas east of the impoundment for reclamation materials rather than the soil stockpiles located to the west between the impoundment and Lake Creek. This approach would reduce potential, short-term sediment impacts associated with erosion of disturbed soil. Maintenance of the decant ponds as a sump, rather than regrading the impoundment surface to drain into a natural drainage outside of the impoundment,

would also reduce the potential for sediment to reach Lake Creek compared with the No Action Alternative.

3.9.5.3 Agency-Mitigated Alternative

The Agency-Mitigated Alternative addresses those issues unresolved by the Proposed Action with respect to the methods of mine water capture, transport, and long-term treatment. This alternative requires that no demolition debris can be buried on NFSL.

Mine Water Discharge

Water Quantity

Similar to the Proposed Action, the continued disposal of mine water via the pipelines to the tailings facility would reduce the flow of groundwater that would naturally recharge Ross Creek and, especially, Stanley Creek. The effect would be continued reduction of flows in upper Stanley Creek which may have occurred as a result of mine development. The mine water intake design for the Service and Conveyor adit portals would be installed inside the adits to minimize freezing issues. The adits would be only partially backfilled but would still be accessible by small equipment through doors to allow maintenance. Both adits would have capture systems because the mine pool would overflow into the adits at the 4,225 foot elevation. Although cross-cuts connect the Conveyor Adit to the Service Adit, the cross cuts would not be maintained in the future, potentially forcing discharge out the Conveyor Adit. The rock surfaces that are below the pooled water in the adits immediately behind the dams as well as the rock around the concrete dams would be grouted to prevent seepage.

Water Quality/Nitrates/Metals/Sediments

The mine water intake structures proposed for the Service and Conveyor adits would minimize seepage of water and mitigate any potential for contamination of Stanley Creek. The Agency-Mitigated Alternative also proposes burying a new pipeline that would transport mine water to the tailings impoundment instead of using the existing tailings pipelines. The existing, buried reclaim water pipeline would be used as a backup line for overflow or if the new buried pipeline needs repair. Installing sensors, valves, and telemetry is designed to monitor the pipeline for leakage and to divert water to the backup line when needed (Appendix G). In addition, the new pipeline would be double-lined at creek crossings to minimize the potential of discharge directly to streams. Implementation of a leak detection system, installation of a new buried pipeline, reuse of the buried backup, and double-lining stream crossings all reduce the risk of affecting local groundwater systems and Stanley and Lake creeks. Although localized contamination of soil could still occur if a pipeline leaks, the risks of contamination of surface water by mine water are low and the impacts would be short-term.

A failure of the new buried pipeline would be partially contained by the fill material surrounding the pipeline, which would reduce the rate of release of water to the environment. The greatest risk would be at stream crossings, where an above ground line could rupture and release pipeline contents directly to surface water. Troy Mine, Inc. would be required to double-line or bury all pipelines at stream crossings to minimize the risk of surface water contamination. Delivery of sediment to streams would

also be reduced under this alternative because there would be no direct discharge of mine water to Stanley Creek as in the No Action Alternative. Finally, sediment delivery from an above ground pipeline break, which could occur under the Proposed Action, would also be eliminated.

Mine Area Surface Water, Seeps, and Springs

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative all have the same potential environmental consequences for mine area seeps and springs because the mine would flood to the same elevation. Refer to the discussion under the environmental consequences of the No Action Alternative.

Mill Site and Portal Patios

Mine Water Quantity and Quality

This plan is similar to the Proposed Action but with some alterations (**Table 2-1**). The Agency-Mitigated Alternative proposes additional design elements for both drainages across the mill patio (Appendix E). In the Agency-Mitigated Alternative, a larger channel would be built across the patio and down the fill slope with rock sized as needed to stabilize and protect the fill and native ground from eroding during the 100-year peak flow event. The channel would be lined with an impermeable liner to prevent the streamflow from going subsurface. The point where the larger channel reaches the toe of the fill slope would be aligned with the original drainage and would reduce erosion between the toe of the fill and Stanley Creek. The existing twin culverts would be plugged with concrete at the both inlet and outlet ends. A rock energy dissipation basin in the channel at the base of the fill slope would be built to prevent scour as in the Proposed Action and a four-foot diameter culvert would be installed beneath the access road for the large drainage. The smaller drainage located above the mill building would be routed along the uphill side of the access road to the larger drainage channel (**Appendix E**). It would also be lined with an impermeable liner and designed to withstand a 100-year flow event. The smaller drainage would be combined with the larger drainage, thus eliminating the need to build two armored channels down the fill slope as in the Proposed Action.

At mine closure, a new buried water pipeline would carry mine water from the Service and Conveyor adits to the decant ponds at the tailings impoundment for disposal and treatment. Should the mine water eventually attain surface water standards, another small channel would be constructed from the Service and Conveyor adits to route mine water directly to Stanley Creek. This channel would be sized to convey the expected maximum discharge from the adits (6.9 cfs).

Fine material on the south end of the mill site fill face below the portals would be regraded to a more stable slope, reseeded, and then covered with an appropriate erosion control mat to prevent erosion until vegetation is established.

Mine patios at the North and South adits would be reclaimed as described in the Proposed Action. However, under the Agency-Mitigated Alternative, a stream channel would be constructed at the West Adit patio, thus reducing sediment delivery to Stanley Creek.

All building demolition material would be removed from NFSL in contrast to burying material on-site as planned in the Proposed Action. This change would eliminate any potential risks to water quality from this material.

Roads and Other Facilities

The existing paved surface on NFSR 4626 from MP 2.39 (junction with NFSR 7148) to 8.36 (junction with NFSR 4626D) would be pulverized in place and converted to 4 inches of gravel surfacing. This would increase sediment delivery to surface water as compared to a paved surface. BMPs such as drain dips would be implemented to reduce potential sediment delivery. Three hundred feet of pavement would be left on either side of bridge crossings to minimize sediment delivery to surface water. BMPs would be implemented on NFSR 4626 from MP 8.36 to 11.56 (junction with NFSR 4629), NFSR 4629, and NFSR 4628 from MP 0.0 to 6.7. These roads would be left in a drivable condition that minimizes adverse impacts on the watershed without the need for regular maintenance (see **Table 2-1**). NFSR 4630A would also be treated to minimize adverse impacts on the watershed without the need for regular maintenance. However, because there is no short-term need for this road, it would not necessarily be left in a drivable condition. **Table 2-1** describes the treatments for each road, and **Figure 3-10** in the Transportation Section shows the location of the roads to be treated.

NFSRs 4624, 4624B, 4626C, 4626D, 4626F, 4626G, 4628C, and 9003 would all be actively decommissioned and treated according to **Table 2-1** and are shown in **Figure 3-10.** Most of these roads were identified as having the potential to cause sediment delivery from road surface erosion and from road fill failures. The exceptions are NFSR 4626C (access to the percolation ponds at the mill site) and NFSR 9003 (access to the water make-up wells). These roads would be decommissioned as actions connected to reclamation of mine facilities. The purpose of the active decommissioning and maintenance treatments would be to decrease road surface erosion, to decrease the risk of fill failures or washouts, to decrease routing of water by the roads, and to enhance infiltration and native revegetation.

The remaining NFSRs would not be physically treated. These roads do not pose a risk to the watershed because of topography, soil type, and/or distance from stream channels. The roads that have no future need would be removed as NFSR by being passively decommissioned (**Figure 3-10**). Most of these roads are revegetated.

Hydrologic effects of those roads on private, patented ground on Mt. Vernon are currently unknown. Some of these roads may be routing water and/or posing a risk of sediment delivery to Stanley or Ross creeks. Under the No Action Alternative and the Proposed Action, no reclamation of private roads is proposed. Under the Agency-Mitigated Alternative, all private roads on Mt. Vernon that would not be needed for a post-mine land use would be treated on the basis of an agency field review to decrease road surface erosion and to decrease the risk of failures or washouts.

The two existing above-ground tailings pipelines would be removed when no longer needed, and the disturbed ground would be scarified and revegetated.

For long-term operation of water management facilities at the mine site, Troy Mine, Inc. would be required either to maintain the existing overhead power line or to replace it with an underground power line that would be installed when the new mine water pipeline is constructed.

The other facilities (makeup well pump station and water reclaim pump station) would be removed. The disturbed ground at the sites would be ripped, recontoured, and revegetated.

The maintenance sump area next to Lake Creek would be recontoured to re-establish premine contours. Any tailings in the sump posing a risk to water quality would be removed and placed in the tailings impoundment prior to reclamation.

Surface Water Quantity

Roads can increase peak flows by routing runoff more directly to stream channels. The proposed road treatments would decrease the effect of road runoff on peak flows.

Surface Water Quality

Replacing the paved surface of NFSR 4626 with gravel would increase the risk of sediment delivery from the road surface as compared to the existing paved condition. Retention of the 300 ft of pavement at the bridge crossings and implementation of BMPs on NFSL would limit the sediment contribution to surface water.

Treatment of NFSRs 4624, 4624B, 4626, 4626D, 4626F, 4626G, 4628, 4628C, and 4629 would result in minor, short-term sediment delivery during the first year following treatment. By the second year, however, revegetation would minimize sediment delivery. Over the long-term, there would be less sediment delivery from surface erosion and stream culvert failures to Ross and Stanley creeks from these roads than under the existing condition or the Proposed Action. The risk of mass failures and the accompanying sediment delivery would also be reduced.

Disturbed ground associated with removal of the power line and removal of the above ground-tailings pipelines would be revegetated. Where the facilities are close to streams, short-term sediment delivery would be possible until vegetation is re-established.

There is the potential of sediment delivery after reclamation of the maintenance sump because it is within 200 feet of Lake Creek. However, sediment at this site would be reduced by design features including control on timing of work, installing sediment traps, establishing a temporary ground cover, and planting site-appropriate shrubs and trees.

Stream Channel Morphology

Short-term sediment delivery from reclamation activities associated with road treatment and other facilities would not be expected to have a measurable effect on stream channel morphology. Stabilizing roads would reduce the long-term risk of mass failures and would protect stream channel conditions in

Stanley and Ross creeks. Reclaiming the maintenance sump would restore the premine floodplain adjacent to Lake Creek.

Tailings Impoundment

Reclamation of the tailings impoundment under the Agency-Mitigated Alternative would differ from the Proposed Action in two ways: 1) soil from the stockpiles located between the impoundment and Lake Creek would be used to cover the tailings impoundment surface; and 2) a revegetated berm would be established between the reclaimed tailings impoundment surface and the decant ponds to prevent sediment from washing into the decant ponds. This effort would reduce long-term maintenance requirements associated with clean-out of the decant ponds to maintain their function as percolation ponds.

Groundwater Quantity

Potential groundwater quantity impacts that would result from implementing the Agency-Mitigated Alternative would be similar to those discussed for the Proposed Action.

Groundwater Quality/Nitrates/Metals

Potential groundwater quality impacts associated with nitrate and metals that might result from implementing the Agency-Mitigated Alternative would be similar to but less than those found under the Proposed Action. Additional measures that would further decrease likely impacts include installing a revegetated berm around the decant ponds to keep storm water and sediment out of the ponds. This berm would keep debris and sediment from plugging the ponds, would maintain infiltration capacity in the decant ponds, and would maintain geochemical conditions needed to attenuate copper.

Surface Water Quantity

Potential surface water quantity impacts resulting from the implementation of the Agency-Mitigated Alternative would be the same as those discussed for the Proposed Action.

Surface Water Quality/Nitrates/Metals

Implementation of the Agency-Mitigated Alternative would result in similar potential surface water quality impacts associated with nitrate and metals as those discussed for the Proposed Action.

Surface Water Quality/Sediment

As compared to the Proposed Action, the Agency-Mitigated Alternative slightly increases the short-term risk of sediment delivery to Lake Creek during reclamation activities because soil stockpiles located near Lake Creek and the toe ponds would be used. The vegetated lower portion of the stockpiles would be retained to filter sediment, and the disturbed area would be revegetated, thus minimizing long-term risk to surface water. See more sediment limiting BMPs in the discussion under western toads in **Section 3.18.5.10**.

Stream Channel Morphology

No effects to the Lake Creek stream channel morphology are anticipated from reclamation of the tailings impoundment under the Agency-Mitigated Alternative.

3.9.5.4 Cumulative Effects

Water Quantity

Under the No Action Alternative, discharging mine water directly to Stanley Creek would increase base flows in this stream, but the relative effect would diminish in the downstream direction. Flows in Lake Creek below the tailings impoundment should not be affected compared to current flows. There could be a small increased flow in seeps, springs, and tributary streams in the vicinity of the mine workings compared to current conditions with the mine operating. However, there would be little change in flow compared to the undocumented premine conditions. Planned vegetation management in the Stanley Creek watershed is predicted to increase cumulative peak flows in upper Stanley Creek by nine percent above flows expected with undisturbed conditions (KNF 2010). These cumulative actions would further increase streamflows in upper Stanley Creek. Peak flows in Lake Creek are and will remain unaffected by vegetation removal on federal and private lands for the foreseeable future. The current 7% equivalent clearcut area is well below a level that could increase peak flows (KNF 2010).

Under the Proposed Action and Agency-Mitigated Alternative, existing reductions to streamflow in Stanley Creek due to interception of groundwater by flooding mine workings would continue. On-going vegetation management in the Stanley Creek watershed elevates peak flows in upper Stanley Creek (USFS 2010). Therefore, reductions in streamflow due to interception of groundwater by the mine workings may be partially offset by peak flow increases due to vegetation management or wildfire. Water discharged from the mine would be returned to the watershed at the tailings impoundment and would result in no net loss to Lake Creek below the tailings impoundment.

Water Quality

There have been occasional low-level exceedances of copper standards in upper Stanley Creek (SC-15). The source(s) of these exceedances may be due to any number of factors, including sediment generated from surface water erosion of naturally copper-bearing soil, groundwater seeping from the mine void, erosion of copper-bearing soil from the portal patios, or groundwater containing naturally-elevated copper concentrations from mineralization in the area. The occasional low-level naturally-occurring copper exceedances in upper Stanley Creek would be expected to continue through post-closure for all alternatives. There have historically been numerous detections of copper in Fairway Creek despite the Fairway site being upgradient of the mine. The most likely reason for these detections is that copper occurs naturally in the region and is present in soils and sediment. Occasional exceedances in any stream in the area should not be ruled out for this reason.

No abandoned or inactive mines within the analysis area have contributed water quality impacts (Hargrave *et al.* 1999).

Minor sediment effects from non-mine-related sources, such as timber harvest roads and private land development, would continue to occur in Stanley and Lake creeks during and post-reclamation under all alternatives. This sediment would be in addition to the reclamation-related sediment. In Stanley Creek, it is expected that other sources would be immeasurable compared to the reclamation work. In Lake Creek, non-mine sediment sources are somewhat more substantial, but would still be substantially less than the sediment generated by the reclamation. There is virtually no potential sediment delivery from other land management sources in Ross Creek because of the undeveloped nature of the watershed.

The currently planned Sparring Bulls timber sale could result in minor short-term sediment delivery from road use. No sediment delivery is expected from harvest units (KNF 2010). Currently planned road BMPs, storage, and decommissioning projects would increase short-term sediment but reduce long-term sediment delivery to Lake Creek (KNF 2010). Most of this work would occur in the Camp Creek watershed which enters Lake Creek just above the tailings impoundment. These projects are expected to begin in 2011 and are likely to be completed well before mine reclamation occurs. As a result, potential sediment impacts from the planned road projects and the reclamation project are not expected to be additive.

No Action

Under the No Action Alternative, metals and nutrients would increase in Stanley and Lake creeks due to the direct discharge of mine water to the stream. This increase in nutrients would be expected to be a short-term effect based on the decrease in nutrient levels observed during temporary shutdown of the mine. On the other hand, the increase in metals would be expected to be a long-term effect. The increase could exceed aquatic life criteria and result in adverse impacts to macroinvertebrates and amphibians in upper Stanley Creek. Based on previous monitoring, it appears unlikely that seeps, springs, and small tributaries in the vicinity of the mine workings would exceed water quality standards as a result of contamination by mine water. The possible exception would be upper Stanley Creek where seeps may express mine water and erosion at the mill site and at the North Portal could contribute copper to the stream.

Sediment generated at the portal patios, mill patio, and at the tailings impoundment would be delivered to streams and result in short- and long-term turbidity and sediment deposition. Under the No Action Alternative, roads would be treated to minimize sediment contributions to area streams, thus reducing the current contribution rate from roads. Sediment levels would remain elevated in Stanley Creek because of potential erosion both at the mill site and at the North Portal and would probably increase in Lake Creek due to erosion at the tailings impoundment. Sediment levels in Ross Creek would decline over time due to the road treatments.

Proposed Action

Under the Proposed Action there would be no direct discharge of mine water to Stanley Creek from the mine portal. Seeps around the plug to the Service and Conveyor adits could occur and result in water quality impacts. These seeps do not presently exist and would be localized in the vicinity of the mine portal. They would be distinct from those existing and potential future seeps located elsewhere in the

vicinity of the mine workings. Based on previous monitoring, it appears unlikely that seeps, springs, and small tributaries in the vicinity of the mine workings would exceed water quality standards as a result of contamination by mine water. A possible exception to this conclusion could occur at upper Stanley Creek where seeps may express mine water and erosion at the mill site and at the North Portal could contribute copper to the stream (see **Table 3-10**).

There would be an on-going risk of accidental release of mine water to Stanley and Lake creeks from a pipeline failure under the Proposed Action. Such a failure could result in water quality standard exceedances in Stanley or Lake creeks until water flow through the pipeline could be shut off. However, these events would be episodic and would only result in relatively short-term releases of mine water and sediment from erosion to surface water.

The Proposed Action would bury demolition material at the mill site that could adversely affect water quality.

There would be a short-term sediment impact to surface waters from reclamation activities at the mill site that would not be completely mitigated by implementation of BMPs. Fine sediment would be flushed from the newly constructed channels. There would be long-term sediment delivery from scour between the toe of the mill site fill and Stanley Creek where the larger drainage is proposed to be routed. Long-term sediment impacts would also potentially occur from erosion of the face of the mill site fill where it is crossed by drainages. There would be an on-going risk of sediment delivery from the road system, including the risk of mass failures, because roads would not be reclaimed under the Proposed Action.

Long-term sediment levels would remain elevated in Stanley Creek because of erosion at the mill site and North Portal and because of the erosion coming from the existing road system. Ross Creek would remain at risk to short-term impacts from sediment delivery from road failures. Tributaries to Stanley and Ross creeks would continue to be degraded by peak flows and by sediment delivery from roads. Under the Proposed Action, there would be a low risk of sediment delivery to Lake Creek from the reclaimed tailings impoundment, but chronic sediment delivery to Lake Creek from the mine site would probably persist for several decades.

Agency-Mitigated Alternative

There would be no direct discharge of mine water to Stanley Creek from the mine portal. Seeps around the dam in the Service and Conveyor adits would be unlikely. Based on previous monitoring, it would be unlikely that seeps, springs, and small tributaries in the vicinity of the mine workings would exceed water quality standards as a result of contamination by mine water with the possible exception of upper Stanley Creek where seeps may express mine water and erosion at the mill site and at the North Portal could contribute copper to the stream (**Table 3-10**).

There would be a lower on-going risk of accidental release of metals-contaminated water to Stanley and Lake creeks from the new buried pipeline as compared with the Proposed Action.

In contrast to the Proposed Action, no demolition materials would be buried at the mill site, so there would be no risk to water quality from this material.

There would be short-term sediment impacts from reclamation activities that could not be completely mitigated by implementing BMPs. Fine sediment would be flushed from the new channel locations. This sediment contribution is expected to rapidly decline after 2 to 3 years. Long-term sediment delivery would be reduced as compared to current conditions and would also be less under this alternative than the No Action Alternative or Proposed Action. Combining the two drainages, as proposed by the Agency-Mitigated Alternative, would reduce long-term sediment impacts from erosion of the face of the mill site fill. Erosion from the mill site fill would be reduced by revegetation. Routing the channel to the pre-existing channel location would also reduce the amount of potential erosion. Erosion above the west ventilation adit would be reduced by constructing a stream channel. Although sediment from NFSR 4626 would be slightly increased by converting the paved surface to a gravel surface, chronic and episodic sediment from the remainder of the road system on Mt. Vernon would be reduced.

Short-term sediment inputs from reclamation activities would decline within 1-2 years. Long-term sediment levels in Stanley Creek would decline as compared to current conditions and would be lower than either the No Action Alternative or the Proposed Action. Sediment levels in Ross Creek would decline over time because of road treatments on Mt. Vernon. Tributary streams to Stanley and Ross creeks would be at less risk from road failures than under the existing conditions or under the Proposed Action. Sediment levels in Lake Creek would be expected to decline to levels lower than the existing condition because the mine-related sediment would be reduced by the reclamation activities, and other road-related sediment would be reduced by the BMP, storage and decommissioning work already planned in other areas on NFSL in Lake Creek watershed.

Stream Channel Morphology

All three alternatives would have a short-term increase in sediment delivery due to reclamation activities. Under the No Action Alternative and under the Proposed Action, sediment delivery from the mine and mill site area would be expected to persist. Sediment would be deposited in lower Stanley and Lake creeks. Under the Agency-Mitigated Alternative, sediment delivery from upper Stanley Creek would be less and more short-term than under the No Action Alternative or the Proposed Action.

Under all alternatives, effects on Lake Creek channel morphology are expected to be undetectable due to the sediment transport capacity of Lake Creek. Therefore, there would be no cumulative effects on channel morphology.

Under the Proposed Action, roads would not be reclaimed, so road failures would be more likely to occur. Road failures could scour steeper headwater reaches and deposit sediments in lower-gradient valley reaches in the northern tributaries of Ross Creek as well. Under the No Action and Agency-Mitigated alternatives, roads would be reclaimed, reducing this potential impact.

Beneficial Uses of Surface and Groundwater

Under the No Action Alternative, copper would exceed chronic aquatic life standards in Stanley Creek and occasionally in upper Lake Creek. Due to direct mine water discharge, aquatic life and habitats would potentially be adversely affected by sediment and metals in these streams. No adverse effects are expected on groundwater quality. Domestic wells in the vicinity of the tailings impoundment would not be affected.

Under the Proposed Action, copper would exceed chronic aquatic life standards in Stanley or upper Lake creeks for brief periods if a mine water pipeline failure occurred. Sediment from the mill site and roads would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact beneficial uses for an extended period of time. Sediment delivery to Stanley and Lake creeks from sources in upper Stanley Creek would occur over the long-term. Cumulative deposition of sediment from erosion would impair fish habitat in lower Stanley Creek. Turbidity, which also adversely affects fish, would occasionally be elevated in Stanley and Lake Creek as a result of sediment from the mine reclamation area. Fisheries habitat in Ross Creek could be adversely impacted by sediment delivery from road failures. No adverse effects are expected on groundwater quality. Domestic wells in the vicinity of the tailings impoundment would not be affected.

Under the Agency-Mitigated Alternative, the new buried pipeline and leak detection system would minimize the risk of accidental discharge of mine water to Stanley or Lake creeks. Short-term sediment delivery from mill site reclamation activities would occur but would be minimized with mitigation. Road stabilization work would decrease long-term sediment delivery. Over time, sediment delivery to Stanley and Lake creeks would decline as compared to the existing conditions and would be lower than under the Proposed Action. Aquatic life and fisheries would be protected under the Agency-Mitigated Alternative. No adverse effects are expected on groundwater quality. Domestic wells in the vicinity of the tailings impoundment would not be affected.

3.9.5.5 Resource Impact Summary

Direct mine water discharge into upper Stanley Creek under the No Action Alternative would impact water quality in Stanley Creek and upper Lake Creek. In comparison to the No Action Alternative, mine water disposal under either the Proposed Action or the Agency-Mitigated Alternative would reduce potential water quality impacts to Stanley Creek and to upper Lake Creek. Under both the Proposed Action and the Agency-Mitigated Alternative, the mine discharge would be routed to the decant ponds for treatment. At the decant ponds, the water would infiltrate and be treated by natural attenuation mechanisms along the groundwater flow path to reduce concentrations of metals of concern to levels that would meet water quality standards. Surface water quality impacts would be further reduced under the Agency-Mitigated Alternative by installing a new buried mine water pipeline and by installing a leak detection and backup system for mine water transport.

Stanley and Lake creeks have been listed on the TMDL 303d list as impaired streams. Probable causes of impairment of Stanley Creek are copper and nutrients. Probable causes of impairment of Lake Creek are nutrients, sediment, and physical substrate habitat alterations. Because nitrate concentrations would

decrease after blasting ceases, closure and reclamation of the mine would reduce nutrient loading to surface water under all alternatives. After mine closure, there would be reduced risk of spills of mine tailings into surface water under all alternatives. The No Action Alternative would result in increased copper loading from mine water discharge to Stanley Creek and would not accomplish the goals of the TMDL program. Both the Proposed Action and the Agency-Mitigated Alternative would reduce the potential for loading of copper to Stanley Creek. Reclamation of mine roads on NFSL under the No Action and Agency-Mitigated alternatives would reduce sedimentation and siltation in Lake Creek over the long-term.

3.9.5.6 Effectiveness of Mitigation Measures

Management of erosion across all reclaimed areas, including decommissioning roads, improvements to revegetation and the implementation of Agency BMPs, is a standard and proven practice that effectively minimizes sediment delivery to surface water. Management of mine water by requiring an appropriately sized and engineered buried pipeline, an engineered leak detection system, and an automated backup system is a standard practice for minimizing the impacts of pipeline failure to surface water. The Agencies' engineered drainage channel design uses standard design methods to effectively minimize erosion and sediment delivery to surface water. Treatment of mine water by attenuation in the glaciofluvial sediments beneath the decant ponds was predicted in the 1978 EIS and has been proven through 30 years of effective operation. Both the exclusion of storm water through use of a berm and the periodic removal of sediment and debris from the decant ponds would effectively maintain their function as percolation ponds and would ensure that mine water continues to infiltrate.

3.9.5.7 Regulatory Compliance

The No Action Alternative would not comply with the Federal Clean Water Act, Montana Water Quality Act, USFS policy, or with the Kootenai National Forest Plan because untreated mine water would be discharged to surface water that would, in turn, exceed water quality standards. Moreover, moderate to high sediment delivery is likely from the mill site, mine portals, and from the tailings impoundment even following the proposed reclamation.

The Proposed Action and Agency-Mitigated Alternative would comply with the Federal Clean Water Act and the Montana Water Quality Act because mine water discharged to the decant pond would be treated by natural attenuation in the soils and aquifer beneath the tailings impoundment. The effectiveness of these mechanisms has been documented to remove metals over the 30-year period of mine operation. Studies conducted for this EIS have demonstrated the long-term viability of treatment by natural attenuation mechanisms to meet water quality standards. **Table 3-11** demonstrates that antimony and copper concentrations downgradient of the tailings impoundment have consistently met groundwater quality standards. The antimony and copper water quality standards have been met at the Lake Creek monitoring station downstream of the impoundment. This indicates that groundwater discharging to surface water in the vicinity of the impoundment does not compromise water quality in Lake Creek (**Table 3-9**).

The Proposed Action would not fully comply with the Federal Clean Water Act because of the potential for sediment impacts to surface waters. Sediment would originate from stream erosion across the mill site. The Proposed Action would also not be fully compliant with USFS manual and policy direction with respect to roads because unneeded roads that pose a resource risk would not be treated, and restoration work on needed roads would not be implemented. Any additional sediment from these sources would add to the already elevated sediment load that currently exists in Stanley Creek and would adversely impact beneficial uses for an extended period of time. Some of this sediment would also be expected to reach Lake Creek, which is listed as impaired for sediment. There is also a greater risk of short-term water quality violations under the Proposed Action because of the higher risk of accidental discharge of mine water from the tailings pipeline to Stanley or Lake creeks.

The Agency-Mitigated Alternative would comply with the Federal Clean Water Act, Montana Water Quality Act, USFS policy, and with the KNF Forest Plan because it would reduce sediment loading both by implementing reclamation actions and by treating mining road-related sediment sources. Thus, sediment levels in Stanley and Lake creeks would be expected to decline over time.

All alternatives would comply with the Clean Water Act with respect to discharging dredged or fill materials into water or wetlands and with Executive Order 11990, which directs agencies to minimize impacts to wetlands. No activities are proposed under any alternative that would discharge fill materials into water bodies or that would impact wetlands.

3.10 Land Use

3.10.1 Introduction

Land use involves either the natural conditions or the human-modified activities that take place in a specific area. Management plans and land use regulations can impact and determine the types of uses that are allowed in an area and often are established to protect sensitive features or areas. This section of the EIS characterizes land use within the Troy Mine Permit Area and surrounding Lake Creek watershed, and it also identifies potential land use changes under each reclamation alternative.

Mining has occurred within the Permit Area for nearly 30 years. After reclamation, the public lands within the Permit Area would be open lands available for recreation, similar to that of surrounding public lands. However, Troy Mine, Inc. or any subsequent owner may continue to restrict public access to private lands within the Permit Area. This section will concentrate on reasonably foreseeable land use changes that could occur on public lands within the Permit Area after mine reclamation is complete.

3.10.2 Regulatory Framework

The 1987 KNF Forest Plan establishes the land management framework for activities on NFSL and serves as the guiding management document until the 2008 Planning Rule is implemented. The 1987 Plan's goal is to promote a balance of multiple uses on KNF lands, including timber management, resource extraction, recreation, and maintenance of natural values. The Plan provides a management framework to harmonize scenic values with operations and to protect fish and wildlife habitats. As such, USFS must

review Troy Mine, Inc.'s reclamation plan to ensure that future uses of public lands within the Permit Area are consistent with management area requirements after cessation of mining.

Additional regulatory framework for this section includes both the Lincoln County Subdivision Regulations and the Lincoln County Floodplain Regulations, which apply specifically to private lands. Lincoln County does not have countywide zoning.

The Montana Subdivision and Platting Act (76-3-101 *et seq.*, MCA) requires local jurisdictions to adopt and enforce local subdivision regulations. Lincoln County has had subdivision regulations in place since 1973, and current regulations were adopted in 2004. There are no known plans for subdividing private lands within the Permit Area following reclamation. If Troy Mine, Inc. or any subsequent owner proposes a subdivision in the future, any plans would be reviewed by local authorities before approval.

Lincoln County has floodplain regulations in place to comply with the Montana Floodplain and Floodway Management Act (76-5-101 *et seq*., MCA) and to ensure compliance with the requirements of the National Flood Insurance Program. Regulated floodplains exist in the northern portion of the Permit Area.

The MMRA requires that all lands disturbed by mining be reclaimed to meet the post-mine land use.

3.10.3 Analysis Area

The analysis area for this section is the Lake Creek watershed, but it focuses on the vicinity of the Troy Mine Permit Area.

3.10.4 Affected Environment

3.10.4.1 Overall Land Ownership

Almost 79 percent of the area comprising the entire 131,000-acre Lake Creek watershed is managed by the USFS as part of the KNF (**Figure 3-6 and Table 3-13**). Most of the remaining 21 percent is privately owned. The State of Montana holds 2,648 acres within the Lake Creek watershed with the closest state parcel located approximately one half mile west of the tailings impoundment area (**Table 3-13**).

3.10.4.2 Kootenai National Forest Lands

Of the nearly 103,000 acres of NFSL within the Lake Creek watershed, there are 18 unique USFS Management Areas (MAs), as well as seven old growth forest sub-classifications. **Table 3-14** provides a breakdown of these lands and associated MAs, which are also detailed on **Figure 3-7. Figure 1-2** shows land ownership surrounding the Troy Mine Permit Area.

Table 3-13. Land Ownership within Lake Creek Watershed

Owner	Acres	Percent
USFS	102,910	78.72%
State of Montana	2,648	2.03%
Stimson Lumber	8,427	6.45%
Plum Creek Timber	449	0.34%
Other Private Parcels	15,088	11.54%
Water	1,199	0.92%
Total	130,721	

Source: KNF 2003

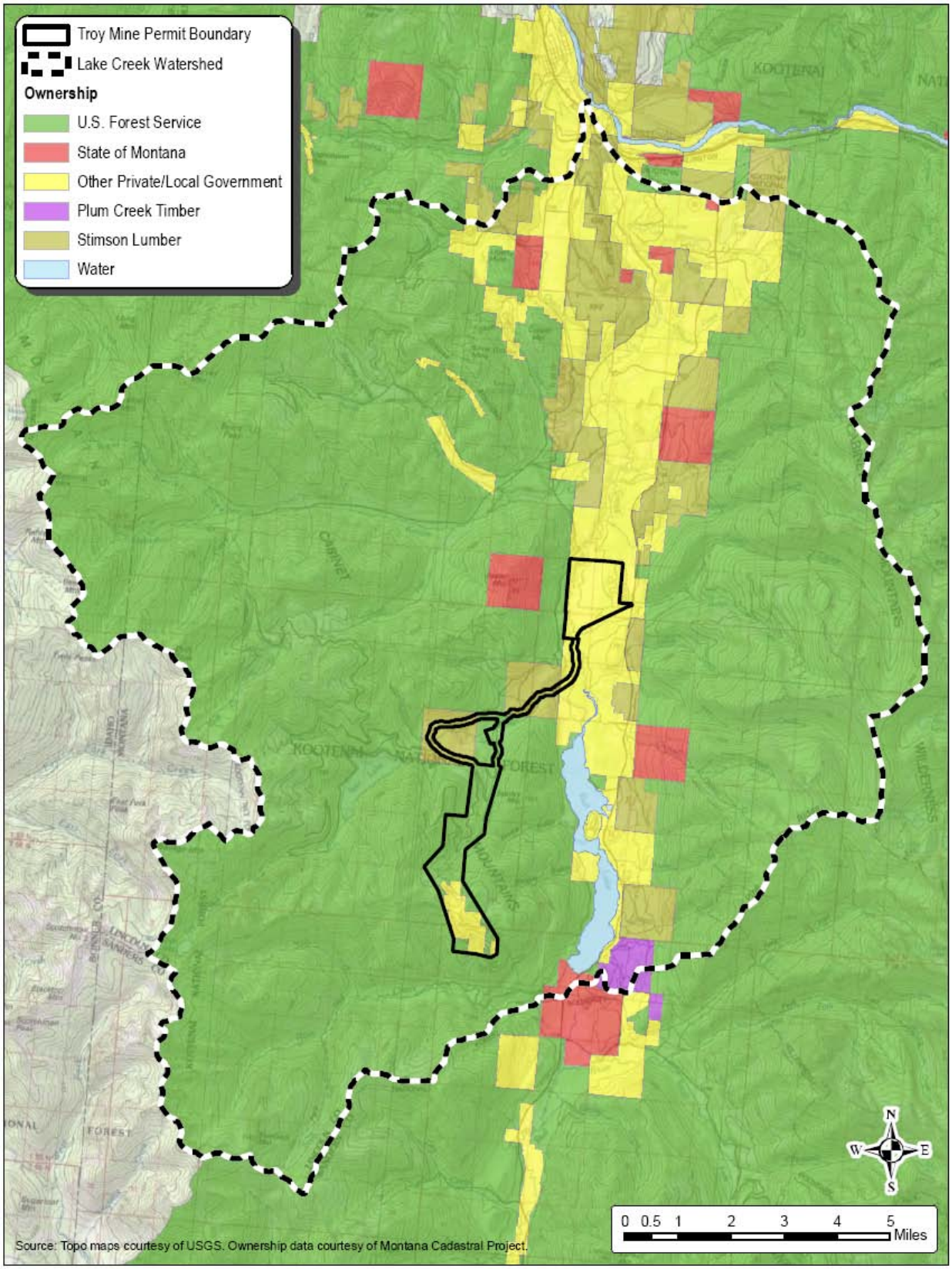


Figure 3-6. Land Ownership within Analysis Area for Land Use

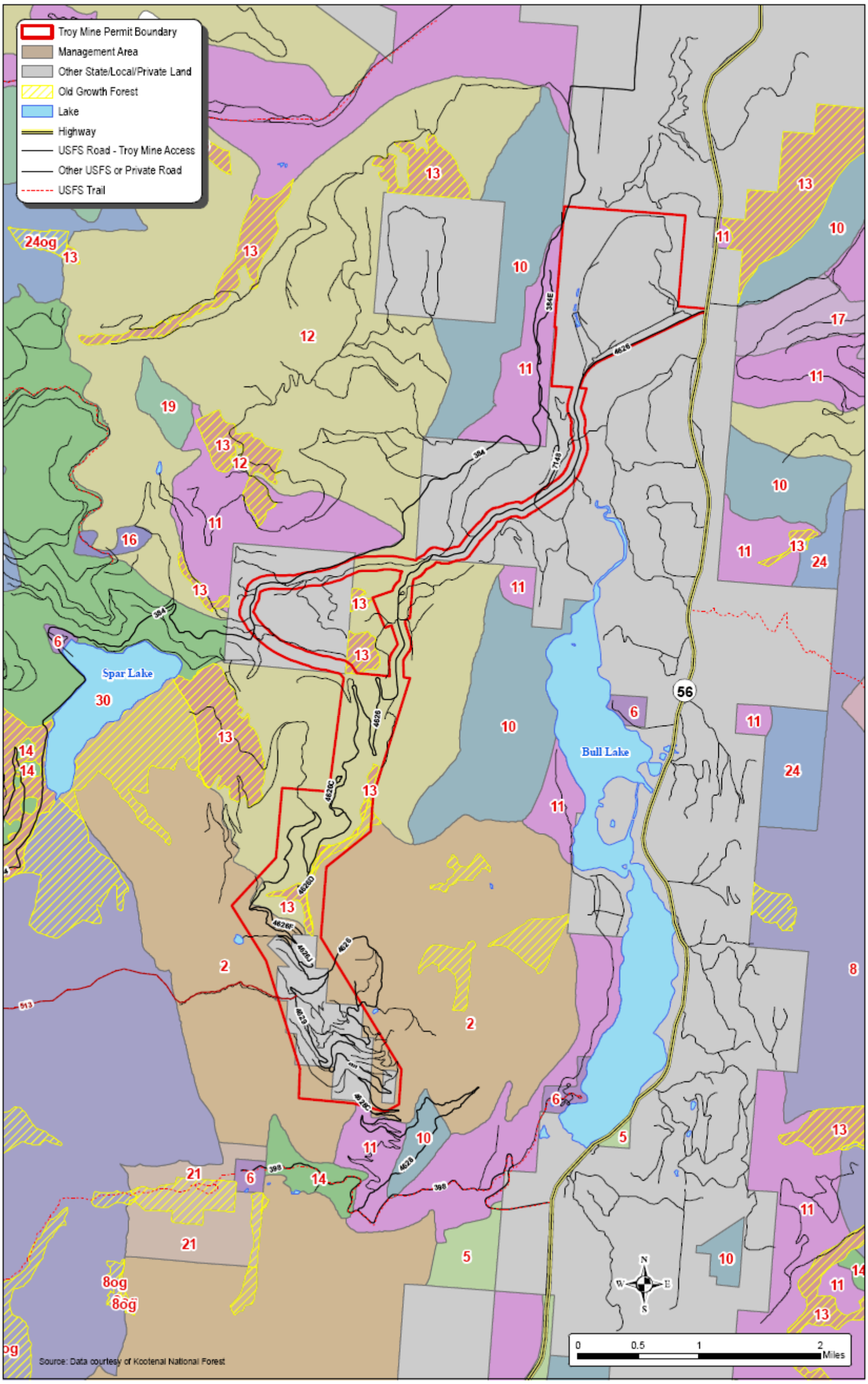


Figure 3-7. NFSL Management Areas

Table 3-14. KNF Management Areas within Lake Creek Watershed

MA	Description	Acres	Percent
pvt	Private land	27,804	21.27%
2	Large and small areas offering roadless recreation opportunities in a semi-primitive setting. Motorized vehicle use must be compatible with the roadless management goal. Timber harvest is not permitted.	14,939	11.43%
2og	Large and small areas offering roadless recreation opportunities in a semi-primitive setting. Motorized vehicle use must be compatible with the roadless management goal. Timber harvest is not permitted. Contains old growth forest.	1,334	1.02%
3	Small natural appearing areas offering opportunities for road-based recreation in a semi-primitive setting. Timber harvest must be compatible with the recreation management goal.	261	0.20%
5	Natural appearing areas containing highly sensitive viewsheds. Timber harvest must be compatible with the visual management goal.	27	0.02%
6	Small areas containing campgrounds, picnic areas, ski areas, etc; providing developed recreation opportunities.	160	0.12%
7	Cabinet Mountains Wilderness.	15,086	11.54%
7og	Cabinet Mountains Wilderness. Contains old growth forest.	115	0.09%
8	Areas being recommended for additions to the National Wilderness System.	20,889	15.98%
8og	Areas being recommended for additions to the National Wilderness System. Contains old growth forest.	2,495	1.91%
10	Areas generally below 4,500-feet elevation on favorable solar exposures which are important for big game winter range. They are generally difficult to manage for timber because of low productivity or difficult environmental problems.	2,849	2.18%
11	Same as Management Area 10 except that productive forest lands are involved which can provide both wildlife and timber benefits.	7,892	6.04%
12	Productive forest lands containing moist or wet habitat types at elevations above 4,500 feet. Managed to provide forage, cover, and security for big game by using compatible timber and road management prescriptions.	17,241	13.19%

MA	Description	Acres	Percent
13	Small areas generally below 5,500-feet elevation providing special habitat needs for old growth timber dependent species. Timber harvest is not permitted.	3,771	2.88%
14	Productive forest lands identified as being essential for the recovery of the grizzly bear. Managed to provide forage, cover, and security by using compatible timber and road management prescriptions.	8,370	6.40%
16	Productive forest lands that will be managed for high timber yields while protecting watershed, soil, fisheries, and providing a high level of protection to visual resources.	60	0.05%
17	Productive forest lands located within sensitive viewsheds. Timber harvest and visual resource management must be coordinated to provide a natural appearing landscape.	646	0.49%
18	Small productive forest areas that contain habitat types those are difficult to regenerate. Timber harvest must be compatible with regeneration goals.	752	0.57%
18og	Small productive forest areas that contain habitat types which are difficult to regenerate. Timber harvest must be compatible with regeneration goals. Contains old growth forest.	47	0.04%
19	Small productive forest areas that are on very steep slopes or in areas difficult and costly to develop roads. Timber harvest must be compatible with soil and watershed protection goals.	2,273	1.74%
19og	Small productive forest areas that are on very steep slopes or in areas difficult and costly to develop roads. Timber harvest must be compatible with soil and watershed protection goals. Contains old growth forest.	73	0.06%
21	Small areas containing both productive and non-productive forest land that are unique or special in some way, including Research Natural Areas. Managed to protect and retain these characteristics for public and scientific purposes.	400	0.31%
21og	Small areas containing both productive and non-productive forest land that are unique or special in some way, including Research Natural Areas. Managed to protect and retain these characteristics for public and scientific purposes. Contains old growth forest.	166	0.13%

MA	Description	Acres	Percent
24	Small areas of non-productive forest lands. Managed to protect soil, watershed, fisheries, and vegetation.	2,466	1.89%
24og	Small areas of non-productive forest lands. Managed to protect soil, watershed, fisheries, and vegetation. Contains old growth forest.	217	0.17%
30	Reservoirs and large lakes.	387	0.30%

Source: KNF 1999

3.10.4.3 Troy Mine Permit Area

The Troy Mine Permit Area is permitted for 2,782 acres. Approximately 57 percent of this area is private and patented land, and the remaining 43 percent is USFS managed acreage. The majority of the USFS acreage within the Permit Area is classified either as MA 2 or as MA 12. **Table 3-15** describes these lands and associated MAs.

Table 3-15. USFS Management Areas (MA) within Troy Mine Permit Area

MA	Description	Acres	Percent
pvt	Private land	1,500	57%
2	Large and small areas offering roadless recreation opportunities in a semi-primitive setting. Motorized vehicle use must be compatible with the roadless management goal. Timber harvest is not permitted.	313	12%
2og	Large and small areas offering roadless recreation opportunities in a semi-primitive setting. Motorized vehicle use must be compatible with the roadless management goal. Timber harvest is not permitted. Contains old growth forest.	31	1%
11	Same as Management Area 10 (described in Table 3-14) except that productive forest lands are involved which can provide both wildlife and timber benefits.	3	0.1%
12	Productive forest lands containing moist or wet habitat types at elevations above 4,500 feet. Managed to provide forage, cover, and security for big game by using compatible timber and road management prescriptions.	731	28%
13	Small areas generally below 5,500-feet elevation providing special habitat needs for old growth timber-dependent species. Timber harvest is not permitted.	57	2%

Source: KNF 1999

3.10.4.4 Private Lands

Private land comprises nearly 24,000 acres within the Lake Creek watershed (**Table 3-14**). Approximately 8,400 acres are owned by Stimson Lumber. Approximately 1,500 acres of private lands are located within the current Permit Area. Most of these lands are owned either by Revett Minerals or by Stimson Lumber (KNF 2003). Any development of private lands in the analysis area may be subject to Lincoln County Subdivision Regulations or to Lincoln County Floodplain Regulations, depending upon the nature of the proposed development.

Lincoln County Subdivision Regulations apply to all land divisions that create parcels smaller than 160 acres. A "Major" subdivision contains six or more lots, and a "Minor" subdivision is defined as one that contains five or fewer lots. A Subdivision Exemption may apply to family transfer situations: when a division of land occurs for the purpose of a single gift or sale to each member of a landowner's immediate family; for situations where a landowner splits off a piece of land for agricultural use only; or for relocating a common boundary between adjoining parcels (no new or additional parcels are created).

Lincoln County Floodplain Regulations apply to all lands within the jurisdiction of Lincoln County as shown on the official Federal Emergency Management Agency (FEMA) floodplain maps and also apply to all amendments or revisions to those maps. These regulations guide how developments in floodplains may be designed.

3.10.5 Environmental Consequences

The three reclamation alternatives were evaluated to determine their potential impacts on the existing and potential land uses within the analysis area. The methods for assessing potential land use impacts generally include analyzing each alternative's potential, according to its location or associated activities and how the alternative will:

- Impact adjacent land uses directly through increased noise, loss of public access, potential water quality violations;
- Foster (indirectly) increased development or other changes in areas adjacent to the site;
- Conflict with applicable local or regional land use management plans or local zoning ordinances; or
- Meet post-mine land use objectives.

In general, all three alternatives are expected to provide an overall positive effect to land use by reclaiming previously disturbed mining lands to a condition that benefits recreation, a primary goal of the KNF Forest Plan for the area. None of the alternatives include provisions on future development or subdivision of private land, and there is a lack of zoning regulation throughout Lincoln County. These topics will not be discussed further. However, potential impacts of each of the alternatives on public lands and private uses are discussed in further detail below.

3.10.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would continue under the specifications of the 1978 Reclamation Plan at the time of final mine closure. Existing mine infrastructure would be demolished and removed, adits would be sealed with development rock fill, adit water would be routed out of the Service Adit across the portal patio to Stanley Creek, and disturbed areas would be regraded and revegetated (see **Sections 3.8** and **3.16** for a further discussion on regrading and revegetation plans).

Per KNF approval, roads no longer deemed necessary for recreation or management access would be removed, and remaining roads (namely NFSR 4626) would be returned to KNF management control (see **Section 3.15** for a further discussion on roads). In general, the Permit Area should be reclaimed to a relatively natural, vegetated state that would return these lands to use by big game populations. Also reopening portions of the KNF (*e.g.,* Spar Lake and Mount Vernon) to recreation that once had only limited or no access potential during mining operations would be consistent with the KNF Forest Plan.

While there would be short-term (2-year) noise and activity-related disturbance to surrounding lands from reclamation activities (*e.g.,* heavy machinery during regrading and demolition operations), disturbance levels are not anticipated to be greater in terms of level or duration than during operation of the mine. As such, reclamation activities should be considered only a minor, short-term negative impact that would be minimal when compared to 30 years of operational noise levels and long-term post-reclamation periods.

Overall, under the No Action Alternative, the return of recreational potential of public lands, a prime objective of the KNF Forest Plan for the area, would restore pre-mine land uses. Reclamation would also return private and patented lands to post-mine land uses of timber production, wildlife habitat, and recreation.

3.10.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented. Future reclamation activities within the Permit Area would follow the specifications of the updated plan. Similar to the No Action Alternative, the proposed reclamation activities under the Proposed Action would allow pre-operational recreational access to and use of public land, a primary goal of the KNF Forest Plan. Under the Proposed Action, reclamation activities would be similar to the No Action Alternative, creating similar short-term disturbances associated with reclamation activities. Any short-term negative impacts to recreation associated with reclamation activities would be minimal in comparison to operational impacts and the long-term benefit of returning some pre-operational recreation access to public lands. Reclamation would return private and patented lands to post-mine land uses of timber production, wildlife habitat, and recreation.

3.10.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and expanded upon to address issues identified during the public scoping and agency review processes. Similar to the Proposed Action, the proposed reclamation activities under the Agency-Mitigated

Alternative would return some pre-operational recreational access and use of public land, a primary goal of the KNF Forest Plan. Reclamation activities would have a greater chance of success than under either the No Action Alternative or the Proposed Action. Any short-term negative impacts to recreation associated with reclamation activities would be minimal in comparison to operational impacts and in comparison to the long-term benefit of returning some pre-operational recreational access to public lands. Reclamation would return private and patented lands to post-mine land uses of timber production, wildlife habitat, and recreation.

3.10.5.4 Resource Impact Summary

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all provide some return to pre-operational land uses within the Permit Area. By closing the mine and reclaiming the land, a large local disturbance would be removed, and the land would be reclaimed to a more natural vegetated state. The potential for big game populations to use the area and for recreational use of public lands within the Troy Mine Permit Area would increase. Reclamation would provide access to surrounding recreational features, such as Spar Lake and Mount Vernon, and should provide some level of pre-operational recreational use of the area, a prime land-use objective of the KNF Forest Plan. This return of recreational potential would provide a long-term net positive effect on local and regional land use on public, private, and patented lands.

3.10.5.5 Effectiveness of Mitigation Measures

No mitigation measures have been identified regarding limits to be imposed on the return of pre-operational levels of access, recreation, and big game use for the No Action Alternative, the Proposed Action, or the Agency-Mitigated Alternative.

3.10.5.6 Cumulative Effects

Cumulative effects on local land use as a result of implementation of the No Action Alternative, the Proposed Action, or the Agency-Mitigated Alternative would include incremental improvement to reclamation of vegetation and lands available for recreational purposes. No other past, present, or reasonably, foreseeable future actions would change the cumulative effects.

3.10.5.7 Regulatory Compliance

All three alternatives would be in compliance with the KNF Forest Plan because all alternatives would restore disturbed lands and return public, private, and patented lands to a balance of uses including timber management, resource extraction, recreation, and maintenance of natural values.

All three alternatives would also comply with the MMRA by restoring disturbed lands and allowing return of pre-operational land uses.

3.11 Recreation

3.11.1 Introduction

This section characterizes existing recreational resources that include developed sites, trails, and wilderness or non-roaded areas in proximity to the Troy Mine Permit Area, and it identifies potential impacts to these recreational resources under each of the reclamation alternatives.

3.11.2 Regulatory Framework

The 1987 KNF Forest Plan establishes the management framework for activities on NFSL lands and serves as the guiding management document until the 2008 Planning Rule is implemented. The 1987 Plan's goal is to promote a balance of multiple uses on KNF lands, including timber management, resource extraction, recreation, and maintenance of natural values. Promoting recreational opportunities is a primary goal of the plan within the portion of the KNF that includes the Permit Area.

On November 2, 2005, the USFS announced final travel management regulations (*36 CFR Parts 212, 251, 261, and 295 Travel Management; Designated Routes and Areas for Motor Vehicle Use; Final Rule*) that require each National Forest to designate and map roads, trails, and areas that are open to motor vehicle use.

The USFS completed a Motor Vehicle Use Map Project, Decision Notice, and Finding of No Significant Impact for the Three Rivers Ranger District in 2009, which officially designates routes open to motor vehicle use. A motor vehicle use map for the entire Ranger District, established in support of this effort, became effective on January 1, 2010.

3.11.3 Analysis Area

The analysis area for this section includes all lands within the Lake Creek watershed and focuses on the vicinity of the Troy Mine Permit Area.

3.11.4 Affected Environment

The Lake Creek watershed provides a wide variety of summer and winter recreational opportunities, which are defined in the USFS's Recreation Opportunity Spectrum (USFS 1986). Classifications include Primitive, Semiprimitive-Motorized, Semiprimitive Non-motorized, Roaded Natural, Rural, and Urban. All but the Urban classification are located within the Lake Creek watershed. Activities vary from backpacking within a roadless area to camping at a developed recreational site.

A large portion of the Scotchman Peaks Inventoried Roadless Area (IRA) (portions are also a proposed Wilderness Area) is located in the west-southwestern corner of the watershed. The Scotchman Peaks area is a popular regional recreational resource known for its scenic beauty. Popular activities include backpacking, fishing, hunting, and snowmobiling. Other popular areas for access and recreation include the Ross Creek drainage and the Spar Lake area, including little Spar Lake, Spar Peak, Hiatt Creek, and Spruce Lakes (KNF 2001).

The Willard-Lake Estelle IRA located along the west-northwestern edge of the Lake Creek watershed has six mountain lakes that provide camping and fishing opportunities, as well as good habitat for big-game animals (KNF 2001). The Cabinet Mountain Wilderness Area and the Cabinet Face West IRA dominate the eastern portion of the watershed and provide primarily primitive or wilderness experiences. Because Bull Lake is also a popular area for boating and water-based recreation, it receives heavy use from boaters, swimmers, campers, and anglers during the summer months.

3.11.4.1 Developed Recreation

Four developed recreation areas are located within the analysis area (**Figure 3-8**). These include Spar Lake Campground off NFSR 384 (Lake Creek Road), Dorr Skeels Campground off MT 56, Bad Medicine Campground off Ross Creek Cedars Road, and Ross Creek Picnic Area off NFSR 398 (Ross Creek Road) (KNF 2001).

- Spar Lake Campground is a small 12-unit campground and camphost site, adjacent to Spar Lake. A small boat ramp is located on site, and the campground is within a few miles of Spar Peak Trail (#324) and Little Spar Lake Trail (#143). Spar Lake Campground became a fee site in 2010.
- The Ross Creek Picnic Area, designated an official Scenic Area in 1960, is a day-use area providing access to about 100 acres of giant western redcedars. A 0.9-mile self-guided nature trail is located on site.
- Bad Medicine Campground is a 17-unit seasonal campground located on Bull Lake. A boat ramp is located on-site, and the campground is within about three miles of the Ross Creek Scenic Area.
- Dorr Skeels Campground is a seven-unit campground open year-round. The site provides a motorized boat ramp, swimming area, and picnicking, and is within about seven miles of the Ross Creek Scenic Area. Dorr Skeels Campground became a fee site in 2010.

3.11.4.2 Dispersed Recreation

KNF recently developed a motor vehicle use map (MVUM) (effective January 1, 2010) in support of the Travel Management Rule (36 CFR 212). The Three Rivers Ranger District (District) is responsible for implementing motorized plans developed for the analysis area. Based on information from the *Motor Vehicle Use Map Project, Decision Notice and Finding of No Significant Impact* (KNF 2009a), several key decisions have been made on motorized vehicle use designations in this area. Namely, approximately 500 miles of USFS roads within the District's jurisdiction are open to motor vehicle use. Moreover, the District allows 300 feet of cross country motor vehicle use off designated USFS roads for the purpose of dispersed camping as displayed in the MVUM, including NFSR 384 in and around the Permit Area. The District now also prohibits motorized use of all National Forest System trails and prohibits cross-country motor vehicle use on 42,000 acres of District land located in Idaho (excluding over-snow vehicles).

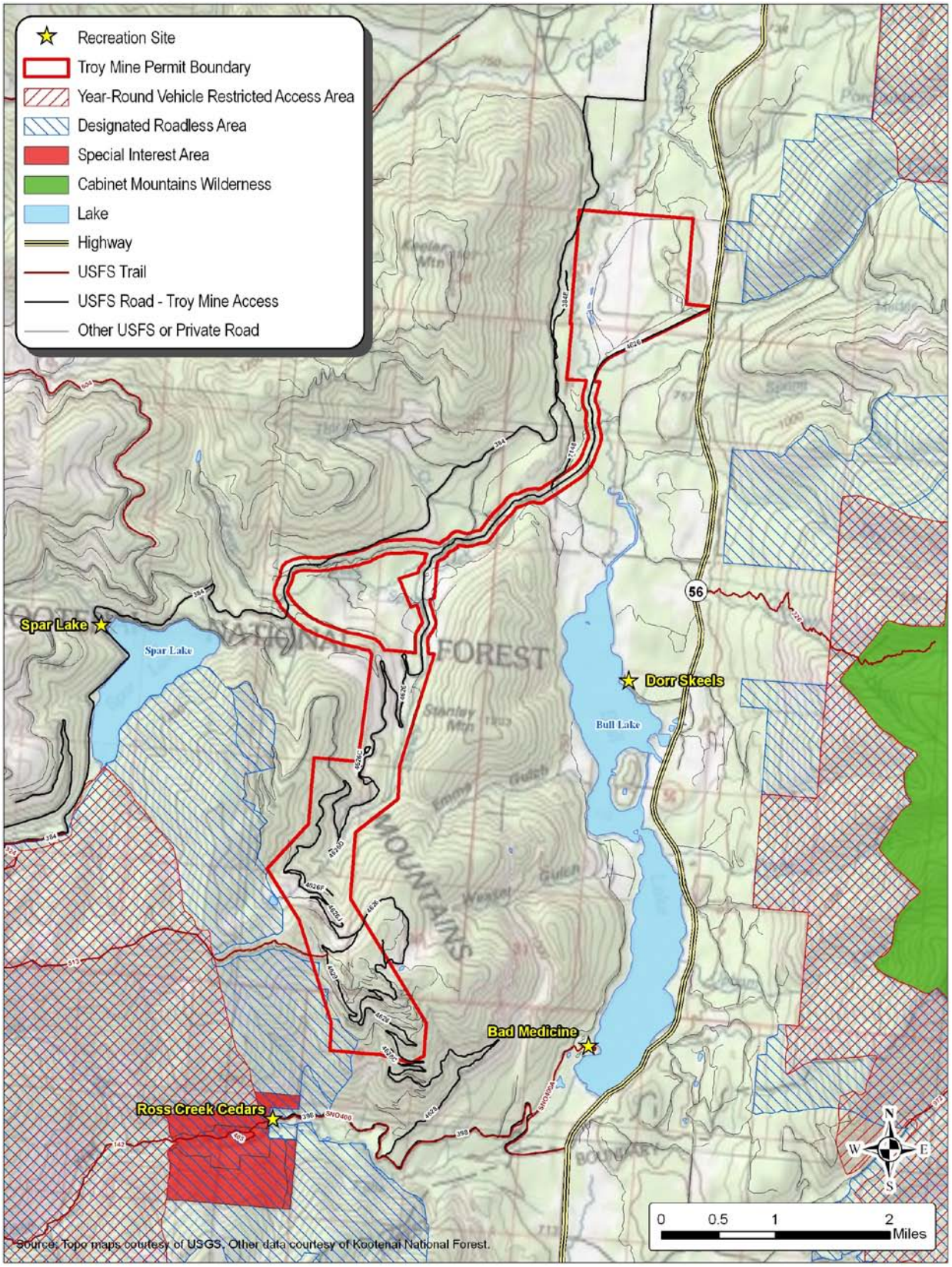


Figure 3-8. Recreation

Several National Forest System trails are located throughout the Lake Creek watershed, including Little Spar Lake Trail, Spar Peak Trail, Ross Creek Trail, South Fork Ross Creek Trail, and Spar Ridge Trail. Spruce Lakes is a fairly popular area among locals for hunting, horseback riding, and hiking. Keeler Creek Road NFSR 473 is used as a groomed snowmobile route from December to April. Other areas available for snowmobile use include the Spruce Lake area and areas around Spar Lake within the Hiatt Creek drainage (KNF 2001).

3.11.4.3 Special Uses

Two outfitters are permitted to operate in the watershed. One outfitter provides hunting and fishing services, including spring bear, fall archery, fall bear, fall general season, and mountain lion hunts. The other outfitter provides horseback rides, primarily in the Spruce Lakes area. The outfitters average about 220 service days per year in this area (KNF 2001).

3.11.4.4 Wilderness Areas/Inventoried Roadless Areas

The Cabinet Mountains Wilderness Area is the only official Wilderness Area in the KNF. Designated under the Wilderness Act of 1964, this 94,360-acre Wilderness Area includes the upper elevations of the east range of the Cabinet Mountains. Lake Creek watershed skirts the western edge of the Wilderness Area, and access is considered moderate to difficult due to steep and rugged topography.

In addition to the official Cabinet Mountains Wilderness Area, the 1987 Forest Plan identified a number of IRAs by name, number, and acreages. There are three IRAs within the analysis area including Scotchman Peaks #662, Willard-Lake Estelle #173, and Cabinet Face West #670. All planned management activities within these IRAs have maintained wilderness characteristics since the Forest Plan was signed in 1987, and all Forest Plan IRAs have since been validated through landscape assessments by using the Roadless Area Inventory Protocol developed in 1996 (KNF 2001).

Scotchman Peaks IRA #662

A large portion of the Scotchman Peaks IRA, confirmed at 54,433 acres on October 1, 1999, is located in the western portion of Lake Creek watershed, and skirts the boundary of the southwestern section of the Permit Area. The main drainages of this IRA include Ross, Spar, and Blue creeks. Large sections of this IRA are within MA 8, meaning it is designated as a proposed wilderness area in the 1987 Forest Plan.

The Scotchman Peaks area is popular for recreation including backpacking, fishing, hunting, berry picking, and snowmobiling. The area is scenic and rugged. Popular areas for access and recreation include the Ross Creek drainage and the Spar Lake area, which includes Little Spar Lake, Spar Peak, Hiatt Creek, and Spruce Lakes (KNF 2001).

Willard-Lake Estelle IRA #173

The western and northwestern corner of the Lake Creek watershed contains the 33,349-acre Willard-Lake Estelle IRA (validated September 30, 1999). Six mountain lakes are located in this area, providing a range of backcountry camping and fishing opportunities, as well as big-game hunting opportunities (KNF 2001).

Cabinet Face West IRA #670

The eastern-most portion of the Lake Creek watershed contains a portion of the Cabinet Face West IRA and includes most of the lands between the Cabinet Mountain Wilderness and MT 56. The validated acreage is 13,690 (October 1, 1999). This area has three hiking trails that access the IRA, but no developed recreational sites. The Cabinet Face West IRA is generally remote; although, its proximity to MT 56 (Bull Lake Highway) does influence the remote character of this area to some degree. Also, the Cabinet Face West IRA buffers the Cabinet Mountain Wilderness further to the east, providing a larger overall roadless area than what is officially designated as Wilderness. In addition, sections of this IRA are within MA 8, and it is designated as a proposed wilderness area in the 1987 Forest Plan (USFS 1987).

3.11.5 Environmental Consequences

The methods for assessing potential recreational resource impacts generally include analyzing each reclamation alternative according to how its location or associated activities will:

- Impact the recreational potential of area public lands with regard to disturbance, noise, and conflicting activities; or
- Modify access to recreational areas on public lands.

Potential impacts of each alternatives are discussed in further detail below.

3.11.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would follow the specifications of the 1978 Reclamation Plan at the time of final mine closure. NFSR 4626 would be maintained by KNF to provide recreational access to the Spar Lake and Mt. Vernon areas (see **Section 3.15** for a further discussion on roads). All other roads would be removed and reclaimed, pending approval of KNF. In general, the Troy Mine Permit Area would be revegetated to promote use by big game populations and the mill site area would be reopened to public non-motorized access.

There would be short-term (2-year) noise and activity-related disturbances to public lands in the vicinity of the Troy Mine Permit Area from reclamation activities (*e.g.,* heavy machinery during regrading and demolition operations). However, disturbance levels would be no greater in intensity or duration than during actual mine operation. They would be considered a minor, short-term negative impact when compared to 30 years of operational noise levels. Finally, over the long-term following reclamation, such disturbances would be largely be removed from the area.

Overall, under the No Action Alternative, reclamation would return pre-operational recreational access to public lands.

3.11.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented and on-going. Future reclamation activities within the Permit Area would follow specifications of the updated plan. Similar to the No Action Alternative, reclamation activities should return pre-operational recreational access and use to public land in the vicinity of the Troy Mine Permit Area, a primary goal of the KNF

Forest Plan. Under the Proposed Action, reclamation activities would create short-term (2-year) disturbances. Any short-term negative impacts to recreation associated with reclamation activities would be minimal in comparison to operational impacts. There would be a long-term benefit of returning pre-operational access to public lands.

3.11.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and expanded to address those issues identified during the public scoping and agency review processes. Similar to the other alternatives, reclamation activities proposed under the Agency-Mitigated Alternative would return pre-operational recreational access and use of public land in the vicinity of the Troy Mine Permit Area, a primary goal of the KNF Forest Plan. Reclamation would have a greater chance of success than under either the No Action Alternative or the Proposed Action. Any short-term negative impacts to recreation associated with reclamation activities would be minimal in comparison both to operational impacts and to the long-term benefit of returning pre-operational recreational access to public lands.

3.11.5.4 Resource Impact Summary

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative should all return some pre-operational recreational use to the Troy Mine Permit Area. By closing the mine and reclaiming the land, a large local disturbance would be removed, and the land would be revegetated, thereby increasing the potential for big game hunting and recreational use of public lands. Return of recreational use is a prime land use objective of the KNF Forest Plan.

Overall, under all alternatives, reclamation of previously disturbed land would improve non-motorized recreational use and access for recreational use of the NFSL in the vicinity of the mine. However, landowners would still control access to private lands.

3.11.5.5 Effectiveness of Mitigation Measures

No mitigation measures have been identified regarding limits on the return of pre-operational levels of access and recreational use by the No Action Alternative, Proposed Action, or Agency-Mitigated Alternative.

3.11.5.6 Cumulative Effects

Implementation of the No Action Alternative, the Proposed Action, or the Agency-Mitigated Alternative would return public lands to pre-operational recreational uses locally within the Troy Mine Permit Area. No other past, present, or reasonably foreseeable future actions would affect recreational resources within the analysis area. Therefore, there would be no cumulative effect.

3.12 Socioeconomics

3.12.1 Introduction

This section describes the socioeconomic characteristics of the human environment and economic activity in Lincoln County, including demographics, employment, and income. It also identifies potential impacts to these resources and communities for each of the proposed reclamation alternatives.

3.12.2 Regulatory Framework

The federal regulatory framework for this section includes:

- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority and Low Income Populations; and
- Executive Order 13045, Protection of Children from Environmental Health and Safety Risks.

Both of these executive orders ensure that federal actions identify and address any potential for disproportionately high or adverse effects to these populations. Although, no specific state regulations exist for this section, DEQ discloses socioeconomic effects to the human environment in its environmental documents.

3.12.3 Analysis Area

The analysis area for this section is Lincoln County, Montana.

3.12.4 Affected Environment

KNF occupies approximately 76 percent of the land base in Lincoln County where it plays a dominant economic role. The two largest private landowners in Lincoln County are Burlington Northern and Plum Creek Timber. Major population centers in Lincoln County include Eureka, Libby, and Troy.

3.12.4.1 Lincoln County Demographics, Income, and Employment

According to the U.S. Census data, Lincoln County experienced an approximate 8 percent increase in total population between 1990 and 2000 but is estimated to have had a 0.6 percent decrease between 2000 and 2009. This compares to an approximately 13 percent increase for the State of Montana between 1990 and 2000 and an estimated 8.1 percent increase between 2000 and 2009.

The civilian labor force grew over 20 percent in Montana between 1990 and 2000, but by less than 2 percent in Lincoln County over this same time frame. Lincoln County also experienced a slight decline in its labor force of nearly 1.5 percent between 2000 and 2009. Lincoln County's unemployment rate remained at 13.8 percent in 2000 as compared to a statewide average of 6.3 percent. This is higher than the statewide average, though somewhat lower than the county's 1990 unemployment rate of 16.1 percent. Based on more recent data from the Bureau of Labor Statistics, Lincoln County's unemployment rate averaged approximately 11.7 percent from June of 2009 to June of 2010.

Lincoln County's median household income levels have been consistently lower than the state average and have not kept pace with the statewide growth. Lincoln County's median household income

averaged $26,754 in 2000 as compared to the statewide average of $33,024, and averaged $33,383 in 2008 as compared to a statewide average of $43,948 that same year. **Table 3-16** provides a demographic and economic breakdown for both the State of Montana and Lincoln County based on available 1990, 2000, and 2009 U.S. Census and Bureau of Labor Statistics data.

Table 3-16. Selected Demographics, Income, and Employment

Characteristic	Montana			Lincoln County		
	1990	2000	2009	1990	2000	2009
Population	799,065	902,195	974,989	17,481	18,835	18,717
Civilian labor force	376,940	454,687	498,907	7,749	7,907	7,792
Percent Unemployment Rate	6.9%	6.3%	6.2%	16.1%	13.8%	11.7%*
Median household income **	$22,988	$33,024	$43,948	$20,898	$26,754	$33,383
Percent of persons below poverty level **	16.1%	14.6%	14.1%	14.1%	19.2%	20.1%

*Not seasonally adjusted
** Based on 2008 data
Sources: KNF 2004b; Census QuickFacts 2010, U.S. Bureau of Labor Statistics 2010

3.12.4.2 Troy Mine Employment/Expenditures

According to Revett Silver Company (parent company of Troy Mine, Inc.) information dated January 2010, Troy Mine had a payroll of approximately $10.7 million in 2009. Average employee wages totaled approximately $58,790 per year based on 182 total employees. Labor breakdown includes mine, mill, and general and administrative labor. This is well above Montana's average wage of $33,759; Lincoln County's average wage of $30,341; and Sanders County's average wage of $26,065 for that same year (Department of Labor and Industry, 2010a, 2010b, 2010c).

Revett's 2009 Troy Mine expenditures topped $29.1 million, approximately 80 percent of which was spent in Montana. Approximately 37 percent of expenditures were labor related, while 56 percent were supply related, and 5 percent were earmarked for mining and property taxes. Of the $16.4 million in supplies purchased in 2009, about 60 percent were purchased in Montana (Erickson 2010).

3.12.4.3 Environmental Justice

Although poverty levels decreased in the State of Montana as a whole between 1990-2009, the percentage of Lincoln County's population below the poverty line increased during this same time period. Namely, Lincoln County had just over 14 percent of its population below the poverty line in 1990, 19.2 percent in 2000, and 20.1 percent in 2009. This compares to 16.1 percent of Montana's population below the poverty line in 1990 and to 14.1 percent in both 2000 and 2009.

While on average, both state and Lincoln County populations are aging, age classes vary somewhat. In 1990, Lincoln County had a slightly higher percentage of its population under 18 years of age as compared to Montana, a nearly identical percentage in 2000, but had a slightly lower percentage of its population under 18 estimated in 2009. In 2009, the State of Montana is estimated to have 22.5 percent of its population under 18, and Lincoln County is estimated to have only 19.9 percent under 18.

Compared to the national average, the State of Montana has a smaller minority population as a percentage of its total population. Moreover, Lincoln County has a smaller minority population as a percentage of its total population as compared to the State of Montana. The 2000 Census and estimates for 2009 showed that over 96 percent of Lincoln County is considered White as compared to just over 90 percent in Montana as a whole. **Table 3-17** provides a detailed breakdown of age and minority populations for Montana and Lincoln County.

Table 3-17. Montana and Lincoln County Age Classifications and Minority Populations

Characteristic	State of Montana			Lincoln County		
	1990*	2000*	2009	1990*	2000*	2009
Total population	799,065	902,195	974,989	17,481	18,837	18,717
Percentage below poverty line	16.1%	14.1%	14.1%	14.0%	19.2%	20.1%
Females	50.5%	50.2%	50.0%	49.8%	49.3%	49.4%
Age < 5	7.4%	6.1%	6.4%	7.2%	5.0%	5.0%
Age <18	27.8%	25.5%	22.5%	30.0%	25.4%	19.9%
Age 65+	13.3%	13.4%	14.6%	12.3%	15.2%	19.7%
White	92.7%	90.6%	90.3%	97.8%	96.1%	96.2%
Black	0.3%	0.3%	0.7%	0.1%	0.1%	0.2%
American Indian	6.0%	6.2%	6.4%	1.6%	1.2%	1.3%
Two or more races	n/a	1.70%	1.8%	n/a	1.9%	1.9%
Hispanic	1.50%	2.00%	3.1%	1.1%	1.4%	2.2%

* 1990 numbers are from 1989 and 2000 numbers are from 1999

** n/a=not available

Source: KNF 2000b; Census QuickFacts 2010

3.12.5 Environmental Consequences

In this section, project alternatives are evaluated to determine their potential impacts on the socioeconomic conditions of the analysis area.

Methods used to assess how the alternative would potentially impact socioeconomic resources generally include analyzing each alternative's potential, due to its location or associated activities, to:

- Change local and regional population levels or demographics;
- Change local and regional economies, labor forces, or incomes;
- Adversely impact minority or low income populations; or
- Adversely impact children.

In general, all three alternatives have an overall small, short-term effect on local and regional socioeconomic resources through reclamation-related job opportunities and associated economic stimulus. While the mine closure and the associated loss of jobs would result in negative impacts to socioeconomic resources in Lincoln County, this job loss would occur regardless of which alternative is selected and, therefore, is outside the scope of this analysis. Economic effects of mine closure will not be discussed further. None of the proposed reclamation alternatives would have any effect on population levels or on demographics; nor would they have any adverse impacts to minorities, low income populations, or to children. Therefore, these topics also will not be discussed further. Specific potential impacts of each of the alternatives are discussed below.

3.12.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would continue under the specifications of the 1978 Reclamation Plan at the time of final mine closure. Reclamation-related jobs, expenditures, and the related economic stimulus from these activities, which would likely be drawn at least partially from local or regional sources, would result in small short-term economic boosts to local and regional economies and populations.

No other socioeconomic resources are expected to be affected by this alternative, and no long-term (*e.g.,* post-reclamation) economic effects are anticipated.

3.12.5.2 Proposed Action

Under the Proposed Action, the 2006 Revised Reclamation Plan would be implemented, and reclamation activities on the Permit Area would follow the specifications of that updated plan. Similar to the No Action Alternative, a short-term, positive impact to local and regional economies would be expected from the Proposed Action. A long-term positive impact would occur under the Proposed Action due to on-going, long-term, post-reclamation water management and monitoring, but the level of economic growth due to this extension would be minimal in comparison to the levels during reclamation. The effects of the Proposed Action would be comparable to those of the No Action Alternative.

3.12.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and further expanded to address issues identified during the public scoping and agency review processes. The Agency-Mitigated Alternative would provide a small, short-term, positive effect to local and regional economies. The increased water management and monitoring activities proposed would provide a minimal economic benefit as compared to the other alternatives.

3.12.5.4 Resource Impact Summary

Overall, all three alternatives would provide a small net positive effect over the short-term to local and regional socioeconomic resources in the form of economic gains related to reclamation activities. However, the alternatives are different in the amount and duration of the long-term effect of water management and monitoring activities. The difference in scope of reclamation is not likely to result in differences in positive economic effects. Potential economic effects due to water management and monitoring activities would be lower than those of the reclamation activities and would be considered minimal. Thus, the positive socioeconomic effects of each alternative can largely be considered equal.

3.12.5.5 Effectiveness of Mitigation Measures

No mitigation measures would be required for socioeconomic resources due to the lack of anticipated negative impacts from any of the proposed alternatives.

3.12.5.6 Cumulative Effects

Cumulative and additive effects of reclamation activities at the Troy Mine with other past, present, and future actions in the analysis area are anticipated to be minimal as far as socioeconomic resources are concerned because of the minimal long-term effects associated with the three alternatives.

3.12.5.7 Regulatory Compliance

All three alternatives would be in compliance with Executive Order 12898 on environmental justice and Executive Order 13045 on the protection of children because no alternative would have any adverse impacts to minorities, low income populations, or to children.

3.13 Reclamation Materials

3.13.1 Introduction

This section characterizes the materials available for use as growth medium in reclaiming the Troy Mine area and identifies potential effects of using these resources under each of the alternatives. It also gives a brief overview of soil resources in the project area.

3.13.2 Regulatory Framework

Forest Service Guidelines

The Forest Service Manual (FSM) guidelines on soil management (FSM 2550) require that NFSL be managed to maintain or improve soil quality (USFS 2009a). The objective with reclamation of disturbed

sites is to restore soil function so that the disturbed areas can absorb and retain water, sustain appropriate native vegetation, and return to forest cover. Regional guidelines also suggest that organic matter retention should follow recommendations contained in Graham (1994) if specific local guidelines are not available.

Kootenai Forest Plan

The Forest Plan incorporates practices, as outlined in the Soil and Water Conservation Practices (SWCP) Handbook (FSH 2509.22), into all land uses and project plans as the principal mechanism for controlling non-point pollution sources, meeting soil and water quality goals, and protecting beneficial uses (USFS 1987). Although the Soil and Water Conservation Practices Handbook does not specifically address hard rock mining reclamation, it directs Forests to develop site-specific SWCPs based on project level evaluation. Examples of project-specific SWCPs or BMPs that could be implemented to protect soil productivity during reclamation include erosion control practices to limit sedimentation to surface water (*e.g.,* recontouring slopes to a stable angle so that vegetation could be re-established).

State Guidelines

The MMRA requires that lands disturbed by mining must be reclaimed such that the disturbed lands can meet the desired land use after mining. The desired future land use on NFSL within the permit area includes timber production, watershed protection, wildlife habitat enhancement, and recreation. The desired future land use at the tailings impoundment on private lands is timber production and wildlife habitat. The MMRA requires the Agencies to evaluate reclamation plans and to determine whether the plan achieves those land use goals. The MMRA also requires that reclaimed lands must be returned to a comparable state of stability and utility as the adjacent lands.

3.13.3 Analysis Area

The analysis area includes all disturbed Troy Mine lands that need to be reclaimed. These include roads used for drilling and other operations, utility and pipeline corridors, mill site, adits and portals, development rock areas, subsidence areas, the tailings impoundment, and the proposed borrow sites (**Figure 2-1** and **Figure 2-2**) (see also Genesis 2006, Table 2-1). Proposed reclamation resources include three types of growth media: rocky glacial materials in the mill pad area and the KNF borrow site; lacustrine and volcanic ash-derived soil materials salvaged from the tailings impoundment site and stockpiled between the tailings impoundment and Lake Creek; and glacial outwash borrow materials from east of the tailings impoundment. Reclamation activities that may result in off-site effects such as sediment delivery to surface waters are discussed in **Section 3.9**.

3.13.4 Affected Environment

The affected environment includes lands associated with the Troy Mine Permit Area that have been disturbed by over 30 years of mining. Development of the mine and related facilities have resulted in unavoidable impairment of land productivity on the sites that were physically disturbed by mining operations.

The reclamation materials in the project area are derived from a combination of glaciation, glaciofluvial deposits, and residual material weathered from the bedrock. Glacial till deposits in the area vary and can contain considerable fines (sands and silts), have subrounded to angular rock fragments, and can be dense enough to restrict root growth. Extensive water-influenced unconsolidated deposits of alluvium, lacustrine (glacial lake) materials, and glacial outwash are found in the valley bottoms. The entire area has a volcanic ash layer over the top of these materials. The soil stockpiled near the tailings impoundment contains lacustrine and volcanic ash-derived soil materials. Soils with this volcanic ash component have greater water retention potential and may result in greater revegetation success.

At the mine site, most reclamation materials would consist of rocky glacial growth medium stored in the mill pad. This material was removed from cut slopes in the mill area and placed in the mill pad for use after mining. The material has been covered with pavement for approximately 30 years. This rocky material includes soil, subsoil, and rocky geologic materials. Soil biological activity would be minimal because the material has been stockpiled and covered for 30 years. The water-holding capacity of the mill pad material would exceed that of the development rock, which was largely used to build the portal patios in the mine area. The organic matter content of material in this area would be minimal, and fertility of the mill pad material would be low.

The USFS borrow site could also be used to help reclaim the mine site disturbances. The borrow source contains rocky glacial materials similar to the mill pad material. Soil biological activity would be minimal, and the materials would include some noxious weed seeds, including rush skeletonweed, which is a state priority for control. The water-holding capacity of the USFS borrow material would exceed that of the development rock, which was largely used to build the portal patios in the mine area. The organic matter content of the borrow would be minimal, and fertility of the borrow material would also be low.

The soil stockpiles at the tailings impoundment contain mostly fine-grained lacustrine materials mixed with weathered volcanic ash that were stockpiled from the tailings impoundment footprint. They have been stockpiled for 30 years and would have minimal biological activity below the upper layer of soil that has been revegetated. The soil stockpiles have been covered with many species of noxious weeds for many years. Over the last few years, Genesis (now Troy Mine, Inc.) has been controlling noxious weeds on the piles by spraying, but the soil would still contain some noxious weed seeds. The water-holding capacity of the stockpiled materials is low but exceeds that of any other growth medium proposed to be used under any of the alternatives. The organic matter content in the stockpiled material would be minimal, and its fertility would also be minimal.

The glacial outwash borrow sites east of the impoundment footprint contain rocky materials that have been used to construct dikes which were used to separate cells in the impoundment, operational roads, and in reclamation test plots. This glacial outwash material would have little biological activity, and the borrow sites have been covered with noxious weeds for many years. Over the last few years, Genesis (now Troy Mine, Inc.) has been controlling noxious weeds by spraying, but the glacial outwash would still contain noxious weed seeds when used for reclamation. Moreover, the water-holding capacity of the borrow materials is low and varies with the rock content. The organic matter content would be minimal, and fertility of the material would also be low.

During mine operations the tailings have been seeded with barley and irrigated to control blowing dust. Many species of plants have also volunteered in the tailings over the 30-year operational period. Some of these plants have displayed yellowing due to a lack of nutrients as well as potential minor metal phytotoxicity.

Genesis (now Troy Mine, Inc.) reclaimed the 42-acre embankment of the tailings impoundment from 1995 to 1998 with an average of 18 inches of lacustrine and volcanic ash-derived soil materials salvaged from the area before the impoundment was built (DSL and KNF 1978, page 68). The starter dam is constructed of local sands and gravels and is 30 feet high. It has a 1.5H:1.0V slope on the upstream (interior) side and a 2.5H:1.0V slope on the downstream (outer) side. Above the starter dam, the embankment is constructed in 10-foot lifts of compacted tailings sands. This portion of the embankment has an overall downstream slope of 3.0H:1.0V, from the embankment crest to the crest of the starter dam (Knight Piesold, 2007). An upstream construction method was used to build the embankment, which means that the disturbance footprint from the embankment will always remain the same. Soil cover on some small areas of the embankment slopes has eroded enough to expose embankment tailings. However, the overall reclamation could be considered successful.

The embankment was planted with the seed mix described in the 1978 Reclamation Plan, which is dominated by introduced grasses. The embankment slopes are currently dominated by a mixture of introduced grasses (*e.g.,* hard fescue) and conifers. Monitoring in 1985 documented from 25 to 85 percent cover on the embankment slopes. Dominant species were timothy, smooth brome, and alsike clover (Genesis 2006, Appendix B, page 1). Since 1985, however, vegetation cover has deteriorated so that the slopes are currently dominated by hard fescue and spotted knapweed. The plants growing on the embankment do not display the yellowing evident in plants growing on raw tailings, an indication that the lacustrine and volcanic ash-derived soil cover materials are providing more nutrients than the tailings and are minimizing the amount of roots that are entering the raw tailings.

3.13.5 Environmental Consequences

Discussed below are potential impacts and benefits from using the various reclamation materials in the disturbance areas under each of the alternatives. The objective of reclamation is to restore soil function, which includes the ability to support a productive biological community, adequate hydrologic function, and nutrient cycling. All alternatives focus on reclamation activities, and there would be minimal “new” soil disturbance (*e.g.,* from road building, use of borrow sources, etc.).

3.13.5.1 No Action Alternative

Mine and Mill Site

To reclaim the mill and mine areas, stockpiled lacustrine and volcanic ash-derived soil materials from the tailings impoundment would be used to cover disturbed areas and to provide a growth medium for revegetation efforts. Approximately 43,560 cy of materials would be needed to reclaim the 27 acres of disturbed area with an average depth of 12 inches of growth medium.

These reclamation materials would be fine-grained and would have the highest water-holding capacity and cation exchange capacity of available reclamation materials. The No Action Alternative would use chemical fertilizer to enhance soil fertility instead of organic matter amendment. Organic matter amendments can increase water infiltration, soil biologic activity, water-holding capacity, or decrease potential soil compaction.. Nitrogen-fixing shrubs, such as alder, would be planted to enhance long-term soil quality.

The reclamation materials approved in the 1978 EIS are fine-grained materials susceptible to compaction (Genesis 2000) and subsequent surface erosion. Erosion risk would increase with compaction and with increasing slopes, particularly those greater than eight percent. The use of mulch as proposed could reduce erosion effects in some areas but would not reduce compaction. No methods to reduce compaction are included in the No Action Alternative. Erosion of reclamation materials would reduce soil quality by reducing soil productivity and stability in reclaimed areas.

As the angle-of-repose portal patios were formed, larger rocks naturally sorted out and rolled to the bottom of the slope, leaving the smaller rock fragments and any fines near the top. The lower slopes of the portal patios would largely not revegetate because they are too rocky and contain little material for plants to invade. They would resemble talus slopes over the long-term. The upper slopes would support some vegetation, including shrubs, trees, and spotted knapweed. These angle-of-repose slopes would not receive additional reclamation treatment under the No Action Alternative.

Overall, the No Action Alternative would apply reclamation materials that improve soil function enough to support vegetation. However, there may still remain issues with erosion of fine-grained soils that would not be stable on slopes over eight percent in the mine and mill area.

Impoundment Area

Reclamation of the tailings impoundment area would use lacustrine and volcanic ash-derived soil materials which are stockpiled between Lake Creek and the toe ponds. Approximately 766,600 cy of soil would be needed to cover approximately 324 acres of tailings impoundment disturbed area with 18 inches of soil (Genesis 2006, Table 4.1). The lacustrine and volcanic ash-derived soil materials were salvaged and stockpiled when the impoundment was originally built. Ninety percent of the stockpiled soil would be sufficient to provide the 18 inches of soil required under the No Action Alternative. These lacustrine and volcanic ash-derived soil materials are described in Section 3.13.4.

Reclamation materials would be placed on the impoundment by using rubber-tired vehicles. This method would compact these materials, and the No Action Alternative does not propose ripping to reduce this compaction. The materials have a low fertility, which would be addressed by applying chemical fertilizers. Although the materials have high erosion potential, the tailings impoundment surface is relatively flat with slopes between one and two percent, so water erosion would be minimal. Wind erosion would still remain an issue, but the No Action Alternative includes irrigation for one year to control blowing dust and to limit loss of growth material.

The No Action Alternative would not include an organic matter amendment to enhance water-holding capacity, infiltration, and soil productivity, or to decrease compaction. While the material would have

adequate productivity to support revegetation, the level of compaction and lack of organic matter would compromise soil function. The 18 inches of soil cover would minimize metal phytotoxicity effects from the tailings.

The lacustrine and volcanic ash-derived soil materials originally supported a productive forest before the impoundment area was disturbed. Tree cover would eventually return even with the presence of noxious weeds and other invasive weed plants, but long-term tree health and vigor would be reduced as compared to trees growing on undisturbed soil.

3.13.5.2 Proposed Action

Mine and Mill Site

The mine and mill site areas would be reclaimed by using rocky glacial material found within the mill and office/shop pads, the upper percolation pond embankment, old warehouse pad slope, or within the USFS borrow site in Section 24 (Genesis 2006, Table 4-1). Up to 12 inches of borrow material (32,400 cy for the mill and mine sites) would be placed on these areas. Regrading under the Proposed Action would include placement of development rock back into the adits, out-sloping the mill and office sites at six to seven percent, and regrading to control surface drainage (see Genesis 2006, Figures 4-2 and 4-3). Other work proposed under the Proposed Action would include burying demolition debris on site.

The rocky glacial growth media has a high coarse-fragment content (DSL and KNF 1978, page 90). It would improve infiltration and reduce compaction and erosion as compared to the lacustrine and volcanic ash-derived soil material proposed under the No Action Alternative. The Proposed Action would not include ripping of the portal patios or mill pad prior to placing growth media or ripping of compacted growth media prior to seeding. As a result, compaction could impair long-term productivity.

As in the No Action Alternative, the angle-of-repose portal patio slopes would not receive additional reclamation treatment and would remain as talus slopes. The adits would be backfilled with coarse rock and covered with an average of 12 inches of rocky glacial material as a growth medium.

The mill and office pads would be out-sloped to six to seven percent and capped with an average of 12 inches of rocky glacial material. The rocky glacial growth media is described in **Section 3.13.4** and would have decreased soil quality, a low water-holding capacity, and reduced productivity as compared to the fine-grained material used under the No Action Alternative.

The natural revegetation observed over the last 30 years on disturbed rocky glacial slopes in the vicinity of the mine indicates that soil function is adequate to support the gradual re-establishment of native forest vegetation. Therefore, using similar materials on reclaimed areas should produce similar results as long as the material is not excessively compacted in the process of placement. Reclamation of the mine and mill areas by using rocky glacial materials would have a lower erosion risk, and the soils would be more likely to stay in place as compared to the No Action Alternative, which would use fine-grained materials. The Proposed Action does not include an organic matter amendment to enhance soil productivity; therefore, soil function would be reduced, similar to the No Action Alternative. Overall, the rocky glacial material would provide better reclamation of the mine and mill areas than the fine-grained

material imported from the tailings impoundment area because of the lower erosion risk. However, under the Proposed Action, soil function would return more gradually than under the No Action Alternative.

No roads would be removed as part of the Proposed Action. The existing road beds would remain compacted and weed-infested, which would reduce long-term soil function on the 2.7 miles of road that would be treated under the No Action and Agency-Mitigated alternatives.

Impoundment Area

The Proposed Action would leave the stockpiled lacustrine and volcanic ash-derived soil materials in place. Glacial outwash borrow gravels would be used for the growth media from the borrow site east of the tailings impoundment. The glacial outwash gravels have no organic matter and a large and varying rock fragment content. Fertility is also low in this rocky glacial material.

The Proposed Action does not include the addition of an organic amendment for the glacial outwash gravels. Chemical fertilizers would be used to enhance the fertility of the growth medium. This treatment would provide a short-term boost, but no long-term fertility. As in the No Action Alternative, no ripping is proposed to reduce compaction of the replaced growth medium. As no ground disturbance would occur at the lacustrine and volcanic soil stockpiles, sediment delivery to Lake Creek and the toe ponds would be minimized.

Genesis (now Troy Mine, Inc.) has conducted reclamation test plots on the tailings impoundment in Cell 2. To test reclamation materials' potential for revegetation, 18 inches of the lacustrine and volcanic ash-derived soil material were placed in one plot, and 12 inches of glacial outwash borrow materials from a borrow source east of the impoundment were placed in another plot. Troy Mine, Inc. asserts that the glacial outwash materials produce better tree growth than do the lacustrine and volcanic ash-derived soils (Genesis 2006, page 2-3).

The results on the glacial outwash borrow materials are mixed. The glacial outwash has a large and variable coarse fragment content. Tree growth was faster on glacial outwash with adequate fines. If the glacial outwash was too rocky, plant growth, including noxious weeds, was limited. Trees did not grow as fast on the lacustrine and volcanic ash-derived soil materials because of competition with seeded grasses and noxious weeds. The finer-grained reclamation materials also exhibited more compaction which limited plant growth (Genesis 2006, Appendix 2, page 5). The Agencies concluded that the lacustrine and volcanic ash-derived soil materials produced adequate tree growth and had a higher density of plant cover and productivity from the introduced grasses in the seed mix. Noxious weeds were widespread on all reclamation materials until Genesis (now Troy Mine, Inc.) started a weed control program in 1999. None of the test plots revealed any of the yellowing of plants observed operationally on the raw tailings.

Based on observations of the tailings test plots (DEQ 2008a), some areas of the tailings impoundment would exhibit much slower plant growth for all species where the glacial outwash material contains excessive rock fragments. The glacial outwash materials have a low water-holding capacity, and plants

would have to depend more on rooting into the tailings material to procure adequate moisture for growth.

Before mining began, a productive forest existed on the lacustrine and volcanic ash-derived soil covered tailings impoundment footprint. The Proposed Action would not replace the stockpiled lacustrine and volcanic ash-derived soil material. However, using a glacial outwash material instead would result in gradual, but slower vegetative recovery. Native revegetation would also occur more slowly because the Proposed Action does not include ripping of compacted soils or adding an organic matter amendment. Fertilization and weed management in the Proposed Action are the same as in the No Action Alternative. **Section 3.16** describes revegetation efforts in greater detail.

The Proposed Action does not include patching the bare areas that currently exist on the reclaimed embankment slopes. Eventually, these bare spots would likely revegetate with a large component of noxious weeds and other aggressive weedy invasive species like cheatgrass.

3.13.5.3 Agency-Mitigated Alternative

Mine and Mill Site

The Agency-Mitigated Alternative for the mine and mill areas would use the same rocky, glacial-growth medium from the mill pad as the Proposed Action but with additional mitigations. To limit compaction, the Agency-Mitigated Alternative would require ripping before and after the growth medium is placed. Ripping would promote better infiltration, deeper root growth, more favorable soil structure, and would set the stage for better overall soil quality on the reclaimed surfaces.

An agency approved, wood-based, organic matter amendment such as wood waste compost would be tilled into the top 12 inches, so as to result in 1,100 lbs of nitrogen per acre (FHA 2007). This amendment would be required to be free of toxic levels of heavy metals, herbicide residues, and noxious weeds. This approach would stimulate biological productivity by favoring a fungus-based soil microbial community, which would favor tree growth. An agency-approved, wood-based, organic matter amendment would enhance reclamation success on the mine areas over both the No Action Alternative and the Proposed Action. The organic matter would increase infiltration, fertility, and the water-holding capacity of the rocky glacial materials, all of which would speed up soil development on the reclaimed areas.

If not enough reclamation material can be salvaged from the mill site, the rocky glacial outwash gravels from the tailings impoundment borrow sites would also be used. These rocky growth media have less risk of erosion on slopes over eight percent than do the finer-grained growth media used under the No Action Alternative. Twenty-five tons/acre of coarse woody debris (larger than three inches in diameter) would be scattered across the reclaimed areas at the mine portals and mill. All disturbed ground would be covered with an agency-approved mulch.

Soil testing would be required to identify fertilizer needs in the growth media. If a need for supplemental fertilization is indicated, slow-release organic fertilizers would be used rather than the chemical fertilizers proposed under the No Action Alternative and the Proposed Action. Chemical fertilizers provide a short-term nutrient flush, which favors weedy invasive species over native species.

The Agency-Mitigated Alternative would result in the passive decommissioning of 3.8 miles of road and the active decommissioning of 2.7 miles of road (**Figure 3-10**). Many roads used for drilling decades ago have revegetated and pose a low erosion risk to the watershed. These roads would be passively decommissioned and allowed to continue to revegetate naturally. However, long-term productivity on these roadbeds is expected to be reduced as compared to treated roadbeds. Road cuts and fills in the mine area have largely revegetated over the last 30 years with alders, conifers, shrubs, and with noxious weeds. Roads to be actively decommissioned would be treated as described in **Table 2-1**, and no additional growth medium would be applied. The only growth medium would be the native rocky glacial materials recovered in place. On roads that would be recontoured, specific measures would be required for clearing established vegetation and placement of organic material back on recontoured surfaces. This treatment would improve soil function and productivity of actively decommissioned roads.

As under the No Action Alternative and the Proposed Action, the angle-of-repose portal patio slopes would not be given additional reclamation treatment. The lower slopes of the portal patios would largely not revegetate because they are too rocky and contain little material for plants to invade. They would resemble talus slopes. However, the upper slopes would be able to support some vegetation including shrubs, trees, and spotted knapweed.

Impoundment Area

The Agency-Mitigated Alternative would use the lacustrine and volcanic ash-derived soil materials to reclaim the tailings impoundment area disturbance as in the No Action Alternative. These materials would be used because they would produce better soil quality and a more productive plant growth medium due to their larger water-holding capacity. The material proposed under this alternative would eventually produce a quality soil with a more productive forested plant community, even with the presence of noxious weeds.

The Agency-Mitigated Alternative would use up to 90 percent of the lacustrine and volcanic ash-derived soil material stockpiles between Lake Creek and the toe ponds. At least 10 percent of the lower slopes of the lacustrine and volcanic ash-derived soil material stockpile, which are currently vegetated, would be left to act as erosion control berms to prevent sediment delivery to Lake Creek and the toe ponds.

As at the mill site, an agency-approved, wood-based, noxious weed-free, organic matter amendment would be tilled into the lacustrine and volcanic ash-derived soil material to result in 1,100 lbs of nitrogen per acre in the upper six inches of the growth media. Soil testing and fertilizer requirements would be the same as listed above under the Agency-Mitigated Alternative for the mine and mill pad area.

3.13.5.4 Resource Impact Summary

All three alternatives would provide reclamation of disturbed sites. The growth medium replacement plans for the tailings impoundment under the No Action and Agency-Mitigated alternatives would produce the best long-term results in terms of soil quality and plant productivity. The necessary volume of soil already exists in the soil stockpiles, and the glacial outwash borrow materials would not be needed under either of these alternatives. No additional disturbance would occur in the glacial outwash borrow areas under these two alternatives. The Agency-Mitigated Alternative would use BMPs not

included in the No Action Alternative to minimize potential impacts of erosion to Lake Creek and to the toe ponds that could possibly result from use of stockpiled materials.

3.13.5.5 Effectiveness of Mitigation Measures

No additional mitigation measures would be required for use of reclamation materials in addition to those listed in the Agency-Mitigated Alternative. The Agency-Mitigated Alternative requirements are standard proven practices for successful reclamation, and the use of these practices at the Troy Mine would produce the desired soil quality and productivity over time. The Agency-Mitigated Alternative would also require appropriate soil testing to identify other amendments, such as organic fertilizer, that may be needed to increase soil quality and revegetation success.

3.13.5.6 Cumulative Effects

Cumulative and additive effects of reclamation materials used under any of the three reclamation alternatives would produce the long-term revegetation necessary to reduce erosion potential within the Stanley Creek, Ross Creek, and the upper Lake Creek sub-watersheds. The Agency-Mitigated Alternative would provide a more productive native plant community and better hydrologic function at the mine and mill site over a shorter period of time than would the No Action Alternative or the Proposed Action. Other past, present, and reasonably foreseeable future actions in the Lake Creek watershed would not add to cumulative soil quality effects.

3.13.5.7 Regulatory Compliance

FSM guidelines require that NFSL be managed to maintain or improve soil quality (USFS 2009a). The objective with reclamation of disturbed sites is to restore soil function so that the disturbed areas can absorb and retain water, sustain appropriate native vegetation, and return to forest cover. All three alternatives would meet these guidelines on NFSL. However, the Agency-Mitigated Alternative would restore soil function in a shorter period of time.

The No Action Alternative would not include specific SWCPs and therefore would not meet current Forest Plan guidelines on NFSL. Both the Proposed Action and Agency-Mitigated Alternative would have project-specific SWCPs; however, the Agency-Mitigated Alternative would meet current standards more effectively and would better provide for future soil productivity.

The MMRA requires the reclamation of all disturbed lands to comparable stability and utility as that of adjacent lands. Where practicable, soil materials from all disturbed areas must be stockpiled and used. The No Action and Agency-Mitigated alternatives would reclaim all mining lands to comparable stability and utility; however, the Agency-Mitigated Alternative would achieve these goals more effectively and would use the soil materials that were stockpiled prior to construction of the tailings impoundment. The Proposed Action would not produce comparable utility on the reclaimed tailings impoundment.

3.14 Sound

3.14.1 Introduction

This section analyzes potential effects from noise, which is defined as "unwanted sound" that can be intermittent, continuous, stationary, or transient. The noise levels heard by a human or an animal are dependent on several variables, including distance between the source and receiver, altitude, temperature, humidity, wind speed, terrain, and vegetation. In the context of protecting the public health and welfare, noise can have adverse effects on people and the environment. The analysis in this section is based on the 1974 EPA report (*Levels Document*) (EPA 1974) that examined levels of environmental noise necessary to protect public health and welfare and a 1979 complementary summary document (EPA 1979).

Human and animal perception of noise is affected by intensity, pitch, duration, and by the auditory system and physiology of the animal. Noise levels are typically measured in decibels (dBA). As a result of the Noise Control Act of 1972, EPA developed acceptable noise levels under various conditions that would protect public health and welfare with an adequate margin of safety. EPA's *Levels Document* indicates that outdoor day-night noise levels less than or equal to 55 dBA are sufficient to protect public health and welfare in residential areas and other places where quiet is a basis for use (EPA 1979). However, the EPA guidelines are not enforceable regulations.

In evaluating the potential for noise impacts, the operational noise levels are compared to reclamation noise levels. Generally, in quieter areas, a smaller increase in noise would result in an impact, while larger increases could occur in noisier areas before an impact would be noticed. Generally, people cannot detect a change in sound levels of less than 2-3 dBA.

3.14.2 Regulatory Framework

The EPA no longer has regulatory authority governing noise. Coordination of noise control activities ceased in 1981 when responsibilities were transferred to state and local governments. There are no federal, KNF, or Lincoln County noise regulations in place for the analysis area.

DEQ analyzes noise impacts in its environmental documents under MEPA.

3.14.3 Analysis Area

The analysis area for this section is the Lake Creek watershed, with a focus on the vicinity of the Troy Mine Permit Area and the surrounding areas that could be affected by reclamation activities, such as the subdivision near the tailings impoundment.

3.14.4 Affected Environment

The project area currently has sound levels characteristic of an operating mine and mill, including heavy machinery, mill equipment, and trucks hauling concentrate to Libby. At closure, the noise impacts would be related to demolition of facilities, regrading, and to hauling growth media. The effects of other sources of human sounds (*e.g.,* highway traffic) are low and normally less noticeable.

Much of the analysis area consists of rural and forested lands. Lands located in or near wilderness areas experience day-night noise levels as low as 30 to 40 dBA (EPA 1979). Noise contributors in forest or wilderness settings typically include wind, wildlife, flowing water, overhead aircraft, and the occasional human visitor.

Other noise sources in the analysis area include vehicles on road surfaces. In addition to mining-related activities, vehicles use roads in the analysis area for recreational purposes, timber management, or for access to private lands.

3.14.5 Environmental Consequences

In this section, the project alternatives are evaluated to determine their potential impacts on the existing sound conditions within the analysis area.

The methods for assessing potential noise impacts generally include analyzing each alternative's potential, due to its location or associated activities, to:

- Introduce new sounds above current levels to an area; or
- Increase the level or frequency of existing noise producers in an area.

The specific potential impacts of each of the alternatives are discussed below.

3.14.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would follow specifications of the 1978 Reclamation Plan at the time of final mine closure. During reclamation activities, existing mine infrastructure would be demolished and removed, adits would be sealed, disturbed areas would be regraded and revegetated, and roads on NFSL would be removed or returned to KNF for maintenance and management responsibilities (see **Sections 3.8**, **3.15**, and **3.16** for a further discussion on regrading, roads, and revegetation plans). During reclamation, a negative noise impact would be expected because of heavy equipment use for activities such as regrading and demolition of buildings and other infrastructure. Noise generation would be typical of construction activities (generally not considered an irritant beyond 500 feet per EPA guidelines), would last only the duration of reclamation activities (1-2 years), and would be at levels similar to historical averages during mining activities (*e.g.,* heavy machinery and milling). As such, the impacts at the mine and mill area would be minor and short-term in nature. At the impoundment, regrading and placement of growth media would increase the duration of noise levels over those currently experienced at the impoundment site. These impacts would be noticeable to local residents but would be minor and would last approximately 1 to 2 years.

After reclamation is complete, human-related activities on the site would drop both in scope and frequency and would approach pre-mine levels. The area would return to recreational use and management of vegetation and wildlife habitat, but with human disturbance, vehicular use, and related sound impacts at reduced levels. After reclamation, a long-term, but minor and positive impact would be expected on sound conditions within the vicinity of the Troy Mine Permit Area.

3.14.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented so that on-going and future reclamation activities on the Troy Mine Permit Area would follow specifications of the updated plan. Under the Proposed Action, reclamation would be carried out and the Troy Mine Permit Area would be primarily used for passive water treatment and recreational purposes. The Proposed Action would demolish and remove or bury on-site all buildings and infrastructure. Pipelines used to transport mine water to the tailings impoundment for disposal would remain in place until water treatment is no longer needed and then be removed.

Other noise sources, such as vehicles on road surfaces, would also be minimized, as recreational use on the roads that remain in service would likely be less than the traffic generated by mine operations.

On private lands at the tailings impoundment, after reclamation and revegetation is completed, sound levels associated with passive water treatment and maintenance of mine water pipelines would continue but at a much lower level and frequency than current mine activities. Recreational use of the private lands would be restricted as during operations. Public access to private and patented lands after reclamation may be restricted to prevent vandalism to water treatment infrastructure such as the above ground mine water pipelines.

The Proposed Action would result in a short-term but minor negative impact on sound during reclamation activities because of heavy equipment and a long-term but minor positive impact on sound after reclamation because of reduced motorized and human-related activities.

3.14.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and expanded to address issues identified during the public scoping and agency review processes. Reclamation activities would be carried out, and the Troy Mine Permit Area would be primarily used for passive water treatment and recreational purposes. While there are differences between the reclamation plans of Proposed Action and the Agency-Mitigated Alternative, their impact on the sound environment of the analysis area would largely be the same.

Other noise sources, such as vehicles on road surfaces, would also be minimized. The Agency-Mitigated Alternative proposes to remove and reclaim select roads that are currently in use by mine personnel (see **Section 3.15** for a discussion of proposed road removal). Decommissioning of some roads would reduce vehicle access to certain areas, but mine closure would open up other areas to non-motorized recreational access. Recreational use on the roads that remain in service would likely be less than the traffic generated by mine operations and would result in less overall noise effects.

Overall, the Agency-Mitigated Alternative would result in a short-term minor negative impact related to sound during reclamation activities due to the use of heavy equipment. It would also result in a long-term minor positive impact related to sound after reclamation due to reduced motorized and human related activities.

3.14.5.4 Resource Impact Summary

In general, all three alternatives would result in a negative noise impact for a period of one to two years, due to the use of heavy equipment during reclamation. Each would also result in a minor long-term positive noise impact, due to a reduction in traffic and human visitation. Noise levels would not return to pre-mine conditions in any alternative.

3.14.5.5 Effectiveness of Mitigation Measures

Due to the low level of potential noise impacts, no mitigation measures have been identified. Standard best management procedures to reduce noise on heavy equipment (such as sound mufflers) would be used to minimize the potential for any sound-related impacts on surrounding areas and people (*e.g.,* local homeowners and recreationists) during reclamation activities.

3.14.5.6 Cumulative Effects

Cumulative or additive effects on noise levels as a result of implementing the Proposed Action or the Agency-Mitigated Alternative would include localized, long-term improvements over operational noise levels. Localized, long-term improvements would result from the decrease in noise levels because of reduced traffic and human visitation within the existing mine area following reclamation. There would be no negative cumulative effects on noise in combination with past, present, or reasonably foreseeable future actions in the analysis area.

3.15 Transportation

3.15.1 Introduction

Transportation relates to the movement of vehicles or people throughout a network of roads. This section of the EIS characterizes Troy Mine access roads within the Lake Creek watershed and identifies potential impacts to these resources under each of the proposed alternatives.

3.15.2 Regulatory Framework

The KNF Forest Plan outlines the following transportation-specific goals (USFS 1987, II-1):

- Construct the minimum number of roads necessary to permit the efficient removal of timber and mineral resources;
- Construct and reconstruct roads only to the minimum standards necessary to prevent soil loss;
- Maintain water quality;
- Minimize safety hazards for a reasonable and prudent Forest user;
- Provide access for fire protection where needed to meet management area goals;
- Maintain a balance of open and closed roads to continue present levels of motorized access;
- Ensure big game habitat security;
- Ensure grizzly bear security to meet recovery goals; and
- Reduce road maintenance costs.

In addition, the USFS issued the final NFSR Management Rule in January of 2001. This rule revises regulations on the management, use, and maintenance of the National Forest Transportation System. The final rule removes the emphasis on transportation development and adds a requirement for science-based transportation analysis. The KNF Three Rivers District published the *Roads Analysis Report: Mt. Vernon/Troy Mine* (hereafter called Roads Analysis Report) in 2004 (KNF 2008a) as a response to this 2001 rule.

In relation to private lands, FSM 2700, Chapter 2730.3 outlines USFS policy to grant adequate access across NFSL in accordance with 36 CFR 251, Subpart D, when no reasonable alternative exists across non-federal lands (36 CFR 251.110(g); 7/2001). An example of this would be when the private land is completely surrounded by NFSL. DEQ reviews road use and reclamation plans proposed in mine permit applications to ensure compliance with proposed post-reclamation land uses.

3.15.3 Analysis Area

The analysis area for this section is the upper Lake Creek watershed, with particular emphasis on all access roads associated with and adjacent to the Troy Mine Permit Area.

3.15.4 Affected Environment

The transportation system within the analysis area serves a variety of purposes and falls under a range of USFS, county, and private jurisdictions. Two primary activities that have taken place throughout this area include mining and timber harvesting. NFSR 4626 and spurs were constructed for timber harvesting and the remaining roads on NFSL and Revett/Troy Mine, Inc. patented property were primarily constructed for mining-related purposes (KNF 2004). The mining-related roads were mostly constructed in the 1960s on NFSL, and portions of this land were subsequently patented in 1977. When the patent was issued, the roads on the patented claims became privately owned. These private roads on patented claims are listed in **Table 2-1**. The USFS retained easements on NFSRs 4628, 4629, and 4551 across the patented ground. In addition, numerous private roads exist on Troy Mine, Inc. land at the tailings impoundment area. See **Figure 3-9** for an overview of the road system in the analysis area.

In addition to serving economic uses related to forestry and mining, the extent of a road network in an area can also influence both wildlife and the level of recreational access available. Roads can impact terrestrial habitats (*e.g.,* for grizzly bear) via direct habitat loss, as barriers to movement, through an increased potential for human-wildlife interactions, and through mortality. This particular analysis area is located within Bear Management Unit 3 (BMU 3) of the Cabinet-Yaak Ecosystem (CYE), which has been designated by the USFWS as a recovery zone for grizzly bears. See **Section 3.18** for more specific information on BMU 3. Roads can also adversely affect watershed conditions. Because of high precipitation, steep topography, and areas of unstable soils, road failures have occurred periodically in this area. Roads in the analysis area also play an important role in providing access for a variety of recreational pursuits that include hunting, fishing, driving for pleasure, berry picking, and wildlife watching (KNF 2004).

3.15.4.1 Troy Mine Permit Area and Vicinity

Within the Troy Mine Permit Area, NFSR 4626 serves as the main access road to the mine and is a main connection with other NFSRs (4605 and 384) that provide recreational access to Spar Lake. Ownership and maintenance jurisdiction of this road varies along its length. **Figure 3-9** depicts roads within the analysis area and shows the agency or private landowner with jurisdiction over each road.

Public access on NFSR 4626 is restricted with a gate at the mill site. South of the mill site, NFSR 4626 provides access to the North Portal and the Mt. Vernon road system. Continuing south past the mill site, NFSR 4626 intersects with NFSR 4829, which in turn intersects with NFSR 4828. From this point, NFSR 4828 connects with Ross Creek Road (NFSR 398), the major access route to the Ross Creek Scenic Area. NFSR 4828 is gated 0.28 miles from its junction with NFSR 398. Given current road restrictions and the gate located at M.P. 0.28 on NFSR 4828, public access on Mt. Vernon between Stanley and Ross creeks is only available to non-motorized users and is the only means by which to access the Spar Peak (#513) trailhead off NFSR 4829.

3.15.4.2 Troy Mine Access Roads/Permitted Roads

Access to the Troy Mine is from MT 56 onto NFSR 4626. The State of Montana granted a “driveway and approach” permit in 1978 to construct from the junction with MT 56 at M.P. 24.6.

The USFS has evaluated roads on NFSL for environmental risk through a roads analysis process. Factors considered include timber management, fire suppression, watershed protection, wildlife protection, and reduction in road maintenance costs. A more detailed discussion of specific road management category determinations can be found in the KNF’s 2004 Roads Analysis Report, Step 5 (KNF 2004), as well as in Appendix A and B of the Roads Analysis Report (KNF 2008a).

The following list describes some of the access roads within the Permit Area:

- NFSR 4551: This road is located near the top of the ridge west of Mt. Vernon and was built for exploratory drilling. The road is located both on patented land and on NFSL. The USFS has jurisdiction on this road and maintains it as access to Trail #513. The USFS would like to convert this road to a trail.
- NFSR 4624: This road spurs off of NFSR 4628 above the South Portal and was built for exploratory drilling. It is partially on patented land and partially on NFSL. A major debris torrent appears to have originated from this road. The USFS has no need for the road.
- NFSR 4624B: This spur off of 4624 is entirely on NFSL. It was built for exploratory drilling. The USFS has no need for this road.

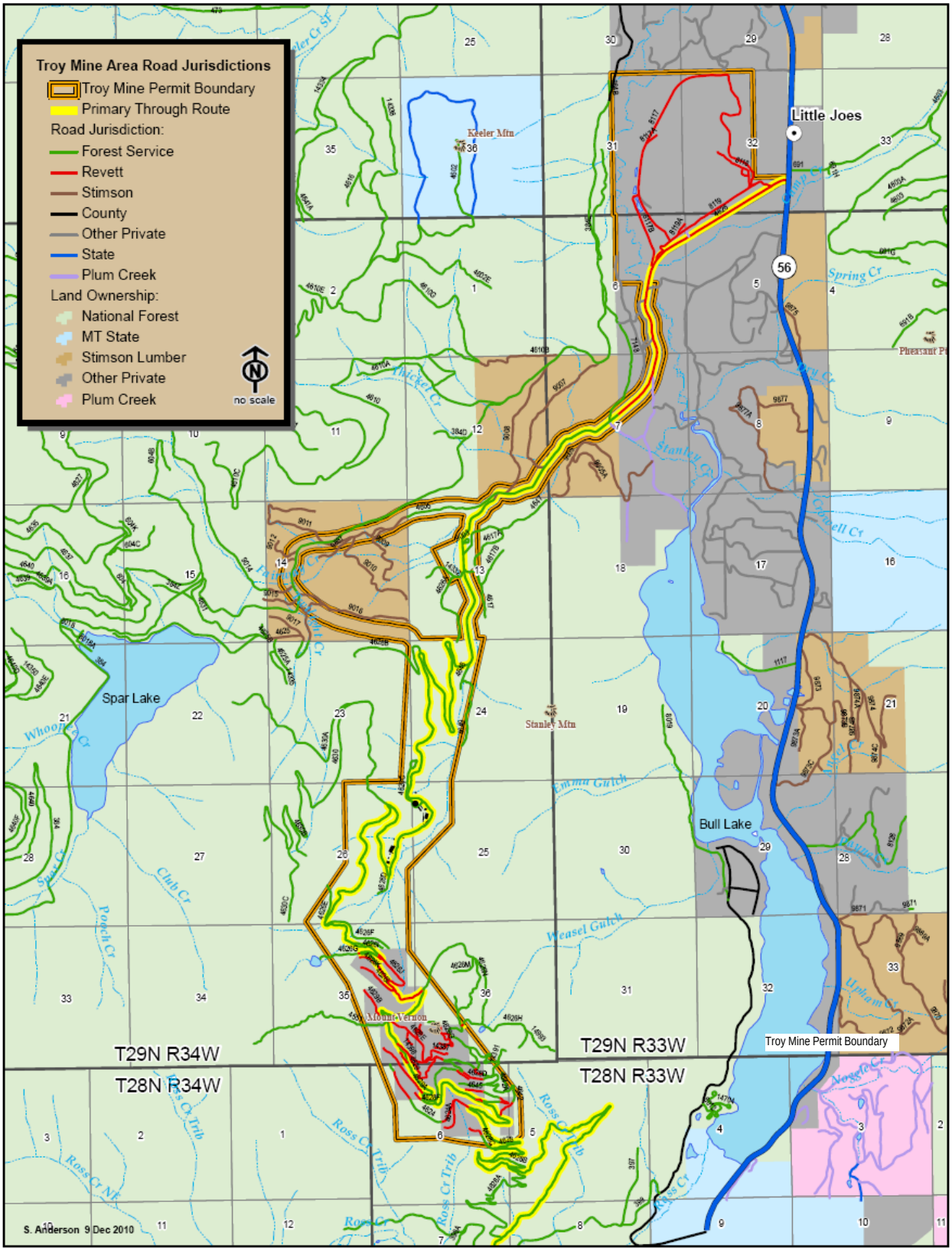


Figure 3-9. Road System in Analysis Area

- NFSR 4626: This is the main road up to the mine site (although public access is restricted through the mill site). It provides the only drivable access from the Stanley Creek drainage over to Ross Creek Road. According to the 2004 Mt. Vernon/Troy Mine Roads Analysis (KNF 2008a), this road currently presents a high risk to water quality in Stanley Creek due to mass failure potential, inadequate stream crossings, surface erosion, and snowplowing. Segments of the road are identified as a high risk to the watershed. BMPs were implemented in 2008 from the mill site to the junction with NFSR 4626F, but beyond the junction with NFSR 4626F, BMP work is needed to prevent sedimentation. Portions of this route on patented mine property do not currently have a USFS easement (public right-of-way). The USFS plans to continue to use this road for wildfire suppression on Mt. Vernon and expects that this route would serve as the primary access route to the patented land on Mt. Vernon.
- NFSR 4626C: This road provides access to percolation ponds maintained by the mine. The USFS has no need for this road.
- NFSR 4626D: This road provides access to a water storage tank at the mill site. It is a source of sediment to Stanley Creek from surface erosion. The USFS has no need for this road.
- NFSR 4626F: This road provides access to the North Portal and east and west ventilation adits. Raw cut slopes and surface runoff are a sediment concern. The road has an undersized 36-inch culvert on an intermittent tributary to Stanley Creek. The USFS has no need for this road.
- NFSR 4626G: This road spurs off of 4626 above the mill site and was built for exploratory drilling. The beginning of the road is on patented land, but the remainder is on NFSL. The outlet to a pond is partially intercepted by the road, and water runs down the road. The USFS has no need for this road.
- NFSR 4628: This road begins near Ross Creek on NFSR 398. It was originally built to provide access for exploratory drilling and adit development. It provides access to the south side of Mt. Vernon including the South Adit. The road is on both NFSL and patentedland. USFS has jurisdiction on NFSR 4628 across the patented land. This road is subject to frequent rockfall and without regular maintenance would become impassable. The road has had previous mass failures and routes water and sediment down the road. The USFS plans to keep this road as long-term access for recreation and timber management.
- NFSR 4628A: This road is located south of the South Adit and was built for exploratory drilling and adit development. The road is entirely on NFSL. Troy Mine, Inc. has used this road for recent drilling operations, and it is currently gated. The USFS determined, in the Spar and Lake Subunits ROD, that this road would eventually be decommissioned and converted to a trail.
- NFSR 4628C/Revett: This route provides access to the South Adit and is partially on patented Revett property. The road routes runoff down to the South Adit. The USFS has no need for this road.
- NFSR 4629: This road lies almost entirely on patented Revett property on Mt. Vernon. It connects NFSR 4626 to NFSR 4628 and currently provides through-access from the mill site to the South Adit and to Ross Creek. This road is not needed by the USFS for motorized access but is desired as a route accessing Trail #513 by non-motorized recreationists. The USFS has jurisdiction on this road from NFSR 4628 to 4551.
- NFSR 4630A: This road is located in Twilight Creek to the west of the mill site, was built for exploratory drilling, and is on NFSL. The road has three stream crossings, one of which has previously failed. The USFS plans to keep this road for long-term access.

- NFSR 9003: This road was constructed to access the water-makeup pump station and surge pond. The road is on NFSL. The USFS has no need for this road.
- Other Mining-Related Roads on NFSL: These roads were constructed for exploratory drilling. The roads were reviewed and determined to have minor or no watershed concerns. The USFS has no need for these roads.
- Other Private Roads on Patented Land (listed in Table 2-1): These roads were primarily constructed for exploratory drilling. Some of them may have been constructed for timber harvest. These roads have not been evaluated for watershed risk.
- Other Private Roads on Troy Mine, Inc. Land: Roads are located on Troy Mine, Inc. land at the tailings impoundment (**Figure 3-9**). These roads are used to access the tailings impoundment.

3.15.5 Environmental Consequences

In this section, reclamation alternatives are evaluated to determine their potential impacts on the transportation resources within the analysis area. The issues considered include:

- Effects on road maintenance costs;
- Modifications of the road system; and
- Changes in access for recreational use.

The effects of the transportation system on wildlife are addressed in **Section 3.18**. The effects of the transportation system on watershed condition are addressed in **Section 3.9.** Depending upon the alternative chosen, certain access roads may be removed and the land reclaimed and revegetated, thus minimizing the impact and maintenance requirements of roads in the area. Specific potential impacts of each alternative are discussed below.

3.15.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would continue to follow specifications of the 1978 Reclamation Plan at the time of final mine closure. NFSR 4626 would no longer be restricted to public access through the mill site which would allow non-motorized access along NFSR 4626 to the patented land boundary. However, all other roads associated with the mining project would be removed and revegetated if approved by KNF. If KNF wants these additional roads to remain following completion of the mining project, then the maintenance of these roads would become the responsibility of KNF.

This analysis assumes that only the roads listed in **Table 2-1** would be reclaimed. There were no road reclamation details provided in the 1978 Plan. The gate currently situated at the mill site would remain in place, and motorized access would continue to be restricted beyond the gate in order to provide wildlife security. Over the snow vehicles would not be allowed.

The No Action Alternative would allow non-motorized recreational access through the mill site, decommission unneeded roads, and reduce road maintenance costs as a result of reducing the total miles of road. **Figure 3-10** illustrates roads after mine closure for the No Action Alternative.

Private roads on Troy Mine, Inc. land at the tailings impoundment were not addressed in the 1978 Reclamation Plan.

3.15.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented, and on-going and future reclamation activities on the Permit Area would follow specifications of the updated plan. Similar to the No Action Alternative, the main access road (NFSR 4626) would remain open to the mill site with the paved portions remaining in place. Under the Proposed Action, the existing USFS roads would remain in place per USFS requirements (Genesis 2006, page 4-1). The Agencies interpret this to mean that no roads would be reclaimed at the time of closure. The gate currently situated at the mill site would remain in place, and motorized access would continue to be restricted beyond the gate in order to provide wildlife security. Over-the-snow vehicles would not be allowed.

The Proposed Action would allow non-motorized recreational access through the mill site. The Proposed Action would not decommission any roads and, therefore, would not reduce road maintenance costs associated with these roads. **Figure 3-11** illustrates roads after mine closure based on Exhibit F of the *2006 Revised Reclamation Plan*.

Private roads on Troy Mine, Inc. land at the tailings impoundment were not addressed in the Proposed Action.

3.15.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the roads identified in **Table 2-1** would be treated. The Agency-Mitigated Alternative would be similar to the No Action Alternative except for treatment of the road surface of NFSR 4626.

Under the Agency-Mitigated Alternative, the asphalt on NFSR 4626 would be pulverized and converted to gravel surfacing. This would reduce the long-term maintenance cost because paved surfaces deteriorate and are difficult to maintain over time. Also, any mine-associated guardrails or safety berms would be removed.

The Agency-Mitigated Alternative would allow non-motorized recreational access through the mill site, decommission unneeded roads, and reduce road maintenance costs as a result of reducing the total miles of road. The gate currently situated at the mill site would remain in place and motorized access would continue to be restricted beyond the gate in order to provide wildlife security. Over the snow vehicles would not be allowed. **Figure 3-10** illustrates disposition of the roads after mine closure for the No Action and Agency-Mitigated Alternatives.

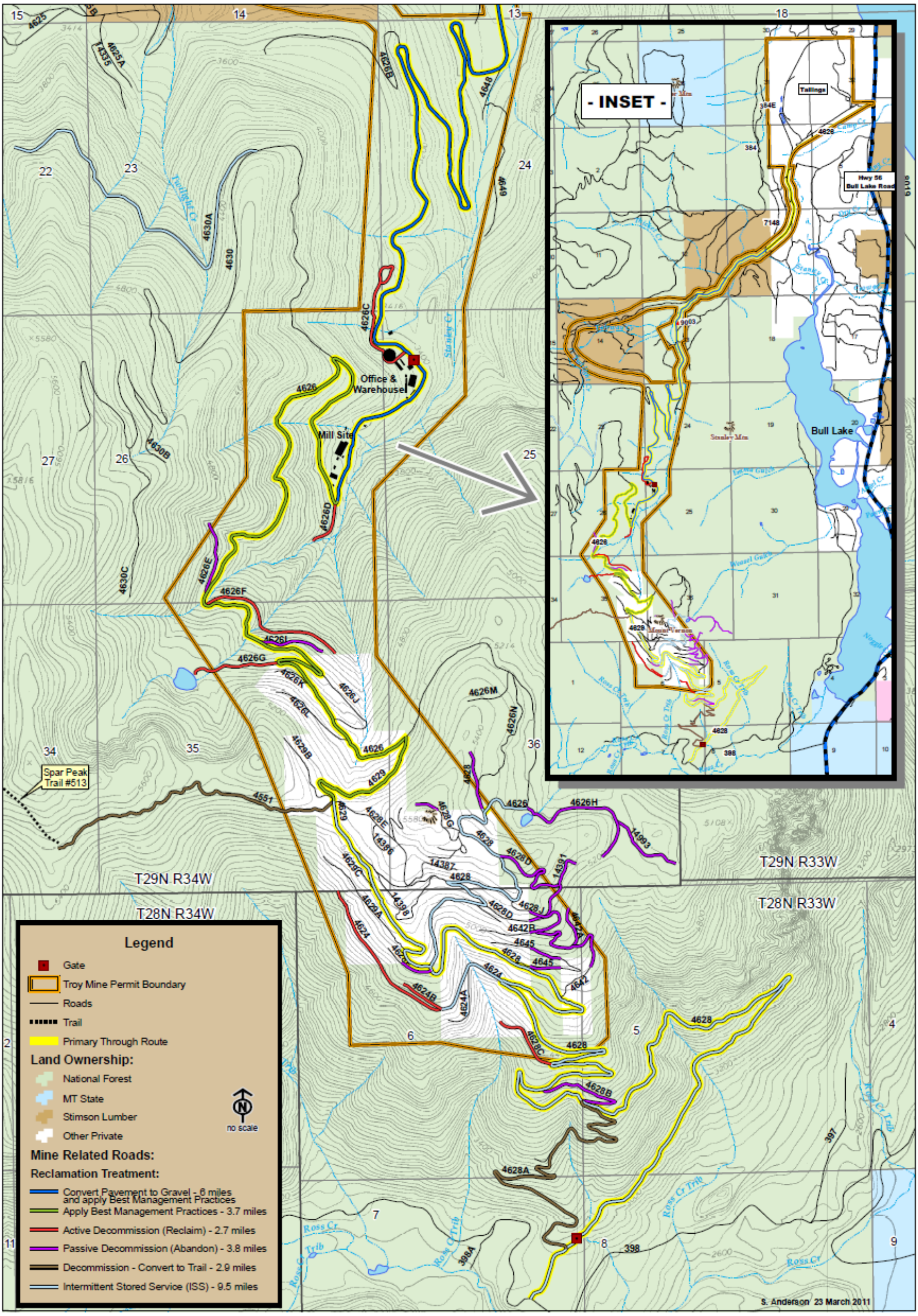


Figure 3-10. Road System Under No Action and Agency-Mitigated Alternatives

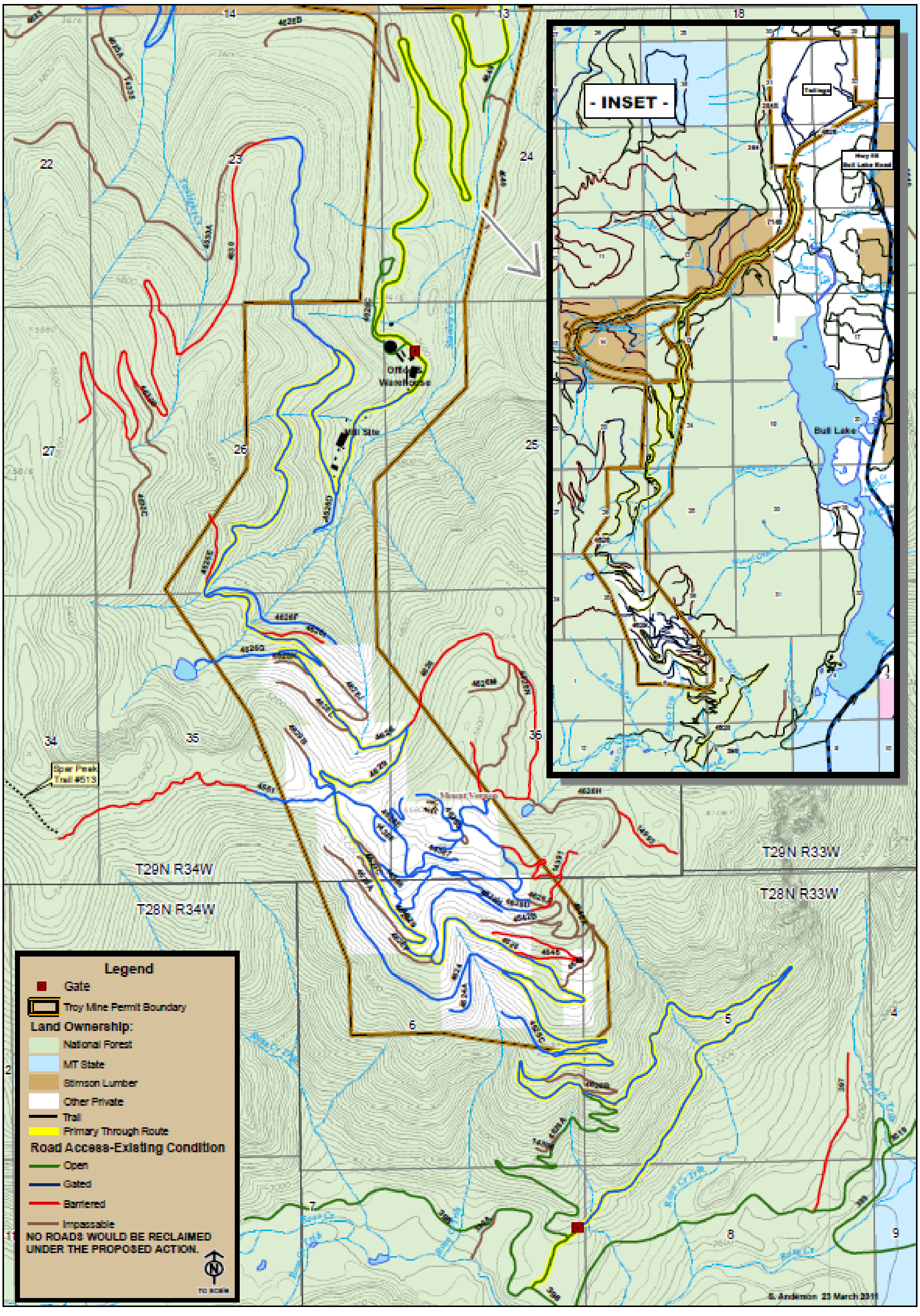


Figure 3-11. Road System Under the Proposed Action

Unneeded roads on NFSL would be removed from the NFSR system by either active or passive decommissioning. BMPs would be implemented as needed on roads where there are concerns about watershed impacts. This includes placing roads in intermittent stored service. NFSRs within the Troy Mine Permit Area would be handled as specified by USFS in the Roads Analysis Report – Troy Mine/Mt. Vernon (as Amended, March 2008) (KNF 2008a).

The Agency-Mitigated Alternative would decommission unneeded roads, reducing road maintenance costs. In addition, existing roads would be improved to USFS specifications, and improve long-term maintenance of NFSR 4626. Private roads on Troy Mine, Inc. property at the tailings impoundment would be field reviewed by the Agencies to decide if they are needed for post-mine land uses. Roads that are not needed would be ripped, covered with reclamation materials, and revegetated.

3.15.5.4 Resource Impact Summary

Under all three alternatives there would be a substantial reduction in traffic after reclamation activities are completed. This reduction in traffic would reduce road maintenance costs on local road networks.

The Proposed Action maintains the existing road system and related road maintenance costs. The No Action and Agency-Mitigated alternatives implement BMPs on 19.2 miles of road needed for long-term access (includes stored service work) and decommissions 6.5 miles of unneeded road, thereby reducing long-term road maintenance costs as compared to the Proposed Action. The Agency-Mitigated Alternative further reduces long-term road maintenance costs by replacing the 6 miles of paved surface on NFSR 4626 with gravel.

3.15.5.5 Effectiveness of Mitigation Measures

Under the Agency-Mitigated Alternative, mitigation measures applied to the transportation system would be standard USFS road specifications and standard BMPs. BMPs are periodically reviewed for effectiveness on NFSL roads.

3.15.5.6 Cumulative Effects

Under all three alternatives there would be a substantial reduction in traffic after reclamation activities are completed. This reduction in traffic would reduce road maintenance costs on roads that receive mine traffic. The No Action and Agency-Mitigated alternatives would further reduce long-term road maintenance costs by implementing BMPs, stored service work, and decommissioning. The No Action and Agency-Mitigated alternatives would permanently reduce the miles of NFSR on NFSL.

All alternatives would allow non-motorized access through the mill site which would improve general recreational access to the area. However, there is currently no legal public access across the patented land on the north side of Mt. Vernon, so public access to Trail #513 to Spar Peak would continue to be along NFSR 4628 and 4629 on the south side of Mt. Vernon.

In combination with other past, present, and reasonably foreseeable future actions, there would be no cumulative impacts from any of the alternatives.

3.16 Vegetation

3.16.1 Introduction

Implementation of the reclamation alternatives would produce few new disturbances; therefore, this section focuses primarily on reclamation, revegetation, and on noxious weed control. A discussion of proposed, threatened, endangered, and sensitive plant species is included, along with an up-to-date list of sensitive plant species known or expected to occur within the project vicinity. Effects to old growth forest are also addressed in this section. Potential impacts to these resources under each of the reclamation alternatives are evaluated.

3.16.2 Native Plant Species and Noxious Weeds

3.16.2.1 Regulatory Framework

The regulatory framework for this section includes:

- Forest Service Northern Region Native Plant Policy (FSM 2070.3);
- The Northern Region National Forest Service Manual (FSM) 2080 – Noxious Weed Management (USFS 2009a);
- KNF Invasive Plant Management Record of Decision (ROD) 2007 (KNF 2007);
- The Montana County Noxious Weed Control Law, as amended (7-22-2101 et seq., MCA);
- The State of Montana County Noxious Weed Management Act (7-22-2116, MCA) ;
- Executive Order 13112 of 1999;
- The Federal Noxious Weed Act of 1974;
- The Federal Insecticide Fungicide and Rodenticide Act (FIFRA) Public Law 92-516;
- The Carlson-Foley Act, Public Law 90-583 of 1968; and
- The MMRA and its implementing regulations.

A brief description of each of these regulations and guidelines follows.

FSM 2070: The Vegetation Ecology section of the FSM contains the Northern Region native plant policy and provides direction on revegetation with native plant species. The policy for selection, use, and storage of both native and non-native plant materials that are used in the revegetation, restoration, and rehabilitation of NFSL is as follows:

- Ensure that genetically appropriate native plant materials are given primary consideration;
- Restrict use of persistent**,** non-native, non-invasive plant materials to only those situations when timely re-establishment of a native plant community either through natural regeneration or with the use of native plant materials is not likely to occur;

- Select non-native plants as interim, non-persistent plant materials provided they will not hybridize with local species, will not permanently displace native species or offer serious long-term competition to the recovery of endemic plants, and are designed to help re-establish native plant communities;
- Base the determination and selection of genetically appropriate plant materials on site characteristics and ecological setting by using the best available information and plant materials;
- Ensure that development, review, and/or approval of revegetation, rehabilitation, and restoration prescriptions (including species selection, genetic heritage, growth stage, and any needed site preparation) is done by a plant materials specialist who is knowledgeable and trained or certified in the plant community type where the revegetation will occur;
- Do not use noxious weeds for revegetation, rehabilitation, and restoration projects;
- Cooperate and coordinate within USFS and with other federal agencies, organizations, and private industry in developing native plant materials and supplies; and
- Anticipate plant material needs for both emergency and planned revegetation and develop core plant lists, planting guidelines, plant material sources and seed caches, and seed storage facilities.

FSM 2080: Noxious Weed Management section directs KNF to use an integrated weed management approach to control and contain the spread of noxious weeds onto both NFSL and adjacent lands. Activities implementing the noxious weed management program must be consistent with the goals and objectives identified in Forest Land and Resource Management Plans.

KNF Invasive Plant Management Record of Decision (ROD) 2007 analyzed the use of herbicides for weed control on the KNF. Herbicide used on KNF for weed control must be completed in accordance with this decision or any subsequent weed management decisions for herbicide use.

The Montana County Noxious Weed Control Law states that designated noxious weeds must be managed consistent with certain weed management criteria; establishes weed management districts throughout the state; gives responsibility to county boards to develop and administer the weed district's noxious weed program; establishes management criteria for noxious weeds on all lands within the weed district; and makes all efforts to develop and implement a noxious weed program covering all land within the weed district owned or administered by a federal agency.

The State of Montana County Noxious Weed Management Act at 7-22-2116 states “it is unlawful for any person to permit any noxious weed to propagate or go to seed on the person’s land, except that any person who adheres to the noxious weed management program of the person’s weed management district or who has entered into and is in compliance with a noxious weed management agreement is considered to be in compliance with this section.” KNF has entered into an agreement with Lincoln County in the form of a Memorandum of Understanding (MOU) which states that “the purpose of this agreement is to document the sharing of expenses and materials between USFS and the County to accomplish mutually beneficial objectives related to the control of invasive and noxious weeds on National Forest System lands and/or private lands” within specific provisions and in accordance with a Financial and Operating Plan.

Executive Order 13112 directs federal agencies to prevent the introduction of invasive species; detect and respond rapidly to and control populations of such species in a cost-effective and environmentally-sound manner; monitor invasive species populations accurately and reliably; provide for restoration of native species and habitat conditions in ecosystems that have been invaded; conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally-sound control of invasive species; and to promote public education on invasive species and the means to address them. The agencies are not to authorize, fund, or carry out actions that are likely to cause or promote the introduction and spread of invasive species. All these actions are subject to the availability of appropriations.

The Federal Noxious Weed Act states that each federal agency shall establish and adequately fund an undesirable plants management program; complete and implement cooperative agreements with state agencies on the management of undesirable plant species on federal lands under the agency's jurisdiction; and establish an integrated management system to control or contain undesirable plant species targeted under cooperative agreements.

The Federal Insecticide Fungicide and Rodenticide Act requires all pesticides, including herbicides, to be registered with the EPA. It also states that it is unlawful to use any registered pesticide in a manner inconsistent with its labeling.

The Carlson-Foley Act authorizes and directs heads of federal departments and agencies to permit control of noxious plants by state and local governments on a reimbursement basis in connection with similar and acceptable weed control programs being carried out on adjacent non-federal land. In other words, this act permits county and state officials to manage noxious weeds with herbicides on federal lands and to be reimbursed for that management, provided that other applicable laws such as NEPA are also met.

The MMRA and its implementing regulations require reclamation to comparable stability (*i.e.,* non-erosive) and utility and that reclamation plans must produce the proposed post-mine land use. While the MMRA does not require planting native species, DEQ encourages the use of native species by its operating permit holders. DEQ also works with operating permit holders to ensure they have a weed control plan approved by the local county weed board.

3.16.2.2 Analysis Area

The analysis area for project impacts and cumulative effects is the Lake Creek watershed, which includes the Spar and Lake Planning Subunits (PSUs) (**Figure 3-12** in **Section 3.18**). A review of the larger planning subunits allows consideration of the presence and spread of noxious weeds and other invasive plants in the vicinity of the Troy Mine Operating Permit Area.

3.16.2.3 Affected Environment

Vegetation within the analysis area is representative of the surrounding landscape and is composed largely of native species-dominated forested plant communities. Both natural and human-caused disturbances have influenced species composition and forest structure and health. Historically,

disturbances related to wildfire and logging have influenced much of the existing vegetation communities. Other natural disturbance agents, such as pathogens (*e.g.,* blister rust) and insects (*e.g.,* bark beetles), also play an important role in forest structure and health. In the Troy Mine Permit Area, forested communities on disturbed lands have been removed, and approximately 504 acres have been disturbed to date (Genesis 2006, Table 2-1).

The original forested habitats were diverse mixtures of native species, but human activities introduced many non-native invasive species and noxious weeds into the surrounding plant communities. Approximately 131 acres have been reclaimed over the life of the mine, including 117 acres in the tailings impoundment area (Genesis 2006, Table 2-1). Seed mixes used in these reclaimed areas included a mixture of introduced grasses and forbs, and native trees and shrubs were planted. However, introduced noxious weeds and other invasive plants, as well as native grasses, forbs, shrubs, and tree species, have all volunteered from the surrounding plant communities. Overall, the reclaimed communities are less diverse than the undisturbed surrounding communities or the disturbed areas which were previously logged.

Operationally, Genesis (now Troy Mine, Inc.) has planted and irrigated barley on the relatively inert tailings surface as a cover crop to limit blowing dust. This barley has survived on the residual nitrogen in the tailings and in the mine water used to irrigate the tailings surface.

Many native and introduced species have volunteered on raw tailings over the years. These plants have shown some yellowing which indicates a lack of nitrogen and/or some potential metal phytotoxicity from residual metals in the tailings or mine water. Many native and introduced plant species have also volunteered on road cuts in native materials and mine development rock over the life of the mine. No yellowing of plants has been observed by DEQ on the road cuts in native materials or on mine development rock on the portal patios or slopes.

Noxious Weeds

A noxious weed is a non-native plant that threatens to invade sites where it has not previously occurred and that has the potential for eliminating or adversely affecting native flora and fauna. Noxious weeds in the vicinity of the Troy Mine Permit Area include spotted knapweed (*Centaurea maculosa),* meadow knapweed (*C. pratensis*), rush skeletonweed (*Chondrilla juncea*), oxeye daisy (*Chrysanthemum leucanthemum),* Canada thistle *(Cirsium arvense),* orange hawkweed *(Hieracium aurantiacum),* meadow hawkweed *(H. pratense),* common St. John's-wort (*Hypericum perforatum*), common tansy (*Tanacetum vulgare*), Dalmatian toadflax (*Linaria dalmatica*), tall buttercup (*Ranunculus acris*), and sulfur cinquefoil (*Potentilla recta*) (KNF 2010). Many of these weeds have been detected on roads and are largely associated with disturbed areas. Some have invaded into adjacent native plant communities.

Biological controls have been released in nearby areas outside of the Troy Mine Permit Area on the KNF for several species including spotted knapweed. Species released were sulphur knapweed moth (*Agapeta zoegana)*, knapweed root weevil (*Cyphocleonus achates)*, and the lesser knapweed flower weevil (*Larinus minutus)*. Releases were made within the analysis area in 1999 and 2000. Effects of these releases are unknown. Since the time of these releases, the release area, which had been logged and

planted with trees, has grown into a pole timber stand with much of the spotted knapweed suppressed by the dense overstory. The biological control insects may have established and migrated to other areas, but whether this happened is unknown.

Another biological control agent, the seedhead fly (*Urophora affinis*), was earlier released, and has become established on the KNF and throughout Montana. It is reducing spotted knapweed seed production.

3.16.2.4 Environmental Consequences

The method for assessing potential vegetation impacts from new disturbances generally includes analyzing each alternative's potential, due to its location or associated activities, to:

- Remove or disturb natural vegetation communities; and
- Introduce or spread noxious weeds or other invasive species.

The method for assessing potential vegetation impacts from reclamation generally includes analyzing the potential of the revegetation plans within each alternative to:

- Comply with the Forest Service Native Plant Policy;
- Comply with KNF, Montana, and County Noxious Weed Laws;
- Comply with the MMRA requirement to produce comparable stability and utility for the post-mine land use; and
- Re-establish native species-dominated, diverse, productive plant communities.

No Action Alternative

Under the No Action Alternative, reclamation activities would follow specifications of the 1978 Reclamation Plan at the time of final mine closure. The lacustrine and volcanic ash-derived soil material stockpiles around the tailings impoundment would be used to reclaim the tailings impoundment and the mine area disturbances. These stockpiles contain 824,634 cy of soil. Approximately 766,600 cy would be needed to cover the 316 acres of the tailings impoundment surface with the approved 18 inches of material (Genesis 2006, Tables 2.1 and 4.1). No additional reclamation except noxious weed control would be conducted on the revegetated tailings embankment. Soil remaining in the stockpiles would be seeded with the introduced seed and native tree and shrub planting mix, which was approved in 1978, and left in the stockpile area.

The mine and mill areas on patented and unpatented claims on NFSL would be reclaimed with stockpiled lacustrine and volcanic ash-derived soil material stored at the tailings impoundment. The USFS borrow site near the mine would also be used to supplement growth medium as needed at the mine and mill areas. About 43,560 cy of growth medium would be needed to reclaim the 27 acres of disturbance in the mine and mill area and in the tailings pipeline and road corridor area (Genesis 2006, Table 4.1).

All of the proposed soil stockpiles and borrow areas contain noxious weeds and other invasive weed seeds that would complicate reclamation efforts. The stockpile materials contain large amounts of

noxious weed seeds in the previously revegetated upper layer. Genesis (now Troy Mine, Inc.) has been controlling weeds since 1999, but noxious weed seed is long-lived. As these materials are used in other portions of the reclamation area, noxious weed control efforts would need to continue. The 1978 Reclamation Plan does not specifically mention control of noxious weeds, but the No Action Alternative would include the current noxious weed control plan that was approved by Lincoln County and KNF.

The soil stockpiles have been in place for almost 30 years and lack organic matter and soil biological productivity. Both the USFS borrow site and the tailings impoundment area borrow sites are rocky glacial materials which have the same problems and also have a larger rock fragment content. No organic matter amendments to the growth medium are proposed in the 1978 Reclamation Plan. The stockpiled lacustrine and volcanic ash-derived soil material in the tailings impoundment area has a low water-holding capacity, but its water-holding capacity is greater than the rocky glacial materials.

Reclaimed areas would be seeded, planted, and fertilized the first growing season after facility removal and regrading of the area were accomplished. A single mixture of introduced grasses and legumes and native shrubs and trees would be used for all revegetation efforts. This seed mix would be composed of common, exotic, and herbaceous grass and forb species (including sweet clover) and a mix of native and non-native woody species. Many of the woody species proposed for revegetation are native and appropriate for the areas even though the seed source may not be local (from within the KNF area).

However, none of the proposed herbaceous species are native to the area, nor was the herbaceous seed mix developed to target specific habitats (*e.g.,* upland vs. wetland) that occur on areas to be reclaimed. The herbaceous seed mix under the No Action Alternative includes: timothy (*Phleum pratense*), hard fescue (*Festuca ovina*), orchard grass (*Dactylis glomerata*), bluegrass (*Poa* spp.), brome (*Bromus* spp.), and sweet clover (*Melilotus* spp.). Many of these exotic, non-native species have been planted historically on disturbed areas on NFSL because of the lack of native plant seed sources. The use of non-native species for reclamation of the Troy Mine disturbances would increase the presence of introduced species and reduce the potential for native plants to colonize reclaimed areas. Using this proposed species mix for revegetation, even though appropriate at the time of the 1978 Reclamation Plan, would not meet current Forest Service Northern Region Policy on use of native plant materials.

Some of the planted woody species would be purchased from woody plant suppliers, and the seed source may be from outside the KNF region. These materials would meet the KNF native plant policy because the policy allows for sources from outside the region to be used when local availability is limited.

Approximately 27 acres of the mill site, office/shop areas, and other smaller disturbed areas, such as the tailings pipeline and road corridors, would be revegetated with the approved mix of seed and tree seedlings. Revegetation of approximately 15 acres at portal patios slopes would not be included in the No Action Alternative, though limited tree planting occurred in this area between 1997 and 1999.

The tailings impoundment embankment was built with compacted sandy tailings. The embankment slopes are 2H:1V between the benches with the overall slope at 4H:1V. Forty-two acres of the embankment slopes and benches were revegetated between 1995 and 1998 by utilizing the 1978

Reclamation Plan, which included covering the embankment with an average of 18 inches of stockpiled lacustrine and volcanic ash-derived soil material and seeding with the introduced herbaceous seed mix included in that plan. The resulting revegetation is dominated by planted native tree species as well as by introduced seeded grasses (*e.g.,* hard fescue) and noxious weeds. The revegetated slopes have some bare spots where the tailings are exposed. The No Action Alternative would not provide any further revegetation on any of these slopes.

The No Action Alternative would revegetate disturbed lands, which on a broad scale, could be viewed as a positive impact on vegetation resources. Even though the reclaimed forested plant communities may eventually resemble surrounding undisturbed plant communities, the new plant communities would have both short- and long-term negative characteristics. While revegetation efforts conducted in the late 1990s under the guidance of the 1978 Reclamation Plan have successfully reintroduced vegetation to portions of the Troy Mine Permit Area, the No Action Alternative would not meet current laws and standards on NFSL in a number of key areas.

Potential negative effects to vegetation under the No Action Alternative include the further spread of noxious weeds. The No Action Alternative does not address control of noxious weeds, which have become established within the activity area. Management of noxious weeds is a standard requirement not only for modern vegetation planning in general but also for activities on the KNF per the FSM on Noxious Weed Management (FSM 2080) and state and county weed control laws. A noxious weed control plan has been approved by KNF and Lincoln County. Because Genesis (now Troy Mine, Inc.) has been controlling noxious weeds since 1999, noxious weed populations have declined in the control areas. However, one of the impacts of chemical weed control is the incidental loss of some native species in the control areas.

Of particular importance are two recent invaders to KNF, meadow knapweed and rush skeletonweed. Meadow knapweed is well established on the tailings impoundment, embankment, the area surrounding the toe ponds, and on the soil stockpiles west of the impoundment. Meadow knapweed is a high priority species to be controlled. The KNF borrow source has also been invaded by rush skeletonweed, a Priority 1B noxious weed in the State of Montana. KNF is currently attempting to eradicate rush skeletonweed from the NFSL. The No Action Alternative's proposed use of the KNF borrow source would likely establish this species in the mine, mill, and tailings pipeline and road corridor areas with both indirect and cumulative negative effects to the surrounding public and private lands.

The approved noxious weed control plan, which includes the use of certified weed-free seed stocks, monitoring revegetated areas for invasion, establishing forest communities to shade out existing weeds, using competitive cover crops, and using herbicides selectively, would continue as during operations.

Past revegetation efforts in the mine, mill, and tailings impoundment areas using the approved 1978 Reclamation Plan have produced non-eroding and productive stands of vegetation on all but the angle-of-repose portal patio slopes and bare areas on the tailings embankment. The portal patio slopes are composed of rocky materials that naturally sorted as they were formed by end-dumping over the slope. The upper portions that contain the most fines would eventually become dominated by native woody

vegetation and noxious weeds. The lower slopes would likely always appear as man-made talus slopes with little or no vegetation, with the possible exception of some shrubs, trees, and spotted knapweed. The eroded portions of the revegetated tailings embankment slopes may eventually stabilize, but the shallow soil areas would probably be dominated largely by undesirable plant species.

While the No Action Alternative would successfully revegetate the Troy Mine Permit Area with a productive, non-erosive stand of vegetation except on the angle-of-repose rocky portal patio slopes, it would not do so in a manner consistent with current standards and laws. As such, the No Action Alternative would not be a feasible alternative for revegetation on public lands. The No Action Alternative would produce a plant community with comparable stability and utility that meets the post-mine land use of timber production, wildlife habitat, and recreation under the MMRA. The loss of many native species would limit wildlife habitat on public and private lands for some species, and it would take several decades for a forest-dominated habitat to develop on reclaimed lands.

After several decades, the reclaimed plant communities in the mine and mill areas would likely be dominated by native woody species that would help shade out most noxious weeds. The diverse native plant communities that were originally present in the mine and mill area would not return in the long-term as a result of the competitiveness of aggressive, introduced, seeded species, and weedy invasive species. Native plant species would also be limited by herbicides used to control noxious weeds.

After several decades, the reclaimed productive plant communities in the tailings impoundment area would also be dominated by native woody species that would help shade out most noxious weeds. The diverse native plant communities that were originally present in the tailings impoundment area would also not return in the long-term on these private lands. Noxious weeds and other invasive weedy species would not be eradicated from any of the reclaimed areas, and new invader weed species would likely spread beyond the vicinity of the Troy Mine Permit Area. The loss of native plant species diversity and the continued presence of invasive weedy species, such as rush skeletonweed, would be an unavoidable adverse and irreversible impact under the No Action Alternative.

Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented, and on-going and future reclamation activities on the Troy Mine Permit Area would follow the specifications of the updated plan. Reclamation materials proposed for reclaiming disturbed areas would include both the USFS borrow site at the mine site and the glacial outwash borrow sites near the tailings impoundment. The lacustrine and volcanic ash-derived soil stockpiles near the tailings impoundment would be used only if other sources do not provide sufficient volumes.

About 766,600 cy of glacial outwash borrow materials would be needed to cover the 324 acres of tailings impoundment area disturbances with the approved 18 inches of growth medium (Genesis 2006, Tables 2.1 and 4.1). No additional reclamation except noxious weed control would be done on the tailings embankment. Approximately 16 new acres of private land would be disturbed to salvage, haul, and stockpile undisturbed soil from the borrow sites, to obtain the glacial outwash growth medium, to

regrade the borrow sites to 2H:1V slopes, and to cover the borrow sites with growth medium (Genesis 2006, Table 2.1).

The mine and mill areas would be reclaimed with growth medium from the USFS borrow site. The lacustrine and volcanic ash-derived soil material stockpile at the impoundment area would be used to supplement the growth medium needed at the mine and mill areas. About 32,400 cy of growth medium would be needed to reclaim the 35 acres of disturbance in the mine, mill, and the tailings pipeline and road corridor area. About one acre of new ground would be disturbed to obtain the growth medium needed and to reclaim the USFS borrow area (Genesis 2006, Table 2.1).

All proposed borrow areas contain noxious weeds and other invasive weed seeds that would complicate reclamation efforts. The reclamation borrow materials would contain fewer noxious weed species and seeds than the soil stockpiles near the impoundment. In particular, rush skeletonweed seed in the USFS borrow site would be spread throughout the area where that material is proposed to be used.

All reclamation materials would have the same problems with lack of organic matter, lack of soil biological productivity, and large coarse fragment content as described in the No Action Alternative. No organic matter amendments to growth media are included under the Proposed Action. The rocky glacial outwash borrow materials and the rocky growth medium approved for use for the mine and mill areas have an even lower water-holding capacity than the lacustrine and volcanic ash-derived soil materials stockpiled near the tailings impoundment. Rocky material would favor the growth and establishment of spotted knapweed.

Unlike the No Action Alternative, revegetation under the Proposed Action would be tailored to specific areas, with five different seed/planting mixtures of native grasses, legumes, shrubs, and trees proposed for site-specific use on the basis of pre-mine species occurrence, establishment potential, growth characteristics, borrow stabilization qualities, commercial availability, experience gained from previously completed reclamation activities, and post-mine land use objectives (Genesis 2006, Tables 6-1 and 6-2). Three upland mixes (grassland, low elevation forest, and upper elevation forest) plus two wetland mixes (herbaceous wetland and forested wetland) would be used, with a focus on native species within each species mix.

The seed mixes would be composed of native perennial herbaceous grass and forb species with a mix of native woody species. Many of the native plant species proposed to be seeded would be cultivars that are commercially available but that may not be native to the KNF area. While many of the species proposed for revegetation efforts are native and appropriate for the specific planting areas, the seed source may not be from the KNF region as noted in the No Action Alternative.

The use of native species for reclamation of the Troy Mine disturbances would increase the potential for native plant species to colonize the reclaimed areas. The use of native plant seed from outside KNF is largely an unavoidable consequence of needing to get large areas of disturbance seeded and reclaimed at one time to limit noxious weed invasion and to limit control efforts that use herbicides.

Reclaimed areas would be seeded, planted, and fertilized the first growing season after facility removal and regrading of the area was accomplished. Species would be planted by broadcast seeding, drilling, or hydroseeding processes, which would be based upon topography, rockiness, and on sub-site size. Seeding would be coordinated with other reclamation activities and would generally occur in the fall or early spring, dependent on weather.

Fertilizer would be applied (except within 200 feet of a perennial stream) to speed up growth. Mulching with unspecified materials would be used on steep slopes to minimize erosion. Annual ryegrass, a fast-growing introduced annual species, would be added in proposed forested areas to minimize the potential for soil erosion and invasion by noxious weeds while slower growing woody species take hold. Irrigation would also be used, if required, during the first growing season to promote stand development on the tailings impoundment surface.

Native woody species would be planted, transplanted, or allowed to reinvade naturally on the basis of sub-site size and characteristics. Large disturbed areas and the presence of aggressive invasive species limit the potential of natural colonization of native herbaceous and woody species.

The approved noxious weed control plan, which includes the use of certified weed-free seed stocks, monitoring of revegetated areas for invasion, the establishment of forest communities to shade out existing weeds, the use of competitive cover crops, and selective herbicide use, would continue as during operations. Finally, monitoring of revegetated sites would occur during the pre-closure and closure phases of the reclamation process, and if poor growth is noted, additional site remediation would occur.

Thirty-five acres of the mill site, office/shop areas, and other smaller disturbance areas that include the tailings pipeline and road corridors, would be revegetated with approved mixes of seed and tree seedlings (Genesis 2006, Table 2.1).

As under the No Action Alternative, the tailings impoundment embankment has already been reclaimed during operations and no further reclamation would be done under the Proposed Action. In addition, wetlands that have formed around the toe ponds installed at the base of the embankment would be maintained.

Test plots on the tailings impoundment surface were completed in Cell 2 by using 18 inches of stockpiled lacustrine and volcanic ash-derived soil material or by using 12 inches of rocky glacial outwash borrow from a borrow area east of the tailings impoundment (Genesis 2006). The test plots were seeded with the approved seed mix and planted with tree seedlings, and some conifers were transplanted from the borrow area with a loader. Test plot data show that the reclaimed plant community is largely dominated by seeded grass species *(e.g.,* hard fescue), planted conifers, and by transplanted native conifers. Genesis (now Troy Mine, Inc.) concluded that reclamation that used the rocky glacial borrow materials had better tree growth than stockpiled soils (Genesis 2006, page 2-6). The Agencies concluded that the glacial outwash borrow material has a large rock fragment content, and revegetation success was variable based on the rock content. The use of coarse borrow materials would also favor growth of spotted knapweed.

Except for the steep portal patio slopes, the Proposed Action would revegetate 359 acres of disturbed lands with mostly native plant species, which would have a positive impact on vegetation (Genesis 2006, Table 2.1). Revegetation efforts would be tailored to sub-site specific characteristics and would make both the short- and long-term stabilization and growth of previously disturbed lands more likely. Based on the range of elevations and habitats, from sub-alpine to high meadows and wetlands, using a variety of seed mixtures would make the initial and on-going success of efforts much more likely than if a single plan and seed mixture were used site-wide as in the No Action Alternative. In addition, the use of mostly native species would produce a more natural reintegration of the planted areas with the surrounding vegetation mosaic once regrowth has occurred. The likelihood of both sub-site and site-wide revegetation success would be high given the flexibility of the revegetation plan under the Proposed Action, which includes multiple seed mixtures, site preparations, seeding plans, mulching and ground cover schemes, weed control, varying potential for fertilizer and irrigation use, and the short-term monitoring of revegetated areas.

Many of the herbaceous and woody species proposed for revegetation efforts are native and appropriate for reclamation use even though the seed source may not be from the KNF region. Revegetation on unpatented claims in the mine, mill, and tailings pipeline and road corridor areas would meet current Forest Service Northern Region Policy on using native plant materials on public lands.

Potential negative effects to vegetation from noxious weed invasion and spread would be minimized under the Proposed Action. Due to the presence of many noxious weed species on the Troy Mine Permit Area, both short-term management of existing populations and long-term management to minimize their spread would be needed for any reclamation effort to be considered successful.

Management of noxious weeds under the Proposed Action would also comply with the FSM on Noxious Weed Management (FSM 2080) and with state and county weed control laws. Noxious weed populations would continue to decline in the control areas. However, the use of chemical herbicides would continue to produce incidental loss of some native species in the control areas. Under the Proposed Action, the use of certified weed-free seed stocks and the long-term application of herbicides to the proposed borrow sources prior to redistribution would combine to limit the potential spread of weed populations during revegetation activities. In general, existing populations of noxious weeds would be controlled from spreading, and new populations would be minimized under the Proposed Action. However, noxious weeds would not be eradicated from any of the reclaimed areas.

The meadow knapweed on the tailings impoundment, embankment, and on the area surrounding the toe ponds would most likely persist despite control efforts. Use of the USFS borrow source would potentially establish rush skeletonweed in the mine, mill, and tailings pipeline and road corridor areas with negative indirect and cumulative effects to the surrounding public and private lands.

The Proposed Action would likely be successful in revegetating the Troy Mine Permit Area with a productive non-erosive stand of mostly native vegetation except on the angle-of-repose rocky portal patio slopes. The Proposed Action would do so in a manner consistent with current standards and laws, and therefore, it would be a feasible alternative for revegetation on public lands.

As in the No Action Alternative, the Proposed Action would reclaim plant communities in the mine, mill, and tailings impoundment areas. These areas would be dominated by native woody species that would help shade out most noxious weeds after several decades. The diverse native plant communities that were originally present in these areas would not return in the long term even though native species would dominate the seed and planting mixtures. This would be caused by the competitiveness of aggressive introduced weedy invasive species and by the indirect impacts of the weed control program.

Overall, noxious weeds and other invasive weedy species would not be eradicated from any of the reclaimed areas. The loss of native species diversity and the presence of invasive weedy species on all disturbed areas would be unavoidable adverse and irreversible impacts of disturbance under the Proposed Action.

The Proposed Action would produce a plant community with comparable stability (*i.e.,* non-erosive) and utility that meets the post-mine land use of timber production, wildlife habitat, and recreation under the MMRA. The loss of many native species would limit wildlife habitat for some species, and it would take several decades for a forested habitat to develop on the reclaimed lands. The forested community on the tailings impoundment would not likely be as productive as the forested community under the No Action Alternative because of the low water-holding capacity in the glacial outwash materials that would be used for a growth medium.

In summary, the Proposed Action would minimize some of the potential short- and long-term negative effects on vegetation resources. Previously disturbed sites would be revegetated with mostly native species and would blend somewhat with the surrounding plant communities. Noxious weeds would be largely controlled and eventually reduced by shading from trees. There would be minimal additional impacts to existing vegetation communities.

However, even with efforts to comply with KNF native plant standards on public lands under the Proposed Action and even with new plant communities being dominated by native tree species, the original diverse native plant communities would not return on public and private lands in the long-term. Noxious weeds would not be eradicated from the reclaimed areas, and rush skeletonweed would be spread with potential effects beyond the vicinity of the Troy Mine Permit Area.

Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be implemented and expanded to address issues identified during the public scoping and the Agencies' review processes. Reclamation materials proposed for use at the mine and mill areas would be salvaged rocky glacial materials stored in the mill pad at the mine site. If the mill and mine sites do not contain enough material, reclamation materials would be supplemented with the rocky, glacial outwash gravels taken from the borrow sites east of the tailings impoundment.

At the tailings impoundment, the fine-textured lacustrine and volcanic ash-derived soil materials in the stockpiles would be used on private lands, regardless of the weed seed content, because of their larger water-holding capacity. No new disturbance would take place under the Agency-Mitigated Alternative. Tailings areas that had been previously reclaimed with glacial outwash borrow materials would be

reclaimed again by using the lacustrine and volcanic ash-derived soil materials unless it could be documented that the majority of the reclaimed area contained a productive, native species-dominated community with no meadow knapweed. The same volume of growth medium would be needed to reclaim the tailings impoundment as in the No Action Alternative, and the same number of acres would be covered.

In the Agency-Mitigated Alternative, the revegetated slopes of the tailings embankment would be inspected, and any bare areas where the tailings are exposed would be recovered with lacustrine and volcanic ash-derived soil materials and replanted. The seed mix proposed under the Proposed Action for the tailings impoundment surface would be used. The amount of soil needed to reclaim bare spots on the embankment would be minimal in comparison to the volume needed to reclaim the 324 acres of disturbance in the tailings impoundment area.

The Agency-Mitigated Alternative would include a plan to minimize destruction of the revegetated plant community on the lower outer slopes of the lacustrine and volcanic ash-derived soil materials stockpiles in order to limit potential sediment impacts to Lake Creek and the toe ponds. Most of the undisturbed, revegetated outer stockpile slopes would be left as a berm to prevent storm water runoff from the disturbed internal portions of the stockpile from leaving the stockpile area. Portions of the slopes that would have to be disturbed to haul soil would use BMPs such as water bars to limit potential sediment impacts to Lake Creek and to the toe ponds.

The Agency-Mitigated Alternative includes adding an agency-approved, wood-based, organic amendment in the top six inches of reclamation materials at the tailings impoundment, and in the top 12 inches of reclamation materials at the mine portals, and mill site. Approximately 1,100 lbs/acre of organic nitrogen would be added to the growth medium. This organic matter addition would benefit revegetation efforts by increasing both the nutrient levels and the moisture holding capacity in the soils. Use of a wood-based organic matter would increase the establishment potential of fungus-based, soil microbe communities which, in turn, would favor forested plant community establishment. Adding organic matter would also improve the soil water-holding capacity of the reclamation materials. The Agency-Mitigated Alternative would use mychorrizal innoculum appropriate to the plant species being established at the mine and mill site. A cover of mulch would be applied over the disturbed ground to help retain moisture and to prevent erosion. The benefit of adding organic matter is that it helps establish desirable native vegetation through increasing moisture available to plants.

The coarse growth medium used at the mine and mill areas amended with organic matter would have a higher water-holding capacity and would help native species establish and compete with weeds that may be present.

The USFS borrow source, which has been infested with rush skeletonweed, would not be used in any reclamation efforts to prevent the spread of this species. As in the No Action Alternative, the lacustrine and volcanic ash-derived soil materials used for tailings impoundment reclamation would contain many noxious weed species and seeds. Weeds would be controlled by the approved weed control plan. Spot weed control would be important in the first few years of post-reclamation but, if not done correctly,

would eliminate many desirable forb species as well as native trees and shrubs. Indiscriminant weed control with chemicals could also kill many volunteering native forb species and favor other weedy invasive species like cheatgrass.

Test plots on the tailings impoundment surface were covered by either 18 inches of stockpiled lacustrine and volcanic ash-derived soil material or by 12 inches of rocky glacial outwash borrow from a borrow area east of the tailings impoundment (Genesis 2006). In these test plots, the borrow materials and especially the finer-grained soil from the stockpiles were compacted in the construction of the test plots as well as during planting and watering (Genesis 2006, Appendix B, page 5). The Agencies concluded that the use of 18 inches of lacustrine and volcanic ash-derived soil materials would eventually produce a more productive forested plant community if the fine-grained materials were not compacted, which would limit root penetration.

If Cell 2 is not redisturbed during operations, the Agencies would have to review the reclaimed test areas for compliance with the reclamation plan under the Agency-Mitigated Alternative (**Section 2.5.2.2**). Areas reclaimed with glacial outwash borrow materials would not comply with the approved reclamation plan and would have to be redone with the approved lacustrine and volcanic ash-derived soil materials from the stockpiles. All reclamation materials used as part of the Agency-Mitigated Alternative would be mechanically treated (*e.g.,* ripping) to reduce compaction after placement. This approach would avoid the compaction problems observed on the reclaimed tailings test plots during operations.

Under the Agency-Mitigated Alternative, the length and scope of proposed revegetation monitoring would be increased, with on-going monitoring proposed until the bond is released, and a proposed final field review by the participating Agencies to determine if further effort would be required.

Changes to the reclamation plan under the Agency-Mitigated Alternative would increase the potential success of the revegetation efforts beyond those expected from implementation of the *2006 Revised Reclamation Plan* under the Proposed Action. These changes include the use of the stockpiled lacustrine and volcanic ash-derived soil materials at the tailings impoundment with its larger water-holding capacity, increased soil organic matter content by using a wood-based organic amendment to stimulate soil microbe community development in all reclamation materials, mechanical treatments to reduce compaction, and the proposed extended post-reclamation monitoring.

As in the other alternatives, the Agency-Mitigated Alternative would revegetate disturbed lands, which would have a positive impact on vegetation resources. Previously disturbed sites would be revegetated with mostly native species by using the same seed and planting mixes as in the Proposed Action. The only difference in the seed and planting mixtures would be that the Agency-Mitigated Alternative would require Troy Mine, Inc. to try to obtain local seed and planting stock that originated in the KNF region. Reclaimed forested plant communities would eventually blend somewhat with the surrounding plant communities. Noxious weeds would be largely controlled and eventually reduced by shading from the trees. As under the No Action Alternative, use of borrow sites would be minimized as a way to minimize additional impacts to existing vegetative communities in the borrow sites. As with the other

alternatives, new plant communities would be dominated by native tree species that would help shade out most noxious weeds over time. Even with the proposed improvements to the revegetation plan to comply with KNF native plant standards, the original, diverse native plant communities that existed pre-mine would not return in the long-term on public and private lands. Noxious weeds and other invasive weedy species would not be eradicated from any of the reclaimed areas. These are largely unavoidable impacts of mine disturbance.

3.16.2.5 Resource Impact Summary

Overall, while all three alternatives would meet the minimum objective of revegetating previously disturbed land, the No Action Alternative would not sufficiently meet current standards on public lands, and thus would be considered not feasible as far as revegetation is concerned.

The Proposed Action and Agency-Mitigated Alternative would produce plant communities with comparable stability and utility that meet the post-mine land use of timber production, wildlife habitat, and recreation under the MMRA. The loss of many native species would limit wildlife habitat for some species, and it would take several decades for a forested habitat to develop on the reclaimed lands.

The Proposed Action and the Agency-Mitigated Alternative would reclaim the disturbed areas to productive, native-species dominated plant communities, which on a broad scale would be viewed as a positive result for vegetation resources. Both the Proposed Action and the Agency-Mitigated Alternative would minimize short- and long-term negative effects to the site and to regional vegetation by reclaiming previously disturbed land back to a more natural vegetated state. But the Proposed Action would spread rush skeletonweed through the use of material from the USFS borrow source. In all alternatives, diverse native plant communities would not be fully re-established, and noxious weeds would not be completely eradicated. Thus, noxious weeds would have the potential to continue to spread into surrounding natural areas.

There would be little new disturbance from implementing the reclamation alternatives. In general, all three alternatives would revegetate areas that have been disturbed for over 30 years. Land that was disturbed for the development of the mine and associated facilities when mining began in the 1970s would be covered with a growth medium to promote vegetation and would be reseeded or planted, thereby returning the land to a more natural, mostly vegetated state. Even though most of the site would eventually become reforested, the diverse native plant communities that were originally present would never fully re-establish.

3.16.2.6 Effectiveness of Mitigation Measures

No additional mitigation measures, beyond those included in the Agency-Mitigated Alternative (*e.g.,* organic matter amendment, etc.) would be required for revegetation. Regardless of these additional revegetation measures, noxious weeds would not be eradicated and the diverse native species that existed in the original plant communities would not return. The No Action Alternative is not practicable as discussed in other sections.

3.16.2.7 Cumulative Effects

No Action Alternative

While the No Action Alternative would reclaim the mine permit area, the use of non-native, aggressive species such as sweet clover would be detrimental to native species within the permit area and potentially beyond. In spite of continued weed control, using reclamation materials from the USFS borrow area and introduced species for revegetation ensures that the No Action Alternative would result in a disturbed landscape that is dominated by introduced herbaceous grasses and by invasive weedy species and noxious weeds, including both well-established and new invader species.

Proposed Action and Agency-Mitigated Alternative

As a result of implementing the Proposed Action or Agency-Mitigated Alternative reclamation plans, cumulative or additive effects on regional vegetation resources would include revegetation of disturbed lands with native species and continued noxious weed control, which eventually would produce forested plant communities that resemble surrounding undisturbed lands. Revegetation and noxious weed control would minimize the potential spread of noxious weeds into surrounding natural areas. Regardless of weed control efforts, noxious weeds and other weedy invasive species would continue to spread in the area as a result of other past, present, and reasonably foreseeable future actions as well as a result of the competitiveness of the weedy species. Intact native plant communities would continue to decrease in the watershed as new disturbances occur and as noxious weeds and other aggressive introduced species spread. The Proposed Action would facilitate the spread of rush skeletonweed throughout and likely beyond the mine permit area, but the Agency-Mitigated Alternative would avoid this effect by using reclamation materials not contaminated with rush skeletonweed.

3.16.2.8 Regulatory Compliance

Because the No Action Alternative includes planting of non-native species, it would not comply with the Forest Service Northern Region Native Plant Policy. Use of the USFS borrow source (which contains rush skeletonweed, a new invader weed species) under both the No Action Alternative and the Proposed Action would not comply with the KNF noxious weed MOU with Lincoln County. The No Action Alternative would use the lacustrine and volcanic ash-derived soil materials from near the tailings impoundment to reclaim the mine and mill areas. However, another new invader species, meadow knapweed, is found in those materials. Use of these reclamation materials on NFSL under the No Action Alternative would not comply with the KNF noxious weed MOU with Lincoln County.

The Agency-Mitigated Alternative would better comply with the regulatory framework because it would not use the USFS borrow area containing rush skeletonweed and would limit the use of lacustrine and volcanic ash-derived soil material containing meadow knapweed to private lands. In the Proposed Action and Agency-Mitigated Alternative, the use of native plant materials would comply with the Forest Service Northern Region Native Plant Policy.

3.16.3 Proposed, Threatened, Endangered, and Sensitive Plants

3.16.3.1 Regulatory Framework

The regulatory framework for this section includes:

- Forest Service Sensitive Species Policy (FSM 2670.32);
- Endangered Species Act (ESA) of 1973;
- The National Forest Management Act (NFMA) (36 CFR 219.19);
- The KNF Forest Plan of 1987; and
- Montana Natural Heritage Program.

Forest Service Sensitive Species Policy: FSM 2670.32 provides guidance to KNF on management of sensitive species with the objective of ensuring that sensitive species do not become threatened or endangered through USFS actions. To implement this objective, the policy directs Regional Foresters to identify sensitive species found within each region. Actions that could affect sensitive species must be analyzed, avoided, and minimized as much as possible while maintaining species viability.

The **ESA** declares that all federal agencies “utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act.” The ESA requires federal agencies to ensure that any agency action (any action authorized, funded, or carried out by the agency) would not likely jeopardize the continued existence of any threatened, endangered, or proposed species. Agencies are further required to develop and carry out conservation programs for these species.

The **NFMA** directs the USFS to manage habitat so that it maintains viable populations of existing native and desired non-native plant species. Forest Service Manual (FSM) 2670.22 requires the maintenance of viable populations of native and desired non-native plant species and avoidance of actions that may cause a species to become threatened or endangered. A viable population is defined as one that has the estimated numbers and distribution of reproductive individuals needed to ensure its continued existence and that is well-distributed throughout the planning area and KNF.

Sensitive species are administratively designated by the Regional Forester (FSM 2670.44) and managed under the authority of NFMA. FSM 2670.5 defines sensitive species as "those plant and animal species identified by a Regional Forester for which population viability is a concern, as evidenced by:

a. Significant current or predicted downward trends in population numbers or density; and
b. Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.”

The **KNF Forest Plan** establishes forest-wide goals, objectives, standards, guidelines, and monitoring requirements. Direction for sensitive species includes determining the status of sensitive species and providing for their environmental needs as necessary to prevent them from becoming endangered (USFS 1987, II-1).

DEQ has no direct regulatory control over sensitive species but evaluates potential effects on sensitive species listed by the Montana Natural Heritage Program and attempts to limit impacts to those species.

3.16.3.2 Analysis Area

The analysis area for project impacts and cumulative effects is the Lake Creek watershed, which includes the Spar and Lake PSUs (**Figure 3-12** in **Section 3.18**). Activities would only take place in the vicinity of the Troy Mine Permit Area. Review of the larger planning subunits allows consideration of plant species known to occur in the vicinity of the project area that may have higher potential to be present within the impacted area.

3.16.3.3 Affected Environment

No endangered plant species are known or suspected to occur on KNF. Additionally, no populations of threatened plant species are known to occur; however, two threatened species, water howellia (*Howellia aquatilis*) and Spalding's catchfly (*Silene spaldingii*) are suspected to occur on KNF. "Suspected" means that the species has the potential to occur, but has not been observed on KNF to date. Of the 52 threatened and sensitive plant species known or suspected on KNF, seven sensitive species are known to occur, and five additional sensitive species are believed to have potential to occur in the vicinity of the project area within the Spar and Lake Planning Subunits. However, none of these species are suspected to occur within the Troy Mine Permit Area. These 12 plant species plus *Howellia aquatilis*, and *Silene spaldingii*, are listed on **Table 3-18** (KNF 2010).

The Spar and Lake PSUs contain one population of *Botrychium pedunculosum* (stalked moonwort), seven populations of *Clarkia rhomboidea* (diamond Clarkia), one population of *Dryopteris cristata* (crested shield-fern), two populations of *Heterocodon rariflorum* (western pearl-flower), three populations of *Lomatium geyeri* (Geyer's biscuit-root), one population of *Mimulus breviflorus* (short-flowered monkeyflower), and two populations of *Phegopteris connectilis* (northern beech fern).

Table 3-18. Threatened and Sensitive Plant Species

Species	Habitat	Conclusion	Justification
Threatened Species			
Howellia aquatilis (water howellia)	Glacial ponds and river oxbows that dry in late summer	No Effect	No habitat in activity area
Silene spaldingii (Spalding's catchfly)	Palouse Prairie grassland	No Effect	No habitat in activity area
Sensitive Species			
Botrychium ascendens (upward-lobed moonwort)	Roadsides	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Species is not known to occur within the project area.
Botrychium crenulatum (wavy moonwort)	Riparian forests, open wet meadows, and roadsides	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Species is not known to occur within the project area.
Botrychium hesperium (western moonwort)	Snow fields, moist road ditches, meadows and grasslands in the montane zone	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Species is not known to occur within the project area.
Botrychium paradoxum (peculiar moonwort)	Mature western redcedar stands or grasslands and meadows	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Species is not known to occur within the project area.
Botrychium pedunculosum (stalked moonwort)	Old growth western redcedar in floodplains and meadows	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Known population in analysis area is protected.

Species	Habitat	Conclusion	Justification
Clarkia rhomboidea (diamond Clarkia)	Submaritime bedrock meadows and open ponderosa pine forest	May Impact*	Activities occur in disturbed areas not likely to provide habitat for this species. Known populations in analysis area are protected.
Corydalis sempervirens (pink corydalis)	Post-fire plant communities and forest openings	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Species is not known to occur within the project area.
Dryopteris cristata (crested shield-fern)	Riparian forests and open wet meadows	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Known population in analysis area is protected.
Heterocodon rariflorum (western pearl-flower)	Road shoulders, open soil areas near talus slopes, and submaritime bedrock meadows	May Impact*	Activities occur in disturbed areas not likely to provide habitat for this species. Known populations in analysis area are protected.
Lomatium geyeri (Geyer's biscuit-root)	Rock outcrops and submaritime bedrock meadows	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Known populations in analysis area are protected.
Mimulus breviflorus (short-flower monkeyflower)	Rock outcrops and submaritime bedrock meadows	May Impact*	Activities occur in disturbed areas not likely to provide habitat for this species. Known populations in analysis area are protected.
Phegopteris connectilis (northern beech fern)	Moist old growth, riparian areas, stream edges, and weeping walls	No Impact	Activities occur in disturbed areas not likely to provide habitat for this species. Known populations in analysis area are protected.

May Impact* = May impact individuals or habitat but will not likely contribute to a trend towards federal listing or cause a loss of viability to the population or species.

3.16.3.4 Environmental Consequences

The method for assessing potential vegetation impacts generally includes analyzing each alternative's potential, due to its location or associated activities, to remove or disturb threatened, endangered, or sensitive species, or their habitat.

There would be little new disturbance as a result of implementation of any of the reclamation alternatives. In general, all three alternatives would revegetate areas that have been disturbed for over 30 years. Land that was largely stripped for the development of the mine and associated facilities in the 1970s would be covered with a growth medium to promote vegetation and then seeded or planted, thereby returning the land to a more natural vegetated state.

No Action Alternative

While the No Action Alternative would revegetate the Troy Mine Permit Area, there would be continuing weed control needed as during operations. Use of stockpiled soils either from the tailings impoundment or from the USFS borrow materials would spread meadow knapweed and rush skeletonweed. In addition, native species would not be used in the revegetation effort. While these actions would not have direct impacts to proposed, threatened, endangered, or sensitive plant species, the overall result would be an increase in noxious and invasive species within both the mine permit area and the surrounding areas. There may be indirect effects to sensitive plant species such as *Clarkia rhomboidea*, which occur on open dry hillsides in the analysis area and which could be impacted by the spread of spotted knapweed.

Proposed Action

The use of native species for revegetation, along with control of noxious weeds, would make the Proposed Action an improvement over the No Action Alternative. Because the Proposed Action would not use stockpiled soils from the tailings impoundment area, the potential spread of meadow knapweed would be less than with the No Action Alternative. However, borrow material from the USFS borrow site would be used, and this material contains rush skeletonweed. Thus, the spread of this weed throughout the Troy Mine Permit Area and likely beyond could pose a hazard to sensitive plant species that may occur in dry open sites, such as *Clarkia rhomboidea*.

Agency-Mitigated Alternative

The Agency-Mitigated Alternative would be an improvement over the Proposed Action because it would not use the USFS borrow site, which contains rush skeletonweed, for growth media and would limit of the use of soil stockpiles containing meadow knapweed to private lands. Therefore, the Agency-Mitigated Alternative would not spread this new invader weed further. Rush skeletonweed could have potential indirect impacts to proposed, threatened, endangered, and sensitive plant species if it were to spread. The use of weed-free organic matter as a soil amendment would encourage desirable native species to establish in the mine permit area. This organic matter amendment increases the potential success of revegetation efforts and decreases the potential for off-site impacts to proposed, threatened, endangered, and sensitive plants from invasive species.

3.16.3.5 Resource Impact Summary

Even though the site would eventually become reforested, the diverse native plant communities that were originally present would never fully re-establish. While communities of threatened and sensitive plant species are known or thought to occur in the general area of the Troy Mine, these species have not been identified within the Troy Mine Permit Area.

3.16.3.6 Cumulative Effects

No Action Alternative

While the No Action Alternative would largely revegetate the Troy Mine Permit Area, the use of non-native, aggressive species in the seed mix, such as sweet clover, and the invasion by other aggressive noxious and invasive weedy species would be detrimental to native species within, and potentially beyond, the permit area. The indirect impacts of chemical weed control efforts would limit some native plant species from establishing. The use of stockpiled soils on NFSL from the tailings impoundment area containing meadow knapweed, and the use of coarse borrow material from the USFS borrow area containing rush skeletonweed for revegetation would ensure that this alternative would produce new plant communities containing noxious weeds. Finally, this spread of weeds beyond the Troy Mine Permit Area and the efforts to eradicate new invader noxious weeds would potentially affect sensitive plant species within the analysis area.

Proposed Action

Cumulative or additive effects on native vegetation as a result of implementing the Proposed Action would include long-term, localized improvements to native plant revegetation and the control of noxious weeds through reclamation of previously disturbed land to a more natural, vegetated state. Both planting native species and controlling noxious weeds would somewhat decrease the potential spread of noxious weeds (especially meadow knapweed) into surrounding natural areas on NFSL. However, noxious weeds may continue to spread in the area as a result of other past, present, and reasonably foreseeable future actions on both public and private lands. Intact native plant communities would continue to decrease in the watershed as new disturbances occur and as noxious weeds and other aggressive, introduced species spread. The Proposed Action would increase the spread of rush skeletonweed throughout the mine permit area and likely beyond. Finally, the spread of weeds throughout and beyond the Troy Mine Permit Area has the potential to impact sensitive plant species within the analysis area.

Agency-Mitigated Alternative

Cumulative or additive effects on native vegetation would be largely the same as for the Proposed Action. However, the Agency-Mitigated Alternative would not use reclamation materials on NFSL containing either meadow knapweed or rush skeletonweed. The Agency-Mitigated Alternative would not promote the spread of rush skeletonweed throughout or beyond the Troy Mine Permit Area. The spread of weeds beyond the Troy Mine Permit Area would have less potential to impact sensitive plant species within the analysis area under the Agency-Mitigated Alternative than under either the No Action Alternative or the Proposed Action.

3.16.3.7 Regulatory Compliance

All three alternatives would be in compliance with the Forest Plan, with Forest Service Policy on Sensitive Species (FSM 2670.32), and with the Endangered Species Act. USFS is mandated to maintain viable populations of all native and desirable non-native species under the National Forest Management Act.

3.16.3.8 Statement of Findings

Based upon this evaluation and the available information on these species' needs, the three alternatives and associated activities would:

- have "*No Effect*" on water howellia or Spalding's catchfly;
- "*May Impact Individuals or Habitat, But Would Not Likely Contribute to a Trend Toward Federal Listing or Cause The Loss of Viability*" to the population or species for diamond Clarkia, western pearl-flower, and for short-flowered monkeyflower; and
- have "*No Impact*" on the viability of other known or suspected threatened or sensitive plant species of the KNF.

3.16.4 Old Growth Forest

3.16.4.1 Regulatory Framework

The Forest Plan directs KNF to maintain a minimum of 10 percent old growth (OG) below 5,500 feet in elevation in each third order drainage or compartment or a combination of compartments (Kootenai Supplement No 85, supplement to FSM 2432.22).

The most recent Forest-wide old growth assessment as documented in the Forest Plan Monitoring and Evaluation Report (KNF 2009b) shows that KNF has 221,536 acres (11.9 percent) old growth designated. The Forest Plan established that maintaining 10 percent old growth habitat is sufficient to support viable populations of old-growth dependent species (Vol. 1, II-1, 7, III-54; Vol. 2, A17).

3.16.4.2 Analysis Area

The analysis area for project impacts and cumulative effects is the Lake Creek watershed which includes the Spar and Lake PSUs (**Figure 3-12**). The activity area is the vicinity of the Troy Mine Permit Area.

3.16.4.3 Affected Environment

The analysis area contains 9,028 acres (10.9 percent) of designated effective and replacement old growth (ROG) below 5,500 feet. Approximately 5,618 acres (6.8 percent) is designated effective old growth, and 3,410 acres (4.1 percent) is designated replacement old growth (**Table 3-19**). Replacement old growth (ROG) has many old growth characteristics, but not enough to be currently considered effective old growth. Replacement old growth is expected to become old growth in time.

Table 3-19 also shows the minimum acres required to be designated to meet Forest Plan standards. Designated old growth stands in the project area support the habitat conditions described in "Old Growth Forest Types of the Northern Region" (Green *et al.* 1992, corrected February 2005). Forest-wide acres are updated as of February 2008, and project area acres are updated as of November 2010.

Old growth stands in the analysis area are mainly composed of old western larch, western redcedar, western hemlock, ponderosa pine, Douglas-fir, and other conifers. Old growth management area designations in the project area were made to conserve the best old growth attributes available and to provide the best distribution, size, habitat type coverage, and quality of what is available. These old

growth stands are physically connected to other old growth stands where possible, or are interconnected to adjacent old growth stands by stands composed of 100+ year old age classes.

Table 3-19. Old Growth Forest Acres Under 5,500 feet Elevation on NFSL in the Analysis Area and Forest-wide

STATUS	Lake Creek Analysis Area Acres (Percent)	KNF Acres (Percent)
Total NFSL	105,315	2,200,200
Total NFSL below 5,500 feet elevation	83,117	1,869,222
Minimum acre designation required by Forest Plan	8,312 (10%)	187,000 (10%)
DESIGNATED OLD GROWTH (OG) (in MA 13, or Old Growth Management Area)		
Designated effective OG	5,618 (6.8%)	139,374 (7.5%)
Designated Replacement Old Growth (ROG)	3,410 (4.1%)	62,633 (3.3%)
Designated unknown (KNF Forest Plan)	0	19,499 (1%)
Total designated OG and ROG	9,028 (10.9%)	221,536 (11.9%)
UNDESIGNATED EFFECTIVE OG AND ROG		
Undesignated effective OG	427 (<1%)	60,730 (3.2%)
Undesignated ROG	438 (<1%)	36,229 (1.9%)
TOTALS FOR BOTH DESIGNATED AND UNDESIGNATED OG AND REPLACEMENT OG		
Total designated and undesignated effective OG	6,045 (7.3%)	199,839 (10.7%)
Total designated and undesignated replacement OG	3,848 (4.6%)	98,892 (5.3%)
All old growth acres below 5,500 feet	9,893 (11.9%)	298,731 (16%)

Less than one percent of the analysis area falls into the category of undesignated effective old growth. These stands have data that indicate the presence of some old growth structural criteria and are being tracked for possible designation in the future. Many of the undesignated effective old growth stands are small isolated stands or are linear stands located adjacent to open road systems.

The most recent Forest Plan Monitoring Report (KNF 2009b) indicates KNF has 1,869,222 acres below 5,500 feet elevation (minus lakes and highways). Using the stand-level data, there are currently 199,839 acres or 10.7 percent of KNF acres below 5,500 feet that are old growth (designated or undesignated). An additional 98,892 acres are replacement old growth (designated and undesignated). Forest-wide, old growth or replacement old growth on KNF totals 298,731 acres or 16 percent of acres below 5,500 feet based on the stand-level data. As described in the Forest Plan Monitoring Report (KNF 2009b), the Forest Inventory and Analysis data are summarized forest-wide and do not measure old growth based on the criteria in the Forest Plan. The Forest Inventory and Analysis data estimate effective old growth forest-wide at 9.0 percent of the Forest, with a 90 percent confidence interval of 7.2 to 10.9 percent. The acres of old growth from the stand-level inventory are just within the confidence interval for the Forest Inventory and Analysis data. However, it must be noted the Forest Inventory and Analysis data are measuring a different land base (all lands, not just lands below 5,500 feet in elevation). Also, to account for changes from when the Forest Inventory and Analysis data were collected, any plots with disturbance (*e.g.,* wildfire) were excluded from consideration as old growth. This is a conservative estimate, since some wildfires may not have affected old growth characteristics. The Forest Plan Monitoring Report (KNF 2009b) indicates the Forest is meeting its Forest Plan requirements for managing 10 percent of the forest as old growth habitat well distributed across KNF lands below 5,500 feet elevation.

3.16.4.4 Environmental Consequences

There is a limited quantity of old growth habitat located within the Troy Mine Permit Area primarily adjacent to roadways. Reclamation activities are not expected to occur in, or impact these areas; thus, effects to old growth forest will not be discussed further.

Since none of the alternatives would impact old growth stands within either the Spar and Lake PSUs or within the Troy Mine Permit Area, there would be no change in the quantity of old growth forest, and the analysis area would continue to meet Forest Plan standards for old growth. All alternatives would re-establish forested vegetation within the Troy Mine Permit Area. Re-establishment of forested cover would create the possibility of old growth within the mine permit area on NFSL after 150+ years. In this sense, the alternatives may be considered an improvement over the existing condition, but the chance of old growth establishment on this site cannot be determined with any accuracy.

3.16.4.5 Resource Impact Summary and Cumulative Effects

None of the three alternatives would have any effect on old growth, and therefore, there would be no cumulative effects to old growth.

3.16.4.6 Regulatory Compliance

All alternatives are consistent with Forest Plan direction to maintain a minimum of 10 percent old growth below 5,500 feet in elevation in each third-order drainage or compartment, or a combination of compartments (Kootenai Supplement #85, Supplement to Forest Service Manual 2432.22).

3.17 Visual/Scenery

3.17.1 Introduction

This section addresses visual quality as viewed from travel routes within the Lake Creek watershed and discusses how visual quality could be evaluated on NFSL, private, and patented lands. Additionally, potential impacts to these resources under each of the reclamation alternatives will be identified.

3.17.2 Regulatory Framework

The regulatory framework for this section includes the visual quality objectives of the Forest Plan (described in **Section 3.17.4.1**) and the USFS Visual Management Assessment System. This system provides a framework to consistently inventory visual resources on NFSL and provides measurable standards to manage these resources. DEQ has no regulatory authority but reviews visual quality effects on private lands within its environmental documents.

3.17.3 Analysis Area

The analysis area for the visual quality analysis is the Lake Creek watershed with an emphasis on Visual Quality Objectives (VQOs) for travel routes within the vicinity of the Troy Mine Permit Area.

3.17.4 Affected Environment

The current visual quality in and around the Troy Mine Permit Area was defined by describing the visual landscape character at locations within the analysis area. Each of these locations was evaluated in terms of its visual significance based upon viewing opportunities provided along important travel routes in the area. Visual quality and VQOs were described on the basis of visual condition class, distance zone, and sensitivity levels (KNF 2001). Each of these visual specifications is described below.

Visual Condition Classes

The existing visual condition is defined in terms of how the visual character of the landscape has been altered by human activities. The landscape is categorized into four condition classes based on the percent of that landscape's apparent visual alteration by human activities. The four classes are defined as follows:

- **Natural Appearing**: Natural landscape character "appears" intact or complete and is free of obvious management activities.
- **Slightly Altered**: Landscape character "appears" slightly fragmented. Some management activities are evident, but the overall level of disturbance is low.
- **Moderately Altered**: Landscape character "appears" moderately fragmented. Management activities are more noticeable and begin to contrast with their surroundings. The level of disturbance is moderate.
- **Heavily Altered**: Landscape character "appears" extremely fragmented. Management activities are very noticeable and dominate the view. The level of disturbance is high.

Distance Zones

Visual landscapes are divided into three distance zones:

- Foreground;
- Middleground; and
- Background

Foreground is defined as up to one-half of a mile from the viewer. Middleground extends from the foreground up to five miles from the viewer. Background extends from five miles from the viewer to the horizon.

Sensitivity Levels

Sensitivity levels are a measure of concern for scenic quality. Sensitivity levels are determined for land areas viewed by those: 1) traveling through the area on developed roads and trails; 2) using areas such as campgrounds and visitor centers; or 3) recreating at lakes, streams, and other water bodies. Three sensitivity levels are employed:

- Level 1 - Highest Sensitivity;
- Level 2 - Average Sensitivity; and
- Level 3 - Lowest Sensitivity.

3.17.4.1 Forest Plan Visual Quality Objectives

The Forest Plan (USFS 1987) provides VQOs for Management Areas within the analysis area. Potential VQOs include:

- **Preservation**: Provides for ecological change only.
- **Retention**: Management activities are not evident to the casual forest visitor.
- **Partial Retention**: Management activities may be evident but must remain visually subordinate to the characteristic (natural-appearing) landscape.
- **Modification**: Management activities may visually dominate the characteristic (natural-appearing) landscape, but must use established form, line, color, and texture and should appear as a natural occurrence when viewed in middleground or background.
- **Maximum Modification**: Management activities may visually dominate the characteristic (natural-appearing) landscape, but they must look like natural occurrences when viewed as background.

3.17.4.2 Travel Routes

The main travel routes that cross the analysis area and from which the Troy Mine Permit Area may be viewed as well as their sensitivity levels are:

- **Sensitivity Level 1 Travel Routes** - MT 56 and Ross Creek Road (NFSR 398), as well as views from Bad Medicine Campground, Dorr Skeels Campground, and Spar Lake Campground;
- **Sensitivity Level 2 Travel Routes** - County roads and Spar Lake Road (NFSR 384); and

- **Sensitivity Level 3 Travel Routes** - the remainder of the roads within the analysis area (KNF 2001).

Area 1 – MT 56: MT 56 runs from north to south down the middle of the analysis area. Most views of the KNF are limited to background views, with some middleground views in the vicinity of Keeler Mountain and Stanley Mountain. The analysis area, except at Bull Lake, is only visible in areas that have received timber management along the travel routes. Otherwise, dense forest blocks views of the area. Most of the private land along MT 56 has had moderate to heavy timber harvest activity or is developed residential subdivision. The forest is a mix of ponderosa pine, larch, Douglas-fir, and lodgepole pine. The area is only partially visible in the foreground view from United States Highway 2 (US 2) and MT 56. A number of roads run through the area along with a power line corridor running east to west. The visual condition class of NFSL within this area is moderately to heavily altered (KNF 2001).

Area 2 – Copper Mountain: Copper Mountain is visible for short durations while traveling on MT 56 but is limited to background views. It is also visible from the Chase Cutoff road (Lincoln County road). The east side of the ridge is characterized by many natural openings interspersed with heavily forested areas. The southern end of the ridge is on private land and some evidence of past logging is visible. Older clearcuts are visible, but have regenerated and are blending into the setting. Overall, the area has recovered sufficiently so that the opening appears natural. The visual condition class is slightly to moderately altered (KNF 2001).

Area 3 – Grouse Mountain: The northeast side of the Grouse Mountain ridge around to the nose of the ridge is visible in background views from MT 56. Numerous natural openings are scattered along the northeast slope intermingled with stringers of forest. The southwest-facing slope is more heavily forested with smaller openings. Tree species are predominantly ponderosa pine, lodgepole pine, and Douglas-fir. The visual condition class is slightly altered (KNF 2001).

Area 4 – Pony Mountain: The Pony Mountain area contains a number of clearcuts and has a high road density. It is not visible from any of the major viewing locations along MT 56, but the lower slopes are partially visible from MT 56. The remaining forest is closed canopy comprised of mixed conifer species. The visual condition class is heavily altered from past management activity (KNF 2001).

Area 5 – Keeler Mountain: The east face of Keeler Mountain is visible for fairly long durations from MT 56 in the middleground view. The lower elevations adjacent to Spar Lake Road (NFSR 384) are not visible due to the surrounding forest. The slope consists of many small openings with rock outcrops on steep slopes. At the present time, the visual condition class of the USFS-managed portion of this slope is natural appearing.

Area 6 – South Fork Keeler: This area is not visible from any of the major viewing locations. The ridgeline from Spruce Mountain to the northeast is roadless. The forest is composed of closed canopy stands with little scenic variation. The area has had some previous harvest, and the visual condition class is slightly to moderately altered (KNF 2001).

Area 7 – Thicket Creek: This area is not visible from any of the major viewing locations. The Thicket Creek drainage has had a number of timber sale units harvested in the past, most of which were

clearcuts. The drainage also has an extensive road system. The visual condition class of the drainage is moderately altered (KNF 2001).

Area 8 – Stanley Mountain: This area is visible from a number of Sensitivity Level 1 roads and viewing areas (campgrounds and water bodies) (KNF 2001).

- **MT 56**: This is the main travel route in the area. Once past Angel Island, the middleground and background scene is dominated by Bull Lake and its backdrop of forested slopes. The ridge framing the backside of the lake includes Mt. Vernon and Stanley Mountain and contains a mix of distinctive landscapes consisting of steep, heavily forested slopes bisected by steep incised drainages. A few small openings exist on the slope. The ridge was split in the past by an earthquake-induced slide that created a rocky sheer cliff behind Bad Medicine Campground (locally known as the Spires). Some management activities are visible. Both parcels of private land on the west side of Bull Lake have had timber harvest. These cutting units are discernible but generally blend into the surrounding landscape. NFSR 4628, which goes from the Ross Creek Road up to Mt. Vernon, is visible on the open slope to the south of the Spires.
- **Boats on Bull Lake**: The view of the analysis area is generally the same as from MT 56 depending upon viewer location on the lake.
- **Dorr Skeels Campground**: The views from this campground are of Bull Lake and Stanley Mountain to the west and of Bull Lake and the Angel Island subdivision to the south.
- **NFSR 398 and NFSR 8019 to Bad Medicine Campground**: This travel route initially passes through approximately one-half of a mile of private land, which has been logged. Once across Ross Creek, views are limited to foreground views of heavily forested areas; additionally, portions of Ross Creek and some riparian areas below the road are visible for brief periods. The west side of the ridge is not visible from any of the major viewing locations, and the visual condition class is slightly altered. The areas to be reclaimed are not visible from this viewing location.

Area 9 – Twilight Creek: The Twilight Creek drainage is a small drainage leading into Fairway Creek. The lower end of the drainage is on Plum Creek lands and has received heavy management activity. The visual condition class of upper portions of the drainage on NFSL is slightly altered (KNF 2001).

Area 10 – Camp/Madge Creeks: The Camp/Madge Creek area, outside of the wilderness, has had moderate to heavy timber management activity in the past. Lower portions of the drainages have a high road density, and the forest in this area is fairly open with some small grassy areas. This area is not visible from MT 56. The upper portion of the area is a grassy opening with scattered trees and rock outcrops. This area is in the middleground view from MT 56 (KNF 2001).

Area 11 – Ross Creek: The Ross Creek area is a major recreation area. Both the Bad Medicine Campground and the Ross Creek Cedars Scenic Area attract large numbers of visitors. From MT 56 to the Cedars, visibility is generally limited to roadside foreground views. An overlook on NFSR 398 provides background views into the Cabinet Mountains to the east, and some views of the south side of Mt. Vernon. Views from this trail system are generally of forest interspersed with grassy shrub openings in the foreground view, and heavily forested stands in the middleground view, with many background views of upper elevation rocky ridges and mountaintops above timberline (KNF 2001).

3.17.4.3 Visual Quality Objectives by Management Area

The Forest Plan describes VQOs for Management Areas (MA) within the analysis area (**Table 3-20**) and the VQOs for MAs within the Troy Mine Permit Area are shown in **Table 3-21**. Detailed descriptions of MAs can be found in **Table 3-14**.

Table 3-20. Forest Plan VQOs for Analysis Area Management Areas (MA)

MA	VQOs
2, 5, 21	Retention
6	Partial retention in foreground
7, 8	Preservation
16	Modification
17	Partial retention
30	Not applicable. The nature of the drawdown area does not lend itself to visual management.
3, 10, 11, 12, 13, 14, 18, 19, 24	Maximum modification for areas of low viewing significance; modification in areas of moderate viewing significance; and partial retention in areas of high viewing significance.

Source: KNF 2001

Table 3-21. Forest Plan VQOs for Management Areas (MA) within the Permit Area

MA	VQOs
2	Retention
11, 12, 13	Maximum modification for areas of low viewing significance; modification in areas of moderate viewing significance; and partial retention in areas of high viewing significance.
2og	N/A - Area of old growth within MA 2
Private	N/A - Private Land

Source: KNF 2001

3.17.5 Environmental Consequences

Visual quality of the Troy Mine Permit Area was addressed in the 1978 EIS. In this section of the EIS, the reclamation alternatives are evaluated to determine potential impacts on visual resources within the analysis area and how reclamation activities would minimize visual effects of the heavily altered disturbed lands that currently exist.

The method for assessing potential visual resource impacts generally includes analyzing each alternative's potential, due to its location or associated activities, to affect visual quality. The following questions must be answered:

- How would any new disturbances impact the visual or scenic quality, both natural and man-made, of an area both locally and from all locations from which it can be viewed?
- How would reclamation minimize the visual effects of disturbed lands?

Specific potential impacts of each of the alternatives are discussed in further detail below.

3.17.5.1 No Action Alternative

Under the No Action Alternative, reclamation activities would continue to follow the specifications of the 1978 Reclamation Plan at the time of final mine closure. Existing mine infrastructure would be demolished and removed, adits would be sealed, and disturbed areas would be regraded and revegetated (**Sections 3.8** and **3.16**). The mine, the mill area, and the tailings impoundment area, however, would not be returned to their approximate original (pre-disturbance) contours. These locales would always appear man-made. Less than one acre of new disturbance would result under the No Action Alternative.

Per KNF approval, roads no longer deemed necessary for recreational or management access would be removed, and the remaining NFSL roads returned to KNF management control (see **Section 3.15**). Road cut and fill slopes that would not be returned to original contours would remain visible on the landscape in the future. Roads reclaimed as part of mine closure would eventually blend into the landscape and end up with a slightly altered look.

In general, most of the Troy Mine Permit Area (including NFSL and patented lands at the mine and mill areas) would be returned to a relatively natural, vegetated state. This would transition the area from a heavily altered visual condition class to a moderately altered class. Relatively level portions of the disturbed areas that are covered with a growth medium would have the potential to eventually transition to a slightly altered visual condition class as revegetation efforts take hold and a canopy begins to develop. The angle-of-repose rocky portal patio slopes would not revegetate and would appear as rocky talus slopes, especially near the bottom of the slopes where coarse development rock has accumulated due to natural sorting.

While some level of modification would always be evident upon close examination of previously disturbed areas in the foreground, the Troy Mine portals and mill areas are generally not visible from sensitive viewing locations (*e.g.,* MT 56 and surrounding campgrounds). Also, due to the surrounding past, present, and potential future timber operations, NFSL in the Troy Mine Permit Area should blend

well with the altered visual character of the general area as a whole after reclamation. A long-term positive effect to visual resources would be expected under the No Action Alternative because the reclaimed NFSL would return to a generally natural look. These reclaimed lands would largely blend with surrounding stands to provide a generally scenic, if slightly altered to moderately altered, view after several decades.

Private lands at the tailings impoundment are at a lower elevation and are surrounded by forested lands. Reclamation of the tailings impoundment with the lacustrine and volcanic ash-derived soil materials would eventually provide a productive forested landscape that would return the existing heavily altered visual condition to a slightly to moderately altered landscape after several decades.

The No Action Alternative would retain some roads for access to private lands and would continue to have a visual effect. Most of the lands would still be reclaimed, and the overall visual effect would not change.

3.17.5.2 Proposed Action

Under the Proposed Action, the *2006 Revised Reclamation Plan* would be implemented, and on-going and future reclamation activities on the Troy Mine Permit Area would follow specifications of the updated plan. Under the Proposed Action, the proposed reclamation activities on both public and patented land at the mine and mill area would produce a recontoured and revegetated landscape that would eventually blend with surrounding lands to provide a moderately to slightly altered visual condition class. This would be an improvement over the heavily altered scenic class that currently exists. Reclamation activities would be generally similar to the No Action Alternative, and overall visual quality at the mine and mill areas would be similar to that of the No Action Alternative.

On private lands at the tailings impoundment, approximately 16 more acres would be disturbed to salvage glacial outwash materials proposed for use in reclaiming the tailings impoundment surface. While these materials would produce a less productive forest, in general the long-term effects on visual quality would be minimal. Overall visual quality at the tailings impoundment area would be similar to that of the No Action Alternative.

3.17.5.3 Agency-Mitigated Alternative

Under the Agency-Mitigated Alternative, the *2006 Revised Reclamation Plan* would be expanded upon to address issues identified during the public scoping and agency review processes. The Agency-Mitigated Alternative would provide for a recontoured and revegetated landscape that would eventually blend with surrounding lands to provide a moderately to slightly altered visual condition class, which would be an improvement over the heavily altered scenic class that currently exists. While reclamation activities would generally be similar to the No Action Alternative and the Proposed Action, the Agency-Mitigated Alternative would have a greater chance of success in establishing vegetation (**Sections 3.8** and **3.16**). Overall, the resulting visual quality at the mine and mill areas would be similar to the No Action Alternative and the Proposed Action.

Reclamation of the tailings impoundment with the lacustrine and volcanic ash-derived soil material would result in a forested landscape that would eventually return the heavily altered visual condition to a slightly to moderately altered visual class after several decades. No new disturbed acres would be needed under the Agency-Mitigated Alternative to obtain growth medium. Potential effects of the Agency-Mitigated Alternative would be similar to the No Action Alternative.

3.17.5.4 Resource Impact Summary

In general, all three alternatives would improve visual resources by reclaiming previously disturbed, non-scenic, mining lands to a vegetated condition that would eventually blend with surrounding forested areas after several decades as trees grow to a size large enough to obscure disturbed landscapes. While the Troy Mine Permit Area is largely not visible to surrounding sensitive viewing locations (*e.g.,* MT 56 and surrounding campgrounds) because of forest stands and ridgelines, some of the disturbed site is visible to recreationists who might be backcountry hiking or camping in areas, including the Cabinet Mountains Wilderness. Although the Troy Mine Permit Area would never return to pre-mine visual quality, this potential increase in scenic potential over operational levels would provide a long-term positive effect on visual resources for all of the alternatives.

3.17.5.5 Effectiveness of Mitigation Measures

No mitigation measures would be required for visual resources because none of the alternatives has a potential for more than minimal negative impacts. Standard reclamation practices have been proven to be effective methods for returning lands to a more natural state, thereby reducing visual impacts.

3.17.5.6 Cumulative Effects

Cumulative or additive effects on visual resources as a result of any of the alternatives would include improvements to both the quality and quantity of vegetation in the Troy Mine Permit Area, which, in turn, would have a small positive additive effect on the scenic value of the analysis area viewshed. Other past, present, and reasonably foreseeable future actions in the watershed (*e.g.,* homebuilding, roads, and highway upgrades) would continue to reduce the scenic quality of the area over time.

3.17.5.7 Regulatory Compliance

All three alternatives would be in compliance with the KNF Forest Plan, which establishes visual quality objectives for each MA within KNF, because reclamation would restore disturbed areas to more natural appearing conditions that would be consistent with the VQOs for each MA within the permit area.

3.18 Wildlife

3.18.1 Introduction

The KNF provides habitat for many species of wildlife, including portions of the Troy Mine Permit Area. The presence or absence of these wildlife species depends on the amount, distribution, and quality of each animal's preferred habitat. In addition to habitat changes, many of these animals are impacted by hunting or trapping. Montana's Department of Fish, Wildlife and Parks (FWP) regulates game and fur

bearing animal populations. Projects proposed on federal lands that might impact species protected by the Endangered Species Act (ESA) require consultation with the U. S. Fish and Wildlife Service (USFWS).

Part of the reclamation project associated with the Troy Mine Permit Area occurs on the KNF. Therefore, this EIS selects wildlife species for detailed analysis that may be affected by reclamation activities. The selected wildlife species include: 1) Species listed as threatened, endangered, or proposed under the Endangered Species Act and which require an effects analysis by the USFWS; 2) Sensitive species, designated by the Regional Forester and for which the disclosure of project effects is required; and 3) Management indicator species (MIS), identified in the Forest Plan (USFS 1987, Appendix 12) and which represent a particular habitat or habitat complex that sustains growth and successful reproduction. The wildlife portion of this chapter is divided into four sections: threatened and endangered species, sensitive species, MIS, and migratory birds.

The analysis area for each species is determined by the requirements of that species but generally falls within the Lake Creek watershed. For determining trends towards viability, the analysis area for each species was determined by using the viability analysis concepts described by Ruggiero *et al.* (1994). Species viability is tiered to the KNF forest-wide conservation plan (Johnson 2004a).

The affected environment for each species is described and generally includes wildlife resources found within the analysis area that could potentially be impacted by mine closure and reclamation in the Troy Mine Permit Area. Wildlife resources include federally-listed threatened and endangered species, KNF sensitive species and/or MIS (**Table 3-22, 3-25, and 3-26**), and important forest habitats. A number of wildlife species have been selected for detailed analysis in the sections below. Species not affected by any alternative (*e.g.* habitat not present within the analysis area) have been reviewed but will not be discussed in detail in this EIS. Important forest habitats, such as old growth forest, are discussed in the Vegetation Section (**Section 3.16**) and in relation to the wildlife species that using those habitats.

Wildlife analyses include baseline conditions (created by all past management practices and natural events); direct and indirect effects of proposed reclamation alternatives; and cumulative effects of past, present, and reasonably foreseeable future actions.

3.18.2 Regulatory Framework

The regulatory framework includes numerous laws, policies, and management direction applied to wildlife resources and their habitats on public lands. The regulatory framework is detailed in the KNF Forest Plan (Forest Plan, USFS 1987) and includes direction to facilitate grizzly bear recovery and augment the existing grizzly population; manage elk habitat for potential habitat carrying capacity; manage habitats so that endemic vertebrate species have sufficient habitat to maintain viable population levels; and to maintain big game habitat to support huntable populations. A revision to the Forest Plan is currently undergoing an extensive review process. The State of Montana does not have similar requirements on private lands.

Several key laws, policies, and management plans are also outlined below:

- **The National Forest Management Act (NFMA) of 1976** (16 USC 1600) directs USFS to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives."
- **The Endangered Species Act of 1973**, as amended, requires federal agencies to undertake programs conserving threatened and endangered species and prohibits them from carrying out or authorizing any action that may jeopardize a listed species or its designated critical habitat. It mandates that the effects of management activities and land uses be evaluated in a biological assessment for listed species. If a project may affect a federally-listed species or critical habitat, Section 7 consultation must be initiated with the USFWS.
- **The Bald and Golden Eagle Protection Act of 1940** (16 USC 668-668d) prohibits all commercial activities and some non-commercial activities involving bald or golden eagles, including their feathers or parts, and makes it illegal "…without being permitted to do so as provided in this subchapter, (to) take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or in any manner any bald eagle commonly known as the American eagle or any golden eagle, alive or dead, or any part, nest, or egg thereof of the foregoing eagles."
- **The National Bald Eagle Management Guidelines** (NBEMG) (USFWS 2007b) provide the recommendations for avoiding disturbance to bald eagles. The NBEMG recommends the following: maintain buffer distance between nest and activity; maintain landscape (natural vegetation) buffers between nest and activity; and avoid certain activities during the breeding season.
- **Montana Bald Eagle Management Plan** (MBEWG 1994). As a revision of the 1986 Montana Bald Eagle Management Plan, this plan gives landowners and resource managers information on bald eagle biology and management guidelines to make informed decisions about land use and to promote conservation of the species and its habitat. This Plan also serves as the conservation and management plan now that bald eagles are delisted. An addendum to the Management Plan was prepared on recent changes in federal bald eagle regulations and to make project planning recommendations for bald eagle conservation (MBEWG 2010).
- **The Migratory Bird Treaty Act of 1918** (16 USC 703-712) implements various treaties and conventions among the U.S., Canada, Mexico, and Japan to protect migratory birds. Under the Act, taking, killing, or possessing migratory birds is illegal. Executive Order 13186 (January 10, 2001) requires federal agencies to ensure that environmental analyses of federal actions evaluate the effects of actions and agency plans on migratory birds, with emphasis on species of concern.
- **Northern Rockies Lynx Management Direction EIS and ROD** (USFS 2007). The Final EIS and ROD for the Northern Rockies Lynx Management Direction (NRLMD) were completed in March of 2007 to amend the Forest Plan by providing lynx habitat management objectives, standards, and guidelines. The decision replaces the interim application of the Lynx Conservation Assessment and Strategy (LCAS) (Reudiger *et al.* 2000). The direction provided in the NRLMD is applied to lynx habitat at the lynx analysis unit (LAU) scale. The KNF has delineated 47 LAUs which approximate the size of a lynx home range. KNF forest-wide lynx habitat descriptions have been updated to reflect the lynx habitat terminology from the NRLMD.

- **1987 Northern Rocky Mountain Wolf Recovery Plan** (USFWS 1987). The delisting action on the gray wolf was vacated by the U.S. District Court, reverting management of gray wolf to the 1987 Northern Rocky Mountain Wolf Recovery Plan. The plan outlines steps to recover wolf populations in portions of their former range in the northern Rocky Mountains. The plan emphasizes gray wolf recovery through natural processes and the conservation of suitable habitat in appropriate recovery areas including northwestern Montana.
- **Selkirk/Cabinet-Yaak Grizzly Bear Interim Access Management Rule Set** (IGBC 1998). The Rule Set serves as an interim guideline for assessing grizzly bear habitat until Forest Plans are revised on the Kootenai, Lolo, Idaho Panhandle, and Colville National Forests. It addresses: 1) habitat security; 2) Core; 3) road management strategies; 4) coordination with state wildlife agencies; 5) no net increases in Open Motorized Route Density (OMRD) and Total Motorized Route Density (TMRD); and 6) Monitoring requirements for Core, OMRD, and TMRD.
- **1993 Grizzly Bear Recovery Plan** (USFWS 1993) identifies the sequence of actions necessary for conservation and recovery of the grizzly bear, ultimately resulting in the removal of the species from “threatened” status in the conterminous 48 states.
- **Montana State Elk Management Plan** (FWP 2004). The plan provides guidance to wildlife and land managers for planning and policy decisions on elk. It was also intended to help FWP personnel prioritize field activities, manage time and budgets, make elk management recommendations, and coordinate management with other state and federal agencies and private landowners. The plan was to remain current through annual updating. Managing Montana’s elk populations at levels compatible with other land uses and meeting the current and future demand for hunting and other recreation has become increasingly complex, demanding increased comprehensive planning.

3.18.3 Analysis Area

The analysis area for each species generally falls within the Lake Creek watershed and includes the Spar Planning Subunit (PSU) and a portion of the Lake PSU (**Figure 3-12**). Potential habitat for the species analyzed below is typically found in both PSUs. This analysis area adequately addresses potential disturbance or displacement that would occur to most species as a result of reclamation activities associated with closure of the project. Analysis at the Lake Creek watershed scale allows for the consideration of effects associated with reclamation activities, without minimizing the potential effects from considering too large an area. Management units for the grizzly bear and Canada lynx serve as the analysis areas in the Lake Creek watershed for these species.

The mine, mill, and utility corridor lie within the Spar PSU. The Spar PSU includes grizzly Bear Management Unit 3 (BMU 3), patented land located atop Mt. Vernon, and part of the Troy Polygon (**Figure 3-13**). The Troy Polygon is an area considered unoccupied by grizzly bears and, therefore, does not have any forest land/management opportunities for grizzly bear recovery (USFS 2009b) within the Cabinet-Yaak Recovery Zone (CYRZ) (USFWS 1993). Spar PSU also contains portions of two Lynx Analysis Units (LAUs): Ross and Keeler.

Lake PSU contains most of the tailings impoundment area, BMUs 1 and 2, and the Crowl LAU. The tailings impoundment area is on private property in the Troy Polygon and a small portion of private property in the Troy Mine Permit Area west of Lake Creek lies within the Spar PSU.

3.18.4 Threatened and Endangered Wildlife Species

Threatened and endangered species are managed under the authority of the ESA and the NFMA. See the Regulatory Framework section above for agency direction from the ESA and NFMA. A current threatened and endangered species list was obtained from the USFWS website (http://montanafieldoffice.fws.gov), updated 8/10/2010. **Table 3-22** shows species status in the analysis area. The USFWS previously concurred with potential listed species distribution maps and resulting consultation areas for the KNF (USFWS 2001).

Table 3-22. Threatened and Endangered Wildlife Species Found within the Analysis Area

Species Name	Status in Analysis Area	Comments
Grizzly Bear (*Ursus arctos horribilis)*, Threatened	Known	Project activities would occur within BMU 3.
Canada Lynx (*Lynx canadensis)*, Threatened; Designated Critical Habitat	Suspected	Project activities would occur within Ross LAU.
Gray Wolf *(Canis lupus)*, Endangered	Known	Suitable habitat throughout the analysis area (USFWS 2001).

3.18.4.1 Grizzly Bear

Grizzly Bear Background

Grizzly bear population ecology, biology, habitat description, and relationships identified by research are described in USFWS (1993), in the annual progress reports for the Cabinet-Yaak grizzly bear research (Kasworm et al. 1989-2009), and by Kasworm and Manley (1988). This information is incorporated by reference. Grizzly bear occurrence data come from recent Three Rivers Ranger District (District) wildlife observation records, from KNF historical data found within the Natural Resource Information System (NRIS) database, and from other agencies (Montana Natural Heritage Program (MNHP) and USFWS).

Reclamation project activities would take place in BMU 3 and in a small area outside of the recovery zone, which includes the private property within the Troy Polygon (Figure 3-13). Although portions of BMUs 1 and 2 are found within the analysis area, reclamation activities would not occur in either BMU. Therefore, the analysis boundary for direct, indirect, and cumulative effects is BMU 3.

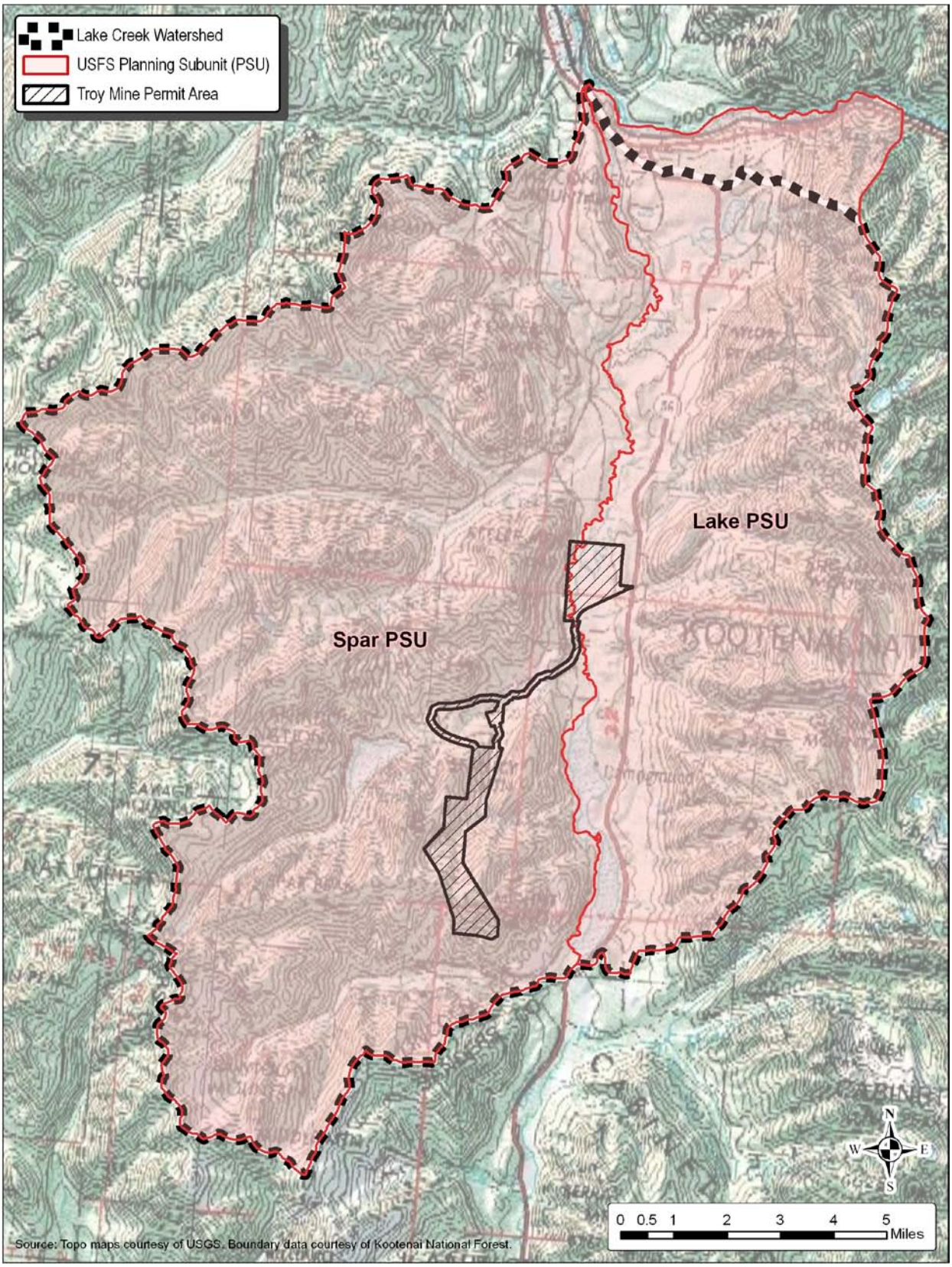


Figure 3-12. Lake Creek Watershed and Planning Subunits

On December 13, 2006, the U.S. District Court ruled to set aside the Grizzly Bear Access Amendment decision of 2004, which would have amended the 1987 Forest Plan (KNF *et al*. 2009). Subsequently, the USFWS rescinded their Biological Opinion, which included updated direction for addressing habitat component standards established in that 2004 decision. As a result, KNF direction for managing grizzly bears reverted back to the standards and analyses that were in place prior to the Access Amendment, as summarized by Johnson (2007). These standards and analyses will remain in place until a new final access amendment EIS and ROD are completed. These requirements come from the 1987 Forest Plan, the 1995 Amended Biological Opinion and Incidental Take Statement on the 1987 Forest Plan, and from the Selkirk/Cabinet-Yaak Grizzly Bear Interim Access Management Rule Set (SCYE 1998).

The proposed project is in the CYRZ (USFWS 1993). The CYRZ is large and diverse, meaning that grizzly bear habitat and use in one part of the ecosystem may not be reflected throughout the entire ecosystem. Breaking the ecosystem down into smaller units (*i.e.,* BMUs) allows analysis of effects associated with the activity's area of influence so that potential effects will not be minimized by considering too large an area (IGBC 1990). The BMUs are biologically meaningful to grizzly bears in that they 1) are based on the average size of a female bear's home range, 2) provide seasonal and elevational movement in response to needs (*e.g.* food and denning habitat), and 3) provide contiguous, unobstructed habitat which allows for displacement (*i.e.,* Core) (Christensen and Madel 1982, IGBC 1990). Delineating BMU boundaries by using topographical features creates a recognizable unit for consistent management and allows for identification of management needs or concerns, activity planning, scheduling, coordination, and monitoring (IGBC 1990) within and among adjacent Ranger Districts.

Affected Environment

Grizzly bears and their associated habitats are found both on the KNF and in the analysis area. There are two grizzly bear recovery zones in KNF, the CYRZ and the Northern Continental Divide Recovery Zone. Habitat conditions in the CYRZ have been improving steadily since 1987 as documented by Johnson (2002), Summerfield *et al.* (2004), and by the annual Forest Plan monitoring reports on threatened and endangered species habitat (KNF 2009b). Currently, the CYRZ grizzly bear population is estimated at a minimum of 47 grizzly bears, with a 78 percent probability of a downward population trend (Kasworm *et al.* 2009). Grizzly bear mortality is generally caused by factors beyond USFS control (*e.g.* management removal due to food attractant on private land, hunter mistaken identity or defense of life, and illegal kill by a human).

Recently, two grizzly bears have been released into BMU 3 to augment the population in the Cabinet Mountains portion of the CYRZ, one in the autumn of 2009 and the second in the summer of 2010. Three other bears were tracked by global positioning system (GPS) collars between 2006 and 2008. One known den site is monitored by USFWS scientists. No females with cubs have been detected in BMU 3 since 1978. Research records indicate one known death (cause unknown) in this BMU in 1959 (Kasworm 2008b).

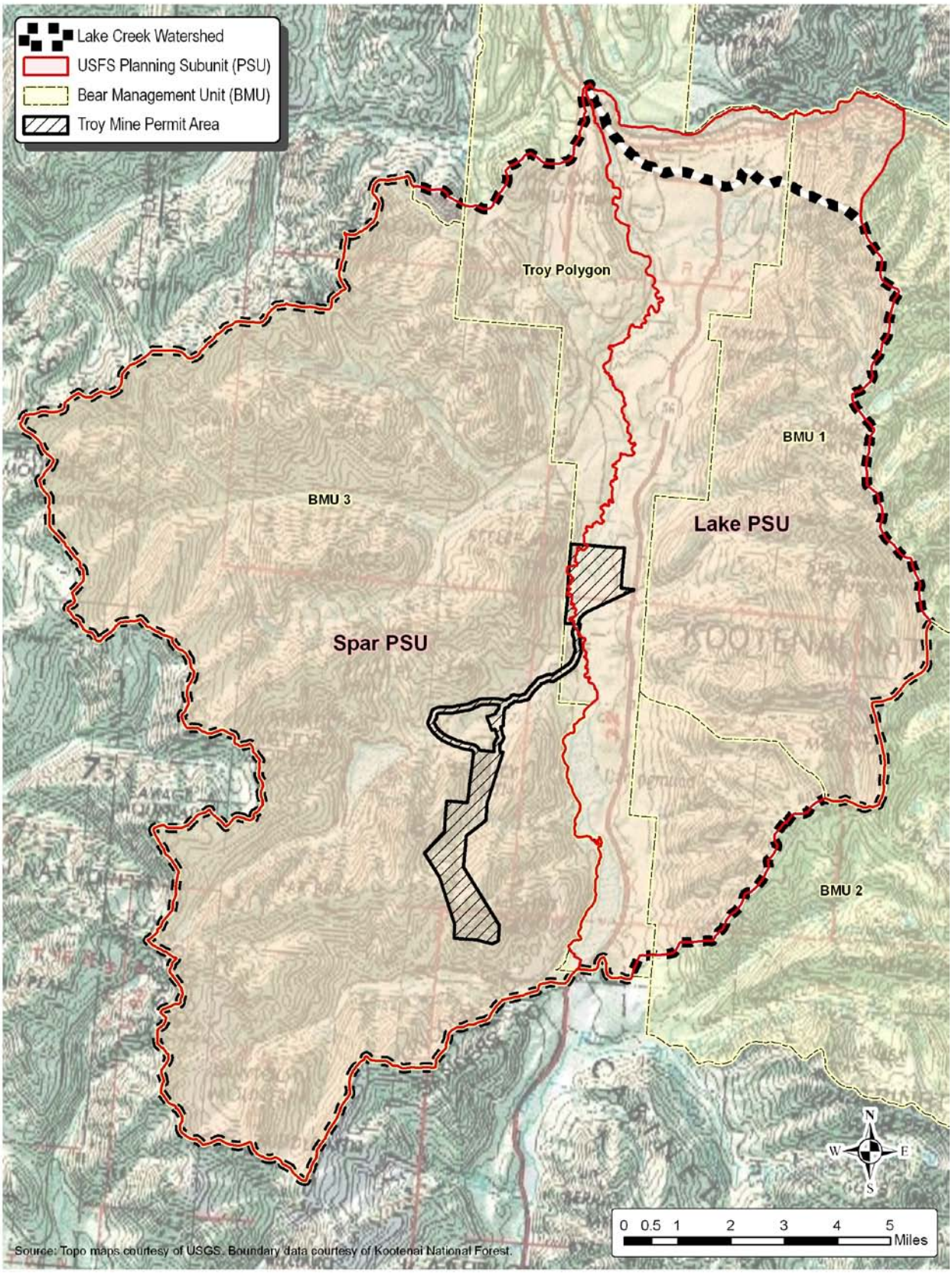


Figure 3-13. Bear Management Units

The grizzly bear management goal on the KNF is to provide sufficient quantity and quality of habitat for grizzly bear recovery. Several measures are used to gauge whether habitat objectives are being met. These measures are implemented within the authority of the USFS to minimize human-caused grizzly bear mortalities.

Road density is an important indicator of the quality of grizzly bear habitat available and is the primary measure of how the Troy Mine reclamation project may affect the grizzly bear. The following analysis describes the potential effects, including cumulative effects, of each of the alternatives. The analysis examines how these measures are implemented and, thus, how the grizzly bear recovery objectives are met.

Objective 1. Provide adequate space to meet the spatial requirements of a recovered grizzly bear population.

Habitat components are based mostly on road density and are used to evaluate the quality of grizzly bear habitat. **Table 3-23** shows current, Bear Year 2009, Habitat Component status in the analysis area (KNF 2010).

Table 3-23. Habitat Component Status for BMU 3

Habitat Component	Current
Habitat Effectiveness (HE) (standard ≥ 70%)	74%
Core Area (standard ≥ 59% of BMU)	62%
Open Motorized Route Density (OMRD) (standard ≤ 33% of BMU ≥ 1 mi./sq.mi.)	27%
Total Motorized Route Density (TMRD) (standard ≤ 26% of BMU ≥ 2 mi./sq.mi.)	26%
Linear Open Road Density (ORD)(standard ≤ 0.75 mi./sq.mi.)	0.57

Habitat Effectiveness: Habitat Effectiveness (HE) is calculated as a percentage of the BMU and should be maintained equal to or greater than 70 percent of the BMU in order to achieve recovery goals. It is the total BMU acres minus Management Situation 3 lands (see Glossary) and all land farther than ¼ mile from open roads and major activities. Current HE, at 74 percent, is better than the standard.

Core Areas: Grizzly bear Core habitat (Core) requirements include no motorized access (roads or trails) during the active bear season, and Core must be at least 0.3 miles from open or gated roads. The goal is that federal agencies will maintain or attain a Core area of at least 55 percent in the BMU. Another goal is that no net loss of Core area will occur on federal ownership within the BMU and that blocks of Core habitat function as displacement areas. Current BMU 3 Core, at 62 percent, is better than the standard.

Open Motorized Route Density (OMRD): OMRD is calculated for each BMU by using moving window analysis (see Glossary) that includes open roads, other roads not meeting all restricted or reclaimed criteria, and open motorized trails. A road is considered open if it has not been effectively restricted or reclaimed to prevent motorized access. The goal is for no net increase in OMRD on NFSL within any BMU. Current OMRD, at 27 percent, is better than the standard of less than or equal to 33 percent.

Total Motorized Route Density (TMRD): TMRD is calculated for each BMU by using moving window analysis that includes open roads, restricted roads, roads not meeting all reclaimed criteria, and open motorized trails. The goal is for no net increase in TMRD on NFSL within any BMU. The current TMRD of BMU 3 at 26 percent meets the standard.

Linear Open Road Density (ORD): ORD is calculated on Management Situation 1 lands (see Glossary) for any BMU and should not exceed 0.75 miles per square mile. Individual bear analysis areas (BAA) may exceed 0.75 miles per square mile if the entire BMU meets the standard, and the BAA is where the activity is occurring or prior consultation has established a different level for the BAA. The current ORD in BMU 3, at 0.57 miles per square mile, is better than the standard of less than or equal to 0.75 miles per square mile. **Table 3-24** shows ORD for each BAA within BMU 3.

Table 3-24. Linear Open Road Densities in BMU 3

Bear Analysis Area	Current ORD (mi./sq.mi.) by BAA
4-3-1	0.88
4-3-2	0.52
4-3-3	0.10
4-3-4	0.97
4-3-5	0.58
4-3-6	0.26
4-9-4	0.25
Total BMU 3	0.57

Objective 2. Manage for an adequate distribution of bears across the ecosystem.

This objective addresses maintenance of movement corridors and access to seasonal resources for grizzly bears. Size and proximity of harvest units will not be addressed because no harvest units are proposed for the Troy Mine reclamation project.

On a larger scale, movement corridors among Core areas exist across the BMUs that run north to south, between the Kootenai and Clark Fork rivers. The BMUs are adjacent to one another in the West Cabinet Mountains and in the Cabinet Mountain Wilderness where the MT 56 corridor is the border between these two mountain ranges. Servheen *et al.* (2003), identifies linkage zones based on landscape views from the Linkage Zone Prediction Model. The analysis area contains the northern end of a wildlife linkage zone that connects the West Cabinet Mountains with the Cabinet Mountain Wilderness from the south end of Bull Lake to the Lincoln County border. This linkage zone actually extends south into Sanders County, to about two miles from the junction of MT 56 and Highway 200. Recommended habitat management for linkage zones is to maintain hiding cover, forage, and seasonal movement corridors for bears and other wildlife to cross the Bull River Valley between mountain ranges.

Guidelines on seasonal components propose activities to avoid known spring and denning habitats during their periods of use. Research conducted by Wakkinen and Kasworm (1997) in the Selkirk and Cabinet-Yaak Ecosystem indicates that major activities should be scheduled to avoid known spring habitats during the spring-use period (April 1 to June 15) and known denning habitats during the denning period (December 1 to March 31).

Objective 3. Manage for an acceptable level of mortality risk.

Most human-caused grizzly bear mortalities on the KNF have resulted from encounters between bears and big game hunters (Kasworm and Manley 1988). Grizzly bear vulnerability to human-caused mortality is partially a function of habitat security. Therefore, mortality risk can be partially assessed by using habitat factors that maintain or enhance habitat security. These include opening size, movement corridors, road density, and displacement (Core) areas which are addressed under the other objectives. Minimizing the potential for grizzly-human conflicts also includes addressing attractants that may be introduced by a proposed project.

Objective 4. Maintain/improve habitat suitability with respect to bear food production.

An important food source for the grizzly bear is the huckleberry (*Vaccinium* spp.). Huckleberries are available within the Troy Mine Permit Area and grow along Stanley Creek. Also, riparian habitats themselves are generally considered to be valuable feeding sites. The huckleberries and riparian habitat will be evaluated in the alternatives below.

Objective 5. Meet the management direction outlined in the Interagency Grizzly Bear Guidelines (51 Federal Register 42863) for Management Situations 1, 2, and 3.

Meeting objectives 1 through 4 helps to meet the intent of the Interagency Grizzly Bear Guidelines (Buterbaugh 1991), with key project considerations being Core, HE, and changes in road density.

Objective 6. Meet the interim management direction specified in the July 27, 1995, Incidental Take Statement (McMaster 1995).

This objective is met by Core, OMRD, TMRD, and ORD standards as addressed in Objective 1.

Outside the Recovery Zone

The tailings impoundment is private property owned by Troy Mine, Inc. Also, most of the tailings impoundment lies within the Troy Polygon which itself is not managed for grizzly bear as stated

previously (**Figure 3-13**). Moreover, all roads used for proposed reclamation activities in the Troy Polygon are currently open to motorized access for mining operation activity.

Environmental Consequences

Direct and Indirect Effects

Reclamation activities in the tailings impoundment area would be located within the Troy Polygon where no reoccurring bear use has been documented. Because these areas have been used historically and would be used in the future, no new impacts to grizzly bears would result from any of the reclamation alternatives proposed for this area. The likelihood of bear use on this private land during reclamation would be negligible.

Objective 1

Reclamation activity for all alternatives would take place over an approximately 2-3 year period and would require heavy equipment use comparable to use in current mining activities. The effects of road reclamation and use of existing roads for other reclamation activities (*e.g.,* removal of structures, mining equipment, recontouring of slopes, etc.) would not be expected to increase disturbance of bears in those areas impacted by current mining activities. All alternatives include reclamation and/or road stabilization work on a number of roads; the specific roads and the detail of reclamation work vary by alternative (see **Transportation Section 3.15**). Most of the roads proposed for reclamation or stabilization are already restricted to motorized access, except NFSR 4626 up to the mill site and NFSR 9003. All alternatives would keep NFSR 4626 open up to the mill site, maintaining the current open status. The No Action and Agency-Mitigated alternatives would reclaim NFSR 9003, which is currently open to motorized access. This short loop road, which extends approximately 250 feet off NFSR 4626, offers little if any access opportunities for motorized use. With respect to BMU 3, habitat component standards are expected to remain at, or potentially become better than, standards for HE, Core, OMRD, TMRD, and ORD for all alternatives.

Habitat Effectiveness: HE would not decrease during Troy Mine reclamation as there would be no new open roads created, and reclamation activities would generally occur in the same areas as present mining activities. HE would be expected to improve once all activities have been completed.

Core Areas: There would be no net loss of Core as Troy Mine reclamation activities do not occur within Core boundaries, and no new open or restricted roads would be created. The Proposed Action would not reclaim any roads and would maintain Core status after the project is finished. The No Action and Agency-Mitigated alternatives propose reclaiming a number of roads. Once project activities cease, a small amount of new Core habitat would possibly be created.

Open Motorized Route Density: All three alternatives propose to keep NFSR 4626 gated at the mill site and restricted to motorized traffic beyond the mill site towards Mt. Vernon. Except for NFSR 9003, all other roads listed in Table 2-1, are either behind gates or on patented and private land and would remain restricted to motorized traffic. The No Action and Agency-Mitigated alternatives propose to reclaim NFSR 9003, which would contribute a negligible decrease in OMRD. Therefore, all of the

alternatives would maintain current OMRD status and would continue to be better than standard for BMU 3.

Total Motorized Route Density: No net increase in TMRD would occur as none of the mine reclamation alternatives propose new roads. The No Action and Agency-Mitigated alternatives also propose to reclaim a number of roads, which would potentially improve TMRD to better than the standard.

Linear Open Road Density: All three alternatives would keep NFSR 4626 gated at the mill site and restricted to motorized traffic beyond the mill site towards Mt. Vernon. Except for NFSR 9003, all other roads listed in Table 2-1, are either behind gates or on patented or private land and would remain restricted to motorized traffic. The No Action and Agency-Mitigated alternatives propose to reclaim NFSR 9003, which would contribute a negligible decrease in ORD. Therefore, all of the alternatives would maintain current ORD status and would continue to be better than standard for BMU 3.

Objective 2

No alternatives propose any timber harvest, and no reclamation alternatives would result in a loss of vegetative structure. Reclamation would eventually re-establish forested habitats on most of the disturbed lands and would improve vegetative structure within several decades.

The identified linkage zone south of Bull Lake would not be impaired by any of the alternatives. The Proposed Action would leave NFSR 4628 in place as is and would not change current conditions in that area. The No Action and Agency-Mitigated alternatives propose road stabilization for NFSR 4628 and would not impair the long-term availability of the linkage zone.

Most proposed activities for all alternatives would take place in areas currently receiving regular use during mining operations. The one exception is NFSR 4628, which accesses the South Adit, does not receive regular mining use beyond NFSR 4628C. Beyond the southern end of the Troy Mine Permit Area towards Ross Creek, BMU 3 has known bear activity (Kasworm 2010). Disturbance and displacement of bears would be expected from the road storage activities south of the more regularly used mining operation sites. Reclamation activities are expected to occur over an approximately two to three year timeframe during the snow free period (April to September). For most of the Troy Mine Permit Area, this timeframe does not change the current condition experienced by bears. The No Action Alternative and Proposed Action do not have any activity restrictions during the important spring bear-use period (April 1 – June 15) and would potentially cause disturbance and avoidance by foraging bears. The Agency-Mitigated Alternative would specify road work on the segment of NFSR 4628 from the junction with NFSR 4628C to Ross Creek outside this period to allow for spring forage opportunities.

No known dens occur within the Troy Mine Permit Area. Activities taking place during the winter months (December 1 to March 31) are not expected to negatively impact grizzly bears.

Objective 3

Revegetation would occur throughout the Permit Area. The No Action Alternative would use an introduced grass and forb species mix and does not differentiate which species would be used in various habitat types. Sweet clover (*Melilotus* spp.) is included in this mix and could create human-grizzly

conflicts in areas where it is planted. Both the Proposed Action and the Agency-Mitigated Alternative would use native grass and forb species mixes that do not include bear attractants. Under the Proposed Action and Agency-Mitigated Alternative, vegetation as a food attractant would not be expected to create human-grizzly bear conflicts.

Taking into consideration the status of the habitat components listed above, the cumulative risk of mortality would not change appreciably due to implementing mine reclamation alternatives. It is important to note that human-caused grizzly bear mortality is also a function of other factors, such as regulation of big game hunting, which are beyond the authority of the USFS to control. Hunting regulation is the responsibility of the State of Montana.

Objective 4

The huckleberry (*Vaccinium* spp.) is an important food source for grizzly bears in this ecosystem (USFWS 1993). No alternatives would decrease this important food source, because proposed activities are directed at sites that are currently disturbed. However, once project activities are completed, huckleberries from adjacent sites may serve as a source for colonization on newly reclaimed sites over time.

The alternatives do not propose activities within currently undisturbed riparian habitat and would follow other KNF riparian management guidelines, Montana Streamside Management Act (HB 731), and INFISH guidelines. The No Action Alternative would leave the intermittent drainage across the mill site in the existing culverts; therefore, there would be no addition to current riparian areas. The Proposed Action and Agency-Mitigated Alternative would replace the culverts with a rock-lined channel leaving only a slight potential for increased riparian area. Adherence to riparian area standards would ensure protection of the food resources in this important zone.

Objective 5

All three alternatives would meet this objective by meeting Objectives 1-4 above.

Objective 6

All three project alternatives would meet this objective by meeting the Core, OMRD, TMRD, and ORD standards addressed in Objective 1.

Cumulative Effects

Past, present, and reasonable foreseeable future actions in the analysis area are presented at the beginning of Chapter 3 (**Sections 3.2 and 3.3)**. Past harvest and natural disturbances have provided a variety of vegetation age classes and successional stages across the analysis area, thus diversifying the landscape. In some cases, past timber harvests and fires even improved habitat for huckleberries and other forage favorable for grizzly bears and big game.

Also, open road densities have declined in the past several years because of restricting/reclaiming roads through decisions intended to facilitate grizzly bear recovery. The No Action and Agency-Mitigated

alternatives would restrict/reclaim additional roads and would therefore have a cumulative beneficial effect.

Basic road maintenance, pre-commercial thinning, mushroom picking, prescribed burning, timber hauling, wildlife habitat improvement projects, and various recreational uses are additional activities that would continue within the analysis area. Potential recreation that has been restricted beyond the mill/office site during mining activities may increase slightly, but likely not far beyond the existing gate location because the road would remain restricted to motorized access after reclamation. Generally, these activities would not have adverse impacts on wildlife species but may incidentally affect wildlife use temporarily within some areas. However, they are not likely to affect the viability of this species.

All alternatives could encourage huckleberry expansion in BMU 3 through reclamation activities by creating potential habitat adjacent to current huckleberry habitat. All of the activities listed above (including reclamation) may disturb a grizzly bear or cause it to temporarily avoid an area until human actions are finished. Although disturbances would affect availability of huckleberries, reclamation alternatives would not create a cumulative effect on potential grizzly bear disturbance.

Mining activities would cease as reclamation activities begin, and reclamation would have no cumulative effect on bear disturbance as the two activities would not take place simultaneously.

With respect to patented lands, there are no known non-mining related activities proposed at the top of Mt. Vernon. Therefore, no cumulative effects on grizzly bears are expected related to this parcel of patented property as part of any of the alternatives.

The likelihood of bear use occurring on private land at the tailings impoundment area, which is within the Troy Polygon, during reclamation would be negligible, and the potential cumulative impacts of displacement would be discountable.

No alternatives are expected to have cumulative effects on grizzly bears or their habitat on NFSL. The standards for Core, HE, and road densities would continue to be met, if not improved upon, following completion of reclamation activities. All alternatives, in combination with the baseline conditions and past, present, and reasonably foreseeable future projects are not expected to have a measurable effect on the grizzly bear or its habitat or to increase grizzly bear mortality.

Regulatory Compliance

ESA: The No Action Alternative, if approved today, would not be in compliance with ESA (*e.g.,* use of sweet clover in the seed mix). The Proposed Action and Agency-Mitigated Alternative are expected to comply with ESA because 1) they meet all standards and guidelines established by USFWS through the IGBC; and 2) consultation with USFWS would occur through the proper procedures.

Forest Plan Consistency: The Proposed Action and Agency-Mitigated Alternative meet Forest Plan goals as they apply to the grizzly bear and as stated in:

- Pages: II-1 #2, #3, #5,II-2 #12, and II-22-23;
- Appendix 8 which addresses grizzly management situation guidelines and augmentation discussion; and
- Appendix 8 which assumes that grizzly bear habitat standards will be adapted based on consultations with USFWS (page 8-7).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide for diverse populations of plant and animal communities with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of the use of introduced grass and forb species.

Statement of Findings

The No Action Alternative would reclaim most roads but it does not address specific reclamation techniques or seasonal timing for roadwork. Furthermore, it uses an introduced species seed mix, including sweet clover. However, because reclamation activities would not result in new roads or disturbed areas and because mining activities would have ceased, the overall effect of the No Action Alternative would be to improve habitat conditions for the grizzly bear in the long-term. The No Action Alternative is determined to "*May Affect, but is not Likely to Adversely Affect"* the grizzly bear.

The Proposed Action would not include road reclamation. However, it also would not build or open roads to motorized traffic, and therefore, would maintain current road densities and motorized access levels. Compared to the No Action Alternative, the Proposed Action is more specific in defining the reclamation techniques to be used and uses native seed mixes for revegetation that do not include sweet clover. The overall effect of the Proposed Action within the Troy Mine Permit Area would be to improve habitat conditions for the grizzly bear in the long-term. The Proposed Action is determined to "*May Affect, but is not Likely to Adversely Affect"* the grizzly bear.

The Agency-Mitigated Alternative would reclaim most roads, use native seed mixes that do not include sweet clover for revegetation, and provide seasonal restrictions on road reclamation work. Overall, the Agency-Mitigated Alternative would improve habitat conditions for the grizzly bear in the long-term and address some of the potential short-term effects. In short, the Agency-Mitigated Alternative would have a determination of "*May Affect, but is not Likely to Adversely Affect"* the grizzly bear.

Therefore, all alternatives "*May Affect, but are not Likely To Adversely Affect"* the grizzly bear. This determination is based on:

- reclamation activities would be comparable to or less than the existing activity during mine operations, and long-term effects would be beneficial through reclamation of habitat to varying levels of quality;

- BMU 3 currently meets the standards and interim guidelines for the Cabinet-Yaak Ecosystem and would continue to meet standards after Troy Mine reclamation; and
- no increase in bear mortality would be expected from reclamation activities.

Canada Lynx

Canada Lynx Background

Lynx population ecology, biology, and habitat description and relationships are described in Ruggiero *et al.* (2000) and in Ruediger *et al.* (2000). These studies are incorporated by reference. In addition, the final lynx listing rule (Clark 2000) gives population and habitat status on a national scale. The most recent lynx distinct population segment status is found in the Biological Opinion on the effects of the NRLMD (USFWS 2007c). Lynx occurrence data come from recent District wildlife observations, NRIS, and from other agencies (FWP, MNHP, and USFWS).

The Final EIS for the NRLMD Record of Decision was completed in March 2007 (USFS 2007). This decision amended the Forest Plan by providing lynx habitat management objectives, standards, and guidelines. The decision replaced the interim application of the Lynx Conservation Assessment and Strategy. The direction provided in the NRLMD is applied to lynx habitat at the lynx analysis unit (LAU) scale. The KNF has delineated 47 LAUs which approximate a lynx home range size. KNF forest-wide lynx habitat has been updated to reflect the lynx habitat terminology from the NRLMD.

The effects analysis follows the standards and guidelines established in the NRLMD. Only the standards and guidelines applicable to the proposed Troy Mine project are analyzed, and they are only applied to lynx habitat on federal lands (in compliance with the ROD). Those standards and guidelines considered but found “not applicable” are found in the EIS project file. Lynx habitat in impacted LAUs was mapped by using the timber stand database version of the KNF model. Connectivity was evaluated by visually examining lynx habitat and by reviewing past management activities to identify possible movement areas and potential areas where lynx travel may be hindered. Here, ridgelines and draws were considered high value movement areas.

The scale for direct, indirect, and cumulative effects analysis is the LAU(s) that may be impacted by the proposed federal action (**Figure 3-14**). Adjacent LAUs are also considered for connectivity effects.

Affected Environment

On March 24, 2000, the USFWS listed the contiguous U.S. distinct population segment of the Canada lynx as threatened (Clark 2000). National population and habitat status descriptions found in that document are incorporated by reference. To date, there are two known occurrences of lynx documented within the analysis area; in the Spar PSU in the upper Spar drainage, and one known occurrence of lynx within the Lake PSU as listed in the MNHP and NRIS databases.

On February 25, 2009, the USFWS issued a final rule which revised critical lynx habitat. The lynx analysis area in this EIS does not fall within critical lynx habitat and currently, all LAUs meet the NRLMD standards (USFS 2007c).

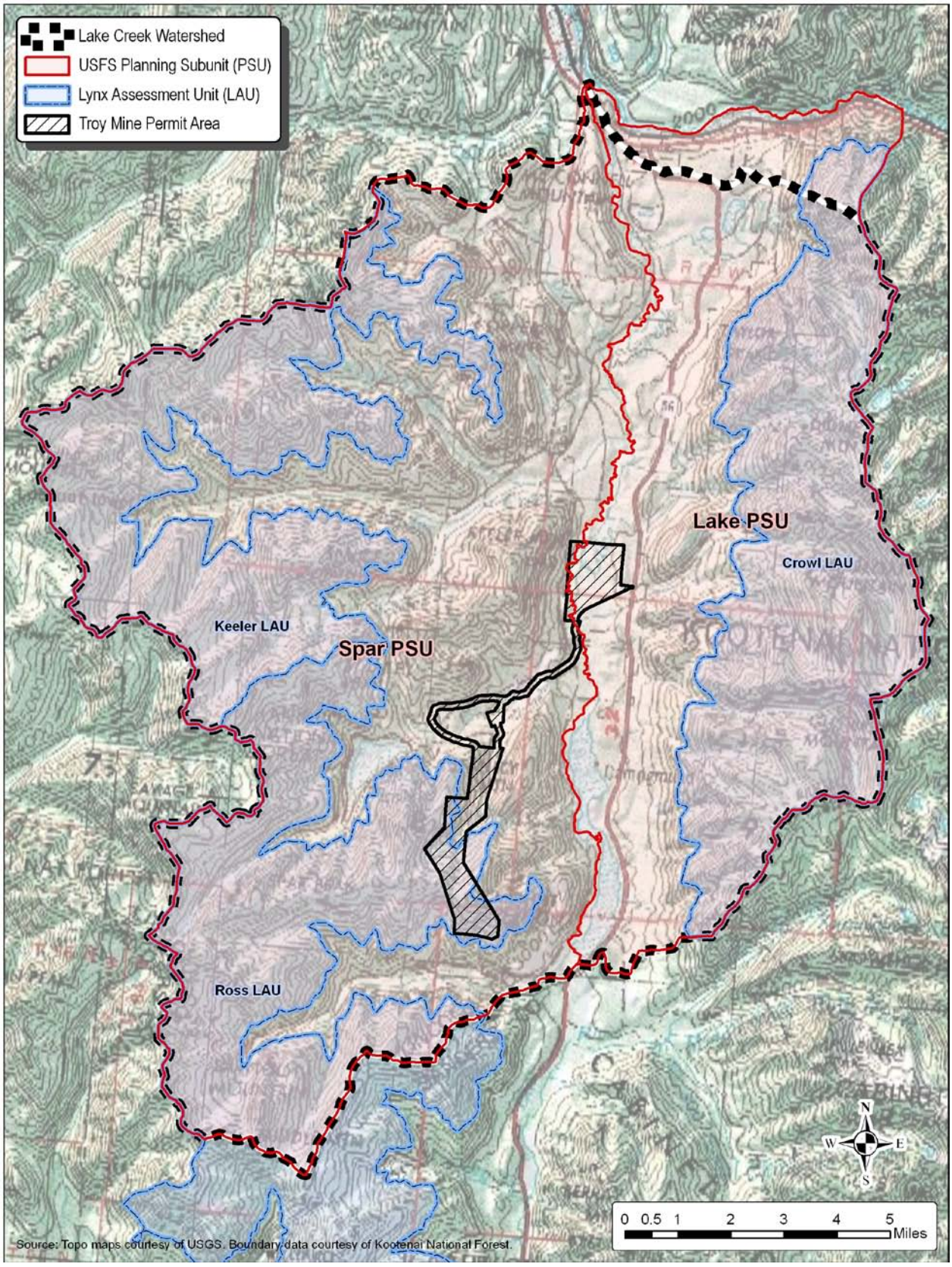


Figure 3-14. Lynx Analysis Units

The analysis area includes portions of three LAUs: Ross and Keeler in the Spar PSU and Crowl in the Lake PSU. Reclamation activities would only occur in the Ross LAU, and the adjacent LAUs would only be considered for connectivity concerns.

There is one identified linkage corridor (USFS 2004) in the project area between the Crowl LAU and the Ross LAU. This linkage corridor is south of Bull Lake and is the same linkage corridor discussed in the grizzly bear section.

Environmental Consequences

Direct and Indirect Effects

Reclamation activities proposed in the tailings impoundment area are not located within the Ross LAU, and therefore, there would be no direct effects on Canada lynx from activities located on these private lands.

The following management direction applies to all NFSL that are known to be occupied by Canada lynx. The goals, objectives, standards, and guidelines address the risk factors found to threaten lynx populations.

Objectives, Standards, and Guidelines Applicable to All Management Projects in Lynx Habitat

Objective ALL O1: Maintain or restore lynx habitat connectivity in and between LAUs and in linkage areas.

The most likely point of access to the one identified linkage corridor south of Bull Lake would be from a more southern portion of the Ross LAU, south of Ross Creek. None of the alternatives propose any reclamation in this part of the LAU, nor do any of them propose activities where the Ross and Keeler LAUs join. Thus, the alternatives would not be expected to impair the linkage between these two LAUs.

Objectives, Standards, and Guidelines Applicable to Human Use Projects in Lynx Habitat

Objective HU O1: Maintain the lynx's natural competitive advantage over other predators in deep snow, by discouraging the expansion of snow-compacting activities in lynx habitat.

All roads identified as restricted within the Troy Mine Permit Area are currently restricted to all motorized activities year-long, including snow vehicles. Because none of the alternatives would increase motorized access, the lynx's competitive advantage in deep snow would be maintained.

Objective HU O2: Manage recreational activities to maintain lynx habitat and connectivity.

None of the alternatives would increase recreational opportunities; the alternatives would return pre-operational recreational access to public lands. Access via roads open to motorized use would not increase. A small increase in foot traffic from the gate currently located at the mill/office site may occur, but would be limited to access by non-motorized means.

Guideline HU G4: For mineral and energy development sites and facilities, remote monitoring should be encouraged to reduce snow compaction.

No new mineral or energy development sites would occur under the reclamation alternatives. However, water quality monitoring would follow mine closure and reclamation activities until such time as the regulating agencies determine that their standards have been met. Monitoring activities would take place at pre-existing sites so that no new effects would be observed and any new monitoring sites would be established only during the non-winter period.

Guideline HU G5: For mineral and energy development sites and facilities that are closed, a reclamation plan that restores lynx habitat should be developed.

Because lynx were not listed when the No Action Alternative was originally proposed in the 1978 EIS, this alternative did not address restoring lynx habitat in the Permit Area. In addition, the plant species mix proposed for reclamation includes non-native species and does not account for differences in habitat type along the elevational gradient. Therefore, the No Action Alternative would have limited benefits to lynx habitat.

Both the Proposed Action and the Agency-Mitigated Alternative would follow direction provided in the NRLMD. These alternatives would occur within and along already disturbed sites, such as roads, and therefore would cause minimal vegetation manipulation. Both alternatives include native plant species mixes and apply different plant species composition to different habitat types along the elevational gradient. These alternatives would improve the habitat at a faster rate which would provide greater benefits to lynx habitat.

Guideline HU12: Winter access for non-recreation special uses and mineral and energy exploration and development, should be limited to designated routes or to designated over-the-snow routes.

All three alternatives would be the same with respect to winter access. Post-mine closure winter motorized access would be restricted, and therefore, no effects would result.

Objectives, Standards, and Guidelines Applicable to All Projects in Linkage Areas Subject to Existing Rights

Objectives LINK O1: Work with other land owners on solutions to reduce potential adverse impacts on lynx and lynx habitat.

See Objective ALL O1 for linkage areas. The only private lands within the Ross LAU are the patented lands located on the top of Mt. Vernon. No alternative proposes any activity on the top of Mt. Vernon other than reclamation and stabilization along restricted roads. No other activities would be proposed on the patented property. All three alternatives would meet this objective on linkage zones between public and private lands.

Cumulative Effects

No known non-reclamation activities are proposed for the patented land on top of Mt. Vernon, and activities proposed on private property in the tailings impoundment area are not located within the Ross LAU, therefore there would be no cumulative effects on these private lands.

The analysis area has received regeneration harvests in the recent past, currently analyzed as unsuitable, but in a few years these stands will become early successional forage habitat. In addition, the Sparring Bulls project plans an additional 139 acres of regeneration harvest that would temporarily change lynx habitat into unsuitable condition (KNF 2010). However, none of the alternatives propose to alter the existing vegetation, would not increase the amount of unsuitable habitat, and would not contribute to cumulative effects with respect to forage habitat. Activities within the Ross LAU are limited to sites already disturbed and to existing roads. Movement corridors within and between the LAUs in the project area would remain available and with vegetative structure for lynx movement.

Regulatory Compliance

ESA: All the alternatives would be in compliance with ESA. This statement is based on: 1) they would be consistent with the ESA; and 2) consultation with USFWS would occur through proper procedures.

Forest Plan Consistency: All three alternatives would comply with Forest Plan direction on threatened and endangered species with respect to lynx (Forest Plan Vol. II-1 #7, II-22) and with the NRLMD.

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide for diverse populations of plant and animal communities by compliance with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, the Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Affect, but is Not Likely to Adversely Affect"* the lynx or its habitat. This determination is based on the analysis that: 1) All objectives, standards, and guidelines in the 2007 NRLMD would be met, and 2) no disturbance to lynx, its habitat, or to its prey base would occur over the long term.

In addition, all three alternatives are not likely to result in the destruction or adverse modification of proposed critical habitat.

3.18.4.2 Gray Wolf

Gray Wolf Background

Strategies to protect and recover wolf populations in Montana as well as their ecology, biology, and habitat descriptions are outlined in the Northern Rocky Mountain Wolf Recovery Plan (USFWS 1987). On April 2, 2009, the USFWS identified a Northern Rocky Mountain distinct population segment of the gray wolf, removing all but the Wyoming population from the List of Endangered and Threatened Wildlife (USFWS 2009). However, this rule was vacated on August 5, 2010 by the U.S. District Court in Missoula, Montana, relisting the gray wolf as an endangered species within the Northwest Montana Recovery (NWMT) area. The NWMT is one of three wolf recovery areas identified for the Northern Rocky Mountain wolf population (Sime *et al*. 2010); the KNF is within the NWMT. Information for this recovery area is provided by the Montana Gray Wolf Conservation and Management 2009 Annual Report (Sime *et*

al. 2010) and is incorporated here by reference. Wolf occurrence data come from recent District wildlife observation records, NRIS database, and from other agencies (FWP, USFWS).

Measurement indicators for this wolf analysis include the following key habitat components found in the Wolf Recovery Plan (USFWS 1987):

1) **Sufficient, year-round prey base for big game or alternate prey**: This component can be measured by adhering to KNF Forest Plan big game management recommendations. For this project area, elk management recommendations were applied (**Section 3.18.6.1**). They include cover/forage ratios, road densities, opening sizes, key habitat features, movement areas, habitat effectiveness levels, and security levels.

2) **Suitable and somewhat secluded denning and rendezvous sites**: Gray wolves are sensitive to disturbance near denning and rendezvous sites (Thiel *et al.* 1998, Claar *et al.* 1999, Frederick 1991). Recommendations to protect dens from human disturbance include restricting human access within a 1.5-mile radius of an occupied den from four weeks prior to whelping to the end of denning activity. Similar restrictions can be implemented for rendezvous sites. Evaluation of potential impacts would include analysis of how each alternative would maintain the habitat integrity of the denning and rendezvous sites.

3) **Sufficient space with minimal exposure to humans**: This component is associated with reducing the risk of human-caused mortality to wolves. Human disturbance and accessibility of wolf habitats (*i.e.,* road densities) are the principal factors limiting wolf recovery in most areas (Leirfallom 1970, USFWS 1978, USFWS 1987, Thiel 1978, all in Frederick 1991). These components can generally be measured by maintaining Open Road Density (ORD) standards required by the Forest Plan and by following big game habitat recommendations for security habitat.

The analysis area for addressing direct, indirect, and cumulative effects on the gray wolf and their habitat is the Lake Creek watershed.

Affected Environment

At the end of 2009, there were 101 wolf packs statewide with 37 meeting breeding pair criteria. The population estimate for Montana's packs is 524 individuals, including a minimum of 166 pups (Sime *et al.* 2010). The KNF is home to 16 resident packs (six with breeding pairs) and six transboundary packs located primarily in Canada, Idaho, and adjacent National Forest lands in Montana (Sime *et al.* 2010, Laudon 2010). These packs had a total of 70 wolves at the end of 2009 (Mack *et al.* 2010, Sime *et al.* 2010). An estimate of 80 wolves was recorded in 2008 (Mack *et al.* 2009, Sime *et al.* 2009). If pack movement, unknown pack numbers, and losses due to depredation (five unknowns, ten lost to hunting, eight removed for depredation) are all considered, the numbers between years are similar, if not slightly increased. Also, recent survey efforts suggest there may be two new packs on the KNF in 2010 (Laudon 2010).

FWP implemented a statewide general hunting season in 2009 which resulted in 72 wolves being harvested; seven from resident packs in the KNF and three from transboundary packs elsewhere in the state (Sime *et al.* 2010). Two resident packs had eight total wolves lethally removed due to depredation in 2009 (Sime *et al.* 2010) and a third pack (eight individuals in 2009) was removed in early 2010 (Laudon 2010). This reduction contributed to a higher level of documented mortality than in 2007 or 2008. It is not specified if the six human-caused wolf deaths (harvested or other) in the Panhandle Wolf Management Zone of Idaho occurred within the Montana transboundary packs or not (Mack *et al*. 2010).

The Twilight wolf pack uses the Spar PSU area as a portion of its home range. The pack was established in 2008; a total of eight wolves were documented, including five pups (Sime *et al.* 2009). Currently, the pack includes four adults and no longer includes a breeding pair. A single wolf was harvested in the 2009 general hunting season; the other "missing" wolves are unaccounted for as none are radio collared. No known livestock depredations are attributed to this pack (Sime *et al.* 2010).

Prey Base

The Spar PSU supports year-round habitat for most big game species, with white-tailed deer being the most abundant found in the area. Other big game species include elk, mule deer, moose, and mountain goats,. Together, this mix of species provides a year-round prey base for wolves. The elk was chosen as the Management Indicator Species (MIS) for the Spar PSU which is identified as a high emphasis area for elk management (Johnson 2004a). See the MIS section (**Section 3.18.6**) for more information on elk habitat conditions and population status in the Spar PSU.

Den and Rendezvous Sites

No den sites for this pack have been located at this time. There is speculation of a rendezvous site near Spruce Lake that has been used in the analysis area since the pack was established. This area continues to be monitored on a yearly basis. This pack has never been radio collared, and only a few days of surveys were conducted in 2009. Once individual wolves can be fitted with radio collars, their activities will be monitored and will provide additional information on their use of the analysis area.

Sufficient Space with Minimal Exposure to Humans

Management Area 12 (MA 12, non-winter big game habitat) and grizzly bear management have the most restrictive ORD standards in the Forest Plan at ≤ 0.75 mi/mi^2. If ORD for the BMU(s) in a project area meets the grizzly standard, it also achieves big game management recommendations for the project area (Schrenk 1995). Most of the NFSL between the tailings impoundment and the patented property on Mt. Vernon are classified MA 12. ORD in BMU 3 (0.57mi/mi^2) currently meets Forest Plan standards (USFS 2009b). Security habitat recommendations for elk are within recommended levels (see MIS section on elk). The analysis area meets the standard for sufficient space with minimal exposure to humans.

Environmental Consequences

Direct and Indirect Effects

Reclamation activities on private and patented lands within the Troy Mine Permit Area could result in some short-term disturbances of wolves and their prey species. However, under all three alternatives, the long-term results of reclamation would not be expected to affect available habitat and disturbance levels.

Prey Base

As discussed in the MIS effects analysis, all alternatives would maintain or improve habitat conditions for elk. This would be primarily through reducing traffic and noise associated within the current mining operations and the reclamation activities. Therefore, prey conditions for wolves are likely to be maintained under any of the alternatives.

Den and Rendezvous Sites

The suspected rendezvous site is over a mile from any reclamation work proposed by any of the alternatives. Also, reclamation activities would be expected to be similar to the everyday mining operations. Wolves have continued to use this rendezvous site despite activity at the mine; therefore, reclamation activities would not be expected to have an increased effect. No den sites are known at this time.

Sufficient Space with Minimal Exposure to Humans

ORD in the Spar PSU meets grizzly bear and big game standards. While reclamation work is being completed on some of the more remote and less used roads, wolves may temporarily avoid the area but transient use could still occur.

For all alternatives, any proposed reclamation and/or BMP work would occur on roads that already exist on the landscape. Also, no roads would be built, and motorized access would not increase. The Proposed Action would not reclaim any roads. The No Action and Agency-Mitigated alternatives would reclaim several roads; however, only NFSR 9003 is currently open to motorized access. Therefore, implementing these alternatives would decrease ORD in BMU 3.

Cumulative Effects

Past timber harvest, mining activities, and road construction projects and natural events have shaped much of the existing habitat conditions found within the analysis area.

Prey Base

Within the past two years, the Twilight Pack was identified in the project area. Establishment of a pack in this project area is a good indicator that a sufficient prey base exists. Other predators already in the project area and competing with the wolf for big game prey include the grizzly bear, mountain lion, black bear, and the coyote. The alternatives would maintain habitat security and result in no net increase in ORD. Past analyses (over the last 10 years) in this analysis area show that big game habitat management standards are being met.

Timber Harvest

Timber harvest activities have occurred and are expected in the Spar PSU. These activities have provided forage for big game and have created more openings in lower elevation stands on big game ranges. Although harvest activities may create short-term disturbances to wolves and their prey species, wolf numbers have increased since 2002. Short-term potential disturbances from the alternatives would not result in a negative cumulative impact on wolves, and mortality risk for wolves and associated prey species is not expected to increase.

Private land development

Land development activities such as construction of roads, clearing of vegetation, construction of residences, and installation of improvements, all make a variety of changes to the landscape. Depending on the magnitude, type, and location of developments and the amount of private land on the landscape, these activities can have negative effects, including the loss of hiding cover and localized disturbance on wolves and their prey species.

While there may be some short-term direct effects on wolves and their prey species, long-term effects on private lands would not be expected. Therefore, there would be no cumulative effect under the three alternatives.

Hunting

On-going hunting activities are regulated by the FWP, and the USFS influences hunter access through road management. After mine reclamation is complete, there may be a slight increase in non-motorized access to the Mt. Vernon area, but access would remain limited and use levels would be low. With the generally limited amount of these activities on private, patented, and state lands, potential cumulative effects to the wolf would be minimal.

Regulatory Compliance

ESA: All alternatives would be expected to be in compliance with ESA because all alternatives address and maintain key habitat components which are identified in the Wolf Recovery Plan (USFWS 1987).

Forest Plan Consistency: The alternatives would meet Forest Plan direction that applies to the gray wolf, threatened and endangered species, and big game recommendations: Pages: II-1 #3, #5, #7, #12 and II-22-23.

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide for diverse populations of plant and animal communities by compliance with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Affect, but is Not Likely to Adversely Affect"* the gray wolf. This determination is based on the analysis that: 1) the alternatives would meet Forest Plan big game management

recommendations; 2) the prey base in the area supports at least one known wolf pack; 3) the alternatives would not affect known denning or rendezvous sites; 4) transient use could continue, but with a possible short-term avoidance of activity areas; and 5) mortality risk to the wolf would not be expected to measurably increase during or after reclamation activities.

3.18.5 Sensitive Wildlife Species

The sensitive species analysis in this document meets requirements for a biological assessment as outlined in FSM 2672.42.

Sensitive species are administratively designated by the Regional Forester (FSM 2670.5) and managed under the authority of NFMA. FSM 2670.22 requires maintaining viable populations of native and desired non-native species and avoiding actions that may threaten or endanger a species.

The NFMA directs the USFS to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives." (16 USC 1604(g) (3) (B)). Providing ecological conditions that support diversity of native plant and animal species in the planning area satisfies the statutory requirements. The USFS's focus for meeting the requirements of NFMA and its implementing regulations is on assessing habitat to provide for diversity of species.

The Forest Plan establishes forest-wide goals, objectives, standards, guidelines, and monitoring requirements. Direction for sensitive species includes determining the status of sensitive species and providing for their environmental needs as necessary to prevent them from becoming endangered (Forest Plan II-1).

In 2010, USFS personnel identified a current listing of all sensitive wildlife species known to occur on the KNF (**Table 3-25)**. This species list was used to help determine which species may be present in the analysis area.

Table 3-25. Sensitive Wildlife Species

Sensitive Species	Status Within Project Area	Comments Specific to Spar Planning Subunit
Bald Eagle (*Haliaetus leucocephalus*)	K	Suitable habitat found within the analysis area. See further discussion below in Sensitive Species section.
Black-Backed Woodpecker (*Picoides arcticus*)	K	Suitable habitat identified within the analysis area. See further discussion below in Sensitive Species section.
Coeur d'Alene Salamander (*Plethedon vandykei idahoensis*)	K	Suitable habitat identified along riparian zones within the analysis area. See further discussion below in Sensitive Species section.
Common Loon (*Gavia immer*)	K	Suitable habitat found within the analysis area. See further discussion below in Sensitive Species section.
Fisher (*Martes pinnanti*)	K	Suitable habitat identified within old growth habitat and along riparian zones within the analysis area. See further discussion below in Sensitive Species section.
Flammulated Owl (*Otus flammeolus*)	S	Preferred habitat exists on Douglas-fir/ ponderosa pine ecosystems within the analysis area. See further discussion below in Sensitive Species section.
Harlequin Duck (*Histrionicus histrionicus*)	S	Suitable habitat present along lower elevation, large creeks within the analysis area. See further discussion below in Sensitive Species section.
Peregrine Falcon (*Falco peregrinus*)	K	Suitable habitat found within the analysis area. See further discussion below in Sensitive Species section.
Townsend's Big-Eared Bat (*Corynorhinus townsendii*)	K	Suitable habitat found within the analysis area. See further discussion below in Sensitive Species section.
Western Toad (*Bufo boreas*)	K	Suitable habitat found within the analysis area. See further discussion below in Sensitive Species section.

Sensitive Species	Status Within Project Area	Comments Specific to Spar Planning Subunit
Wolverine (*Gulo gulo*)	K	Suitable habitat identified along high elevation ridgelines within the analysis area. See further discussion below in Sensitive Species section.
Northern Bog Lemming (*Synaptomys borealis*)	NS	Preferred habitat does not occur within the analysis area. Closest known occurrence is 55 air miles to the north near Northwest Peak. **Therefore, this species is not impacted by proposed reclamation project and will not be considered in further analyses.**
Northern Leopard Frog (*Rana pipiens*)	NS	Preferred habitat does not occur within the analysis area. Closest known population is 75 air miles to the northeast near Eureka. **Therefore, this species is not impacted by proposed reclamation project and will not be considered in further analyses.**

** Status Key:*
K = This species is known to occur within the project area
S = This species is suspected to occur within project area.
NS = This species is not suspected to occur within the project area, and is, therefore, dropped from further evaluation.

3.18.5.1 Bald Eagle

Bald Eagle Background

Eagle population ecology, biology, habitat description, and relationships identified by research are described in MBEWG 1991, MBEWG 1994, MBEWG 2010 USFWS 1995, USFWS 1999a, and in USFWS 2007a. That information is incorporated by reference. Eagle occurrence data come from recent District wildlife observation records, NRIS database, and from other agencies (FWP and USFWS).

The analysis area for project impacts and cumulative effects to individuals and their habitat is all lands within the bald eagle habitat area boundaries agreed to by the USFWS (2001). This bald eagle habitat area consists of a corridor approximately one mile on either side of Lake Creek from Bull Lake to the Kootenai River.

Affected Environment

The bald eagle was officially removed from the threatened species list on August 8, 2007. It was immediately placed on the Forest Service Northern Region's sensitive species list for a period of five years, after which time a status review will be made to determine if the eagle needs to remain on that list. In Montana, the number of bald eagle nesting territories has grown from 31 in 1980 to 490 in 2008 (Hammond 2009). Known nesting success in 2007 was 79 percent (DuBois 2008).

Bald eagles occur as both seasonal migrants and year-round residents, and nesting has increased over the last two decades within the boundaries of KNF. Only one active nest was known to occur in 1978; however, 27 nests (11 on NFSL and 16 on private land) were known and monitored in 2007 (KNF 1978 to present). Nest success for the active nests in 2007 was 38 fledglings. This number is above the average year of 24.5 fledges over the last 20-year period (DuBois 2008).

Wintering bald eagle numbers have fluctuated over the years depending on food sources (fish from open waters and dead animals along roads and railroad tracks) and winter conditions (open versus frozen water for foraging habitat). Mid-winter bald eagle counts have averaged 96 bald eagles over the past 20 years (KNF bald eagle monitoring records). In 2009, 98 bald eagles (75 adults and 23 immatures) were tallied on the winter count.

There is one bald eagle nest site in the Spar PSU, on the south end of Bull Lake. Two nests occur in the Lake PSU; one is on the north end of Bull Lake and the other lies outside the analysis area. A winter wind event in 2009 damaged the older nest (north end of Bull Lake), and no eagles were seen perching or roosting near the site. The nest was still in disrepair in the summer of 2010. A newer nest (south end of Bull Lake) was established in 2007, and the eagle pair has produced fledglings in the past couple of years.

Eagles are occasionally observed near Bull Lake in the winter if the lake is not frozen over. Eagles are known to use the Kootenai River corridor in the winter within the Lake PSU. Besides the forage opportunities along water bodies, these raptors scavenge along US 2 and MT 56 and along the railroad tracks that parallel the Kootenai River.

The Montana Bald Eagle Working Group (MBEWG) (1994) identifies bald eagle mortality risks as shooting, accidental trapping, poisoning, diseases, and electrocution. On the KNF, bald eagles have also died from collisions with motor vehicles and trains. All of these risks remain in the analysis area.

The Montana Bald Eagle Management Plan (MBEWG 1994 and MBEWG 2010) recommends distance buffers based on the presence or absence of visual buffers and seasonal restrictions for heavy construction activities near bald eagle nests (active and inactive), concentrated forage areas, and winter roost sites. The area buffers range from ¼ mile to ½ mile (depending on visual buffers) with seasonal restrictions from February 1 to August 15 (nest building, egg laying/incubation, and hatching/rearing seasons).

Environmental Consequences

Direct and Indirect Effects

None of the alternatives would include any activities closer than one mile to the active nest located on the south side of Bull Lake. This distance surpasses the ½ mile buffer distance recommended for potentially disturbing activities near active bald eagle nest sites. None of the alternatives would result in direct or indirect effects on the active nest in the analysis area.

Lake Creek runs along the west side of the tailings impoundment. Bald eagles may use this as part of their foraging habitat. Because reclamation activity levels are expected to be similar to current mining operations, bald eagles using the area would not likely experience any new effects.

Cumulative Effects

The eagle nest on the south end of Bull Lake is near an active boat ramp and campground. It was located in 2007, and the eagles have produced fledglings in the successive years. Recreational activities are apparently not disrupting breeding or nesting efforts.

None of the alternatives would contribute to any cumulative impacts on the bald eagle or its habitat. The viability of known bald eagle populations would not be affected by implementing any of the alternatives.

Regulatory Compliance

Forest Plan Consistency: All alternatives would meet Forest Plan direction as applicable to the bald eagle and sensitive species (Pages: II-1 #5, #6, #7, II-2 #13, and II-22-23).

NFMA: All alternatives would comply with NFMA direction to provide for diverse populations of plant and animal communities by compliance with Forest Plan standards and guidelines (Johnson 2004a).

Bald and Golden Eagle Protection Act: All alternatives would be consistent with the Bald and Golden Eagle Protection Act (16 USC 668-668C 1978).

Migratory Bird Treaty Act: All alternatives would be consistent with the Migratory Bird Treaty Act (17 USC 703-712).

Statement of Findings

The No Action Alternative, Proposed Action, and the Agency-Mitigated Alternative would all result in a determination of "*May Impact Individuals and/or their Habitat, but Will Not Likely Contribute to a Trend Towards Federal Listing or Loss of Species Viability to the Population or Species*". This determination is based on the analysis that: 1) all alternatives would meet the USFWS guidelines outlined in the NBEMG for avoiding nest disturbance; 2) the bald eagle pair that currently occupies the active nest site have exhibited some tolerance for current levels of recreational activity in the vicinity; and 3) the project would not impact bald eagle foraging opportunities throughout the year.

3.18.5.2 Black-backed Woodpecker

Black-backed Woodpecker Background

Black-backed woodpecker population ecology, biology, habitat description, and relationships are described in Cherry (1997), Hutto (1995), O'Connor and Hillis (2001), and in Powell (2000). The above information is incorporated by reference. Black-backed woodpecker occurrence data originate from recent District wildlife observation records, NRIS database, and from other agencies (MNHP).

High quality habitat is defined as recent (< 5 years old) mixed-lethal or stand-replacement fire areas where an abundance of snags are available and found to be almost restricted to early post-fire forests (Hutto 1995). Potential territories may include general forest habitat (low quality), but must include some burned or decadent acres of overstory that attract and support the beetle larvae species the woodpecker preys on (Bonn *et al.* 2007, Cherry 1997). The analysis area for addressing direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Habitat for black-backed woodpeckers consists of boreal and montane forest where beetle outbreaks have occurred as a result of disturbances caused by fire, wind, and disease. Within the analysis area, black-backed woodpecker habitat consists mainly of lower quality general forest habitat with small scattered patches of snags produced by insects and disease. This lower quality habitat supports low populations of resident black-backed woodpeckers.

Recent fires (within the last three years) in the Spar PSU (Ross Creek drainage) have provided snag habitat for black-backed woodpeckers, and therefore, the woodpeckers are expected to be found in the vicinity of the Troy Mine Permit Area (KNF 2010). Also, a single female was recorded along the west shore of Bull Lake (MNHP). Within the Lake PSU, there are also records of two individuals observed between Camp and Madge creeks (MNHP).

Environmental Consequences

Direct and Indirect Effects

None of the reclamation alternatives would remove snags in the analysis area because activities would be centered on existing disturbed sites. General forest may provide some habitat for the black-backed woodpecker, and some individuals may be present in the vicinity of reclamation activities. As reclamation activity levels would be similar to current mining operations, black-backed woodpeckers that use the area would not likely experience any new effects.

Cumulative Effects

The USFS Sparring Bulls Project is proposing a combination of activities that would remove or reduce some general forest foraging opportunities, but that would also create foraging habitat through associated prescribed burns (KNF 2010). Burned areas would consist of some trees killed by fire effects and thus would set up conditions for beetle occurrence and woodpecker foraging opportunities. Activities replicating historical conditions created by mixed-severity fires could provide high quality black-backed woodpecker habitat for two to three years, then decline, and rarely provide insect food sources beyond five to seven years (Caton 1996, Murphy and Lehnhausen 1998). The Sparring Bulls project would not reduce high quality habitat and would not affect the viability of black-backed woodpecker populations. None of the Troy Mine reclamation alternatives would affect high quality habitat; therefore, there would be no cumulative effect on black-backed woodpecker.

Firewood cutting could remove snags and reduce the availability of nesting and foraging habitat along open roads. Because none of the alternatives would increase motorized access, there would be no cumulative effect from firewood cutting.

Timber stand improvement would not impact woodpecker habitat, as stands that are typically thinned are too young to provide forage for this species. Fire suppression could directly impact the black-backed woodpecker; however, due to steep terrain and limited road access, fire suppression activities have not had an adverse effect in the analysis area. The Troy Mine reclamation alternatives would not affect fire suppression effectiveness and therefore, would have no cumulative impact on the black-backed woodpecker.

No adverse cumulative effects from reclamation activities would be expected either. Finally, the viability of known black-backed woodpecker populations would not be affected by implementing any of the alternatives.

Regulatory Compliance

Forest Plan Consistency: All alternatives would meet the Forest Plan direction applicable to the black-backed woodpecker and sensitive species (Pages: II-1 #6, #8, #17, and II-22-23).

All alternatives would be consistent with the Forest Plan direction for old growth below 5,500 feet (FP Vol. 1 II-1 #7; II-7; II-22 and 23; Appendix 17; and Kootenai FSM 2432.22 Supplement No. 85).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with the NFMA direction to provide diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Impact Individuals or their Habitat, but will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Viability to the Population or Species"* for the black-backed woodpecker. This determination is based on the following considerations: 1) the Sparring Bulls Draft EIS (KNF 2010) estimates that nearly 4,000 acres of high quality habitat would be created over the next decade within the analysis area, thereby replacing and augmenting the present habitat; 2) reclamation activities would occur in previously disturbed areas; 3) wildfires would still occur and create habitat for the woodpecker, despite fire suppression management; 4) snag levels would be maintained above Forest Plan standards; and 5) the Potential Population Index (the number of pairs the habitat could support) for the species would remain the same or slightly increase within the analysis area over time (KNF 2010).

3.18.5.3 Couer d'Alene Salamander

Couer d'Alene Salamander Background

Coeur d'Alene salamander population ecology, biology, habitat description, and relationships are described in Cassirer *et al.* (1994) and in Maxell (2000). The above information is incorporated by reference. Coeur d'Alene salamander occurrence data come from recent District wildlife observation records, NRIS database, and from other agencies (MNHP).

This salamander is considered a sensitive species because few populations are recorded and their habitats are isolated. Their specialized habitat consists of springs, seeps, waterfall spray zones, and damp stream banks near fractured rocks (Werner *et al*. 2004). NFSRs built in the past may have impacted some of the specialized habitats preferred or used by salamanders. Road building on the District has declined since adoption of the Forest Plan, and grizzly bear management has also reduced the number of roads open to motorized access.

The analysis area to address direct, indirect, and cumulative effects is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Three observations from the analysis area are found in MNHP and NRIS records and are located in a seep zone on a canyon face above Spar Lake, the Ross Creek Drainage, and at Payne Creek Falls about one mile east of Bull Lake. Johnson (1999) shows Coeur d'Alene salamander presence confirmed at 13 different sites on the KNF. Salamanders have been confirmed in additional sites since 1999, so that the known sites now total 36. Known populations on the KNF are isolated by miles of unsuitable habitat that cannot be crossed (based on Maxell 2000, p 69 and Maxell *et al.* 2003, p 40).

Environmental Consequences

Direct and Indirect Effects

None of the alternatives would include activities within areas of known Coeur d'Alene salamander populations. However, road reclamation or stabilization activities may create short-term sedimentation in streams that may be inhabited by salamanders. For example, some stream crossings may be impacted by road reclamation/reconstruction work under the alternatives. Over the long term, precipitation events could continue to erode vulnerable sections of deteriorating roads, and sedimentation resulting from this may impact habitat that is used by the Coeur d'Alene salamander. Both the No Action and Agency-Mitigated alternatives would minimize this effect by either reclaiming or stabilizing roads. Under the Proposed Action, this erosion could continue in some locations and could affect the Coeur d'Alene salamander. Although there is a low risk that individuals could be impacted, it would have a minimal effect on the overall population and thus would not be expected to affect the continued viability of the Coeur d'Alene salamander within the analysis area.

Cumulative Effects

Because no new or temporary roads would be built under any of the alternatives, there would be no cumulative effect from road construction. Watershed work related to Sparring Bulls on deteriorating roads may create a short-term pulse of increased sedimentation, but the current erosion of the road surface would be mitigated in the long-term. Overall, there would be a low risk of cumulative impacts to individual salamanders.

No on-going or foreseeable actions in the analysis area are expected to impact Coeur d'Alene salamander populations or their habitats. The viability of known salamander populations would not be affected by implementing any of the alternatives.

Regulatory Compliance

Forest Plan Consistency: All alternatives would meet the Forest Plan direction applicable for the Coeur d'Alene Salamander and sensitive species (Pages: II-1 #6, #7, #13, and II-22-33).

All alternatives would be consistent with Forest Plan riparian standards and guidelines (Pages: II-28-33) as amended by INFISH.

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow the NFMA direction to provide for diverse populations of plant and animal communities by compliance with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and the Agency-Mitigated Alternative would all result in a determination of "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* for the Coeur d'Alene salamander. This determination is based on the following considerations: 1) no reclamation activities would occur in areas of known salamander populations; 2) none of the alternatives would build any new roads or conduct activities in undisturbed riparian areas; 3) road reclamation and stabilization work proposed in the alternatives could create a short-term pulse of sediment delivery into stream channels bisecting the affected roads and mine sites; 4) deteriorating road prisms in the analysis area could remain susceptible to erosion and may impact potential salamander habitat; and 5) the occurrence of suitable habitat and frequency of stream crossings is low within the area to be reclaimed.

3.18.5.4 Common Loon

Common Loon Background

The current status and distribution of common loons in western Montana can be found in the Third Annual Common Loon Report (Bissell 2005) and in the USFWS Conservation Plan (Evars 2004). Skaar (1989) and Dolan (1994) established interim goals and strategies for maintaining nesting habitat and stable population levels; they also described the ecology, biology, habitat use, status, and conservation of the common loon. Data from these documents are incorporated by reference.

The analysis area centers on Bull Lake, which is located in the Lake Creek watershed. The analysis focuses on direct effects to loons and their habitat. Addressed are both the shorelines within 500 feet of nesting loons (Dolan 1994) and the waters of Bull Lake. Any direct effects to loons and their habitat would be limited to these waters. Analysis of indirect and cumulative effects would also be the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Common loons have been observed in all eight planning units on the KNF (Johnson 1999). Johnson (1999) summarizes available loon habitat across the KNF. In western Montana, since the formation of the Common Loon Working Group in 1999, the total number of lakes surveyed has stabilized with the total number of adult loons counted each year ranging between 150 and 200. Annual variability in adult counts could be attributed to changing population size or possibly to survey conditions or efforts, particularly on large reservoirs and lakes (Bissell 2004). The Montana Loon Society loon count data show the total number of loons in northwest Montana has remained relatively stable over the last six years (Bissell 2004). Over the last five years, these same data show rather wide fluctuations in the number of chicks produced. Causes for lower production in some years include weather (flooding) and competition among nesting pairs.

No observations of nesting loons have been recorded for the analysis area for at least 10 years. Common loons are seen and heard on Bull, Spar, and Savage lakes but such presence is transient use. Spar Lake is not free of snow or ice until mid- to late-May, while lower elevation lakes of an adequate size on the District already support a nesting pair of loons. Human settlements along the shorelines of Bull and Savage lakes have reduced some potential nesting habitat sites. Increased recreational activities in these waters create waves or other impacts that discourage loon nesting success.

Other lakes in the analysis area are either too small for adequate loon habitat or are too high in elevation for nesting or foraging opportunities. These lakes include Milnor, Spruce, Little Spar, and Grouse lakes.

Environmental Consequences

Direct Effects

No alternative proposes activities within 500 feet of the waters of Bull Lake, and the existing transient use of area lakes by loons would be expected to continue.

Due to the popularity of these lakes for recreational use and for continued waterfront development, it is not likely that use by loons would increase. Indirect effects, such as noise disturbance from reclamation activities, would not be noticeable compared to disturbances associated with other existing uses of Bull Lake.

Cumulative Effects

Since there would be no direct or indirect effects from any of the alternatives to loon habitat, there would be no cumulative effects. Therefore, the viability of the loon population on the KNF would not be affected.

Regulatory Compliance

Forest Plan Consistency: All alternatives would meet Forest Plan direction on NFSL for sensitive species (Pages: II-1 #6, II-22-23).

All alternatives would be consistent with Forest Plan riparian standards and guidelines (Pages: II-28-33) as amended by INFISH.

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow the NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and the Agency-Mitigated Alternative would all have "*No Impact"* on the common loon or its habitat. This determination is based on the following considerations: 1) no common loon nesting or examples of successful reproduction has occurred in the analysis area for at least 10 years; 2) none of the project alternatives would impact habitat or vegetation for potential loon nesting habitat; and 3) common loon habitat and reproduction levels are stable on the district.

3.18.5.5 Fisher

Fisher Background

Fisher population ecology, biology, habitat description, and relationships are described in Powell and Zielinski (1994) and in Heinemeyer and Jones (1994). The above information is incorporated by reference. Fisher occurrence data originate from recent District wildlife observation records, NRIS database, and from other agencies (MNHP). Approximately 110 fishers from Minnesota were introduced forest-wide between 1988 and 1991 (USFS 2001). The analysis area for addressing direct, indirect, and cumulative effects to fishers and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Fisher observation and monitoring data indicate that historical sightings of two fisher occurred (1996, 2006) in the analysis area, along Ross Creek and Lake Creek north of the Troy Mine Permit Area. Johnson (1999) shows fisher presence was confirmed in five of the eight planning units on the KNF. A research project trapped six individual fishers in the analysis area (Vinkey 2003).

Ruediger (1994) shows the KNF as a primary habitat area for fisher. Additionally, the analysis area is assigned as a primary fisher conservation area and determined to be moderate quality fisher habitat

(Johnson 2004b). Fisher habitat has been modeled for the analysis area by using the Kootenai fisher habitat model 2008 and identified 10,980 acres of potential habitat (KNF 2010). The potential population index (PPI) (habitat acres divided by average home range acres) was calculated by using 10,000 acres as the average male and 3,700 acres as the average female fisher home range (Powell and Zielinski 1994). This index shows both male and female fishers because their home ranges overlap extensively (Powell and Zelinski 1994). Based on the average male and female fisher home range sizes and the modeled habitat acres, the PPI for the analysis area is approximately three female fishers and one male fisher (KNF 2010). By using the modeled year-long habitat acres from Johnson (1999), the minimum PPI for the KNF would be 29 male and 80 female fishers.

Since the last augmentation of the population in the early 1990s, the predator has been successful in establishing a small population in the Cabinet Mountains; however, the long-term outlook for this population is uncertain (Vinkey 2003). A variety of factors including deep snows, low habitat quality, and behavioral and genetic characteristics of the transplanted fishers may have predisposed this translocation to failure (Vinkey 2003). Since the 1990s, about four percent of the analysis area has been regeneration harvested, and about nine percent has been improvement cut. Old Growth is nearly 12 percent of the forested lands below 5,500 feet elevation and meets the Forest Plan standard of at least 10 percent (KNF 2010).

The Spar and Lake PSUs provide adequate foraging and denning habitat for fishers (KNF 2001).

Environmental Consequences

Direct and Indirect Effects

Two small stands of identified old growth habitat are adjacent to NSFR 4626. However, none of the proposed reclamation alternatives would affect old growth stands, and none of the alternatives propose activities within or immediately adjacent to undisturbed streams. Re-establishing the stream channel at the mill/office site under the Proposed Action and the Agency-Mitigated Alternative may provide better connectivity with Stanley Creek in the future. The No Action Alternative would not provide this connectivity.

All the alternatives have reclamation activity levels which are expected to be similar to current mining operations. Fisher using the area may experience disturbance and thereby avoid the area in the short-term while this activity takes place. Road reclamation and stabilization work under the alternatives would occur on existing roads that are adjacent to fisher habitat. This work would not reduce fisher habitat, but reclamation activities may disturb the fisher. In addition, the road network intersects movement corridors for the predator; however, many of these roads have received regular activity during mining operations. Therefore, reclamation activities would not further impact the fisher.

Potential fisher habitat in the Troy Mine Permit Area has likely been disturbed to some degree already due to mining operations. None of the reclamation alternatives would likely reduce PPI for the Troy Mine Permit Area.

Under all of the alternatives, reclamation activities proposed for the tailings impoundment area would be located on private property. None of the alternatives would be expected to change conditions measurably from current conditions as activities would occur in previously disturbed sites.

Cumulative Effects

No past, present, or reasonably foreseeable future projects would affect fisher habitat. Tree thinning projects would not affect habitat (other than in time), and these stands would grow trees that may actually provide shelter or forage potential for the animal. However, conversion of corporate timber lands to private real estate would decrease potential fisher habitat at the lower elevations.

Any existing old growth stands near perennial streams would continue to offer fisher habitat. The mosaic of vegetation within the analysis area would still offer habitat for fisher foraging. Suitable fisher habitat would not be decreased due to timber harvest activities; none of the reclamation alternatives would affect fisher habitat. Therefore, there would be no cumulative effects.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction for sensitive species (Pages: II-1 #6, II-22-23).

All alternatives are consistent with Forest Plan riparian standards and guidelines (Pages: II-28 thru 33) as amended by INFISH.

All alternatives are consistent with Forest Plan direction for old growth below 5,500 feet (Pages: II-1 #7; II-7; II-22 and 23; Appendix 17; and Kootenai FSM 2432.22 Supplement No. 85).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction on providing for diverse populations of plant and animal communities by compliance with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Impact Individuals or Their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* for the fisher. This determination is based on the following considerations: 1) disturbance to fishers and short-term avoidance of areas affected by large, recontouring activities and road reclamation/stabilization work in infrequently used areas would be expected; 2) no undisturbed habitat would be reduced by the action alternatives; 3) proposed reclamation activities, in general, would be comparable to current mining operation activities; and 4) no change in the species PPI for this project area would be expected.

3.18.5.6 Flammulated Owl

Flammulated Owl Background

Flammulated owl population ecology, biology, habitat description, and relationships are summarized in Hayward and Verner (1994). More recent research on nesting, food habits, home range and territories, and on habitat quality conducted in Colorado, Idaho, and Montana is discussed in Linkhart (2001), Linkhart and Reynolds (1997), Linkhart *et al.* (1998), Powers *et al.* (1996), Wright (1996), and Wright *et al.* (1997). The above information is incorporated by reference. Flammulated owl occurrence data come from recent USFS wildlife observation records and from the NRIS database (KNF 2008b).

Johnson (2004a) determined the PPI (number of potential territories) for breeding pairs by dividing potential habitat acres by 40 acres. Potential effects of the alternatives are evaluated by assessing potential changes to habitat and the resulting PPI.

The analysis area for direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

A summary of the status of flammulated owls on the KNF was documented by Johnson (1999). The summary shows that potential habitat occurs across all eight planning subunits. Forestwide, there are 237,098 acres of potential habitat (Johnson 1999). Field surveys have confirmed flammulated owl presence in six of eight planning units.

District flammulated owl observation and monitoring data indicate that owl presence has not been detected either in the analysis area or in the Troy Mine Permit Area. Flammulated owl surveys (which consist of using taped owl calls to draw a response from nesting birds) have been conducted intermittently within the analysis area over the last decade. Surveys did not detect flammulated owls in the analysis area, and it is unknown if flammulated owls actually inhabit Spar or Lake PSUs. Given the lack of dry habitat, the owls' presence is not expected; therefore surveys have not been a priority in the Spar or Lake PSUs.

Flammulated owl habitat is limited in the Spar and Lake PSUs because these sites are fairly wet. The owls are adapted to drier habitats that consist of stands of mature to over-mature ponderosa pine/Douglas-fir habitat types (KNF 2010). Flammulated owl habitat was modeled by using the USFS Region One Summary Database, which synthesizes field data gathered in the database "FSVEG" to provide an overview of the potential for a species' habitat. The vegetation model identified potential flammulated owl habitat in 551 acres within the analysis area (KNF 2010). Of these acres, only three blocks of potential habitat are 40 or greater contiguous acres in size. These blocks vary from 43 to 56 acres, and all have been intermediate harvested in the past 10 years (KNF 2010). However, over time, as the shrub and seedling understory grows, insects may increase in these stands to the point that a prey base becomes available for flammulated owls.

Based on the average flammulated owl pair territory size and the modeled habitat acres, the PPI for the NFSL within the analysis area is three flammulated owl pairs (KNF 2010). Using the nesting (modeled)

habitat acres from Johnson (1999), the minimum PPI for KNF would be 5,927 flammulated owl pairs. These estimates of PPI are considered high on the basis of actual survey results.

Environmental Consequences

Direct and Indirect Effects

None of the reclamation alternatives would affect potential flammulated owl habitat, but reclamation activities that result in revegetation in the long term could potentially increase owl habitat. However, given the amount of precipitation in the analysis area, it is unlikely that reclaimed areas would result in dry forest types such as ponderosa pine and Douglas-fir that are preferred by the owls.

Cumulative Effects

Past harvest activities may have altered potential flammulated owl habitat through such actions as regeneration harvest or stand conversions to western larch. Due to the amount of precipitation in this project area, it is highly unlikely that many dry sites (ponderosa pine and Douglas-fir) exist in this area. Past or reasonably foreseeable future pre-commercial thinning might affect the owl's prey base if the stand is being managed for dry site tree species. Wildfires and prescribed burns would reduce fuels, allow more sunlight to reach the forest floor, and may encourage more pine or Douglas-fir to regenerate in the burned areas. None of the reclamation alternatives would affect fire suppression effectiveness, and there would be no cumulative effects on owl habitat.

Regulatory Compliance

Forest Plan Consistency: All three alternatives meet Forest Plan direction for sensitive species (FP II-1 #6, II-23).

All alternatives are consistent with Forest Plan direction for old growth below 5,500 feet (FP Vol. 1 II-1 #7; II-7; and II-22 and 23; Appendix 17; and Kootenai FSM 2432.22 Supplement No. 85).

All alternatives meet Forest Plan standards for snags (FP II-1 #8; II-22 and 23; and Appendix 16).

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow the NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and the Agency-Mitigated Alternative would all have "*No Impact"* on the flammulated owl. These determinations are based on the following considerations: 1) no loss of potential habitat; 2) current records do not show a presence of the species in the area; and 3) the alternatives would not impact potential nesting territories or the PPI of the flammulated owl on the KNF.

3.18.5.7 Harlequin Duck

Harlequin Duck Background

Harlequin duck population ecology, biology, habitat description, and relationships are described in Cassirer *et al.* (1996). The above information is incorporated by reference. Harlequin duck occurrence data come from recent MNHP surveys, USFS wildlife observation records, NRIS database, and from other agencies (FWP).

The analysis area for direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Harlequin duck observation and monitoring data indicate that there is suitable habitat for harlequin ducks within the analysis area, but the only documented occurrences are within the Spar PSU. Harlequin duck observation and monitoring data indicate that two sightings of harlequin ducks occurred in 1988 (NRIS database). One sighting was a male and female near Spar Lake. The other sighting was of two ducks (sex unknown) on Lake Creek. Johnson (1999) shows harlequin duck breeding confirmed on a total of ten streams in six of the eight planning units on the KNF. These streams provide about 71 miles of habitat within the KNF.

Potential habitat for the duck in the analysis area is confined to the larger creeks such as Keeler and Lake creeks. This area comprises about 15 miles of riparian habitat along the main valleys in the project area. No recent surveys for this species have taken place.

Environmental Consequences

Direct and Indirect Effects

None of the reclamation alternatives would include activities in areas with potential harlequin duck habitat. Road reclamation or stabilization activities may be associated with some stream crossings, but these would be small tributaries that do not provide harlequin duck habitat.

Cumulative Effects

Because there would be no direct or indirect effects on the harlequin duck habitat from any of the alternatives, there would be no cumulative effect.

Other past, present, and reasonably foreseeable future projects would be designed with sufficient riparian buffers to protect harlequin duck habitat from adverse effects of timber management.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction for sensitive species (FP II-1 #6, II-23).

All alternatives are consistent with Forest Plan riparian standards and guidelines (FP Vol. 1 II-28 thru 33) as amended by INFISH.

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow the NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all have "*No Impact"* on harlequin duck. This determination is based on the consideration that none of the reclamation activities would impact potential habitat for the species.

3.18.5.8 Peregrine Falcon

Peregrine Falcon Background

Peregrine falcon ecology, biology, habitat use, status, and conservation are described and summarized in USFWS (1984, 1999b) and in Rogers and Sumner (2004). The above information is incorporated by reference. Peregrine falcon occurrence data come from USFS observation records, the NRIS database, and from other agencies (MNHP).

Because the peregrine is a previously listed species, peregrine falcon management follows direction provided in the Recovery Plan (1984) revised in 1984 and amended in 1993. That plan recommended protection of existing and potential nesting habitat and elimination of unfavorable land use practices that disturb key habitats. The plan prohibited: 1) activities that alter the character of hunting habitat, the prey base within ten miles, and/or the immediate habitats within one mile of a nest site; 2) activities within ½ mile of a nest site during the nesting period (February 1-August 1); and 3) the use of pesticides/pollutants that are harmful and that could accumulate in the falcon or its prey base. That direction is still appropriate for management of peregrine falcons as a sensitive species. There is no Conservation Assessment for peregrine falcons in Montana.

The analysis area for direct, indirect, and cumulative effects is the Lake Creek watershed. The boundary for determining trends toward viability is the KNF.

Affected Environment

In 2009, there were five active peregrine falcon territories. These active territories were monitored again in 2010. One site is located on cliffs above Bull Lake within the Spar PSU. During the summer of 2010, two adults and one fledgling were observed (Montana Peregrine Institute 2010).

Environmental Consequences

Direct and Indirect Effects

Reclamation activities under the Proposed Action would be farther than one mile from the nest site on the cliffs above Bull Lake. In the No Action and Agency-Mitigated alternatives, proposed stabilization work on NFSR 4628 would come within approximately ½ mile of the active nest site at its closest point but would remain outside the nest buffer. In addition, the rugged topography of the area would provide both a visual and a noise buffer between the nest and the activity. The road work would not alter the

character of the hunting habitat as the work would take place on an existing road. Seasonal restrictions protecting spring habitat use for the grizzly bear would also limit the season of activity for this work to the summer season after June 15, further limiting any potential for noise disturbance to the nesting peregrines on NFSL. None of the alternatives would use pesticides or pollutants, except herbicides for weed control, as part of reclamation activities.

Reclamation of disturbed areas under each of the alternatives would potentially increase vegetated areas and thus conditions for the falcon's prey species. All alternatives would result in a forested condition in the long term, and there would be no effect on peregrine falcon habitat.

Cumulative Effects

With no direct or indirect effect on peregrine falcon habitat from any of the alternatives, there would be no cumulative effect. Accordingly, there would be *No Impact* on the viability of the falcon at the Forest scale.

Other past, present, and reasonably foreseeable future projects would be conducted to avoid impacts both to peregrine falcon nesting periods and to its prey base on NFSL.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan goals as applicable to the peregrine falcon, sensitive species, and to the MIS (Pages II-1 #5, #6, #7, II-22-23).

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all have "*No Impact"* on the peregrine falcon. This determination is based on the following considerations: 1) no disturbance to the falcon would occur during its breeding, nesting, or rearing periods; and 2) none of the alternatives would affect foraging opportunities for the falcon.

3.18.5.9 Townsend's Big-eared Bat

Townsend's Big-eared Bat Background

Townsend's big-eared bat population ecology, biology, habitat description, and relationships are described in the following: Christy and West (1993), Kunz and Martin (1982), the Montana Natural Heritage Program (1993), Perkins and Schommer (1991), Pierson *et al.* (1999), Reel *et al.* (1989), Ross (1967), Thomas and West (1991), and in Whitaker *et al.* (1977). The above information is incorporated by reference. Townsend's big-eared bat occurrence data come from recent USFS wildlife survey records, the NRIS database, and from other agencies (MNHP).

Suitable habitat in the analysis area is probably associated with historical mining activity (mines and tunnels), rock crevasses in cliff faces, lakes, or in stands containing large snags (usually old growth) (KNF 2001). Old growth stands were identified by using KNF old growth mapping data. Old growth forest in the Lake Creek watershed was discussed in **Section 3.16.4**.

The analysis area for potential direct, indirect, and cumulative effects on individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Townsend's big-eared bats have been documented in the Spar PSU and more specifically, within the Ross Creek area (Hendricks *et al.* 1995, 1996, MNHP). A status summary of the Townsend's big-eared bat on the KNF was documented by Johnson (1999). Surveys of the KNF (1993-1995) by Hendricks *et al.* (1995, 1996) have located the species in all planning units (Johnson 1999); however, no key roosting sites (such as caves or mines) have been located.

Suitable roosting habitat such as mines and caves are found within the Spar PSU. USFS and MNHP Townsend's big-eared bat observation and monitoring data indicate that caves and tunnels for winter habitat are also available within the Spar PSU. The Troy Mine and the small privately-owned Montana Morning Claims Mine are the only mines known to exist within the analysis area. No observations of the bat have been recorded for either mine.

The Townsend's big-eared bat also has the potential to roost in tree cavities (Perkins and Schommer 1991, MNHP 1993). Larger diameter snags or trees with cavities could also be used for summer roosting. The species shows a preference for old growth forest for roosting habitat (Thomas and West 1991). As discussed in **Section 3.16.4**, the analysis area has 11.9 percent old growth, which comprises 9,893 acres. These stands and the remaining timbered habitat provide suitable roosting habitat in the form of large snags with cavities, as well as abundant foraging habitat across the forest landscape. Cavity habitat potential on NFSL within the analysis area is 75 percent.

Townsend's big-eared bats are known to feed along forest edges and can be associated either with dry or with wet type coniferous forests. Both young and mature forests are used for feeding (Thomas and West 1991), with primary foraging areas near lakes (Grindal 1996). Overall, forested stands across the analysis area provide potential foraging habitat for the bats.

Environmental Consequences

Direct and Indirect Effects

None of the reclamation alternatives would affect known roost sites, snag habitat, or old growth habitat that may contain roost sites for the bat. Currently, these bats do not roost in the Troy Mine. Those bats which use the surrounding forested habitat already tolerate current mining activities, and no alternative proposes timber harvest. Moreover, the bats would experience similar disturbances during reclamation activities as they do during the current mining operations. Under the Agency-Mitigated Alternative, gates would be installed in the Service and Conveyor adits that have the potential to allow bat access. It

is possible that after mine closure, bats could find these mine openings and begin to use it as a roost or hibernacula site. However, all other mine entrances would be sealed.

Reclamation of disturbed areas under each of the alternatives would have the potential to increase vegetated areas and thus improve conditions for insect prey species of the bats. All alternatives would produce a forested condition in the long term, and there would be no effect on Townsend's big-eared bat habitat.

Cumulative Effects

Because there would be no new direct or indirect effect on Townsend's big-eared bat habitat from any of the alternatives, there would be no cumulative effects. Accordingly, there would be no impact on the viability of the bat at the Forest scale.

Other present and reasonably foreseeable future projects on NFSL would be conducted to avoid impacts to bat roosting sites and would not affect foraging habitat for the bat (*e.g.* rivers, lakes, and meadows). Past timber harvest likely contributed to snag loss in the analysis area; however, more recent timber management projects have included snag retention requirements. Neither watershed improvement activities nor road maintenance work would affect bat habitat. Although fire suppression may affect the availability of snags across the landscape, none of the reclamation alternatives would affect the effectiveness of current fire suppression activities within the analysis area.

As the economy improves, increased development of private land is expected to continue in the project area. Habitat on federal lands is considered sufficient to provide cavity habitat to cavity dependant species. The existing 75 percent cavity habitat potential for NFSL would be above the minimum 40 percent needed to maintain self-sustaining populations of snag-dependent wildlife (Thomas 1979, pg. 72).

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction as applicable for the Townsend's big-eared bat and sensitive species (Pages II-1 #6, #7, #8, and II-22-23).

All alternatives are consistent with Forest Plan direction for old growth below 5,500 feet (FP Vol. 1 II-1 #7; II-7; II-22 and 23; Appendix 17; and Kootenai FSM 2432.22 Supplement No. 85).

All alternatives meet Forest Plan standards for snags and down wood (FP II-1 #8; II-22 and 23 and Appendix 16).

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all have a "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* finding on the Townsend's big-eared bat. This determination is based on the following considerations: 1) no old growth would be affected by any of the reclamation alternatives; 2) the alternatives would not affect key roosting or hibernation habitat associated with caves, mines, or any buildings and would not be expected to impact the species natality or mortality rates; 3) cavity habitat in the form of snags, wildlife trees, and leave trees would continue to be provided across the KNF in managed (no less than 40 percent snag habitat levels) and unmanaged areas; and 4) disturbance associated with reclamation activities would be comparable to current mining operations.

3.18.5.10 Western Toad

Western Toad Background

Western toad ecology, biology, habitat use, status, and conservation are described and summarized in Maxell (2000) and Reichel and Flath (1995) and are incorporated herein by reference. Western toad occurrence data come from USFS wildlife observation records, NRIS database, and from other agencies (MNHP). The analysis area for direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Western toads require over-wintering, breeding/metamorphosis, and foraging habitat; they may also be dependent on habitats suitable for migration if the three required habitat types are isolated spatially (Maxell 2000). Over-wintering may take place in underground caverns or in rodent burrows (Maxell 2000). Breeding/metamorphosis takes place in aquatic sites such as shallow areas of lakes or temporary ponds, and foraging habitat is largely terrestrial uplands (Maxell 2000). The highest elevation the species has been documented in Montana is 9,220 feet.

KNF status summary of the western toad was documented by Johnson (1999), and the species has been found in seven of the eight planning units. Many surveys have been conducted on the KNF since 1993. Surveys conducted between 1993 and 1995 located only 63 adults. Of the 134 wetland sites surveyed during the 1993-94 field season, only 10 had evidence of successful breeding (Werner and Reichel 1994). Five additional sites were confirmed during the 1995 field season (Werner and Reichel 1996). Surveys of approximately 200 potential sites were conducted in the Bull River drainage south of the analysis area during the 1997-98 field season, but evidence of breeding (tadpoles and eggs) was found at only eight sites (Corn *et al.* 1998). Historic and active breeding sites were summarized by planning unit on the KNF by Johnson (1999). Forest-wide, approximately 35 breeding sites were verified between 1995 and 1998 (Johnson 1999).

There are three known breeding sites within the analysis area. These sites are located in some of the man-made toe ponds at the Troy Mine tailings impoundment, in man-made ponds along Keeler Creek,

and in Spruce Lakes. Additional breeding habitat is likely to occur in temporal ponds and roadside ditches. The terrestrial habitat within the analysis area is considered upland foraging habitat.

Criteria used to compare potential impacts on the western toad and its habitat between alternatives include:

- known breeding/metamorphosis habitat impacted; and
- acres of upland foraging habitat disturbed.

Environmental Consequences

Direct and Indirect Effects

The 1978 EIS predicted localized adverse effects to the eight amphibians and reptiles potentially found within the Troy Mine Permit Area. The construction of the toe ponds created habitat that is now used by western toads. None of the alternatives would affect wetlands on NFSL, and no known natural wetlands occur in any of the previously disturbed sites proposed for reclamation activities. Proposed reclamation activities would follow other KNF riparian management guidelines, the Montana Streamside Management Act (HB 731), and INFISH guidelines.

Any natural wetlands and non-wetland waters of the U.S. under the tailings impoundment were destroyed when the impoundment was constructed. Four man-made toe ponds located along the western perimeter of the impoundment embankment contain impoundment seepage, natural groundwater, and runoff from the embankment face. The three northern ponds usually contain standing water and have developed into wetland habitat, becoming documented breeding sites for the western toad.

None of the alternatives would remove the toe ponds which are located on private property and which have documented western toad breeding activity. However, each alternative proposes different reclamation activities in the vicinity of the toe ponds that would affect western toads and their habitat.

The No Action Alternative does not directly address the long-term management of the toe ponds, and it would be expected that they would remain in their present form. The stockpiled lacustrine and volcanic ash-derived soil stored west of the toe ponds would be used for reclamation materials. The tailings impoundment surface east of the toe ponds would be covered with 18 inches of the stockpiled material and revegetated. No timing of activities has been identified. Should activities occur between May 1 and September 1, there is a potential risk of mortality of breeding adults and juveniles using the toe ponds by crushing from heavy equipment (Maxwell 2010). Reclamation activities would disturb toads using the toe ponds, increase mortality, negatively affect breeding success, and crush migrating juveniles as they leave the toe ponds during hauling operations. Use of the ponds as a breeding site would be expected to continue following the completion of the hauling operation. Also, once the area has been revegetated, the tailings impoundment would increase the amount of upland foraging habitat potentially available over time.

Under the Proposed Action the stockpiled reclamation materials would remain in place and the tailings impoundment would be covered with rocky glacial outwash gravels from a borrow site east of the tailings impoundment and then revegetated. The Proposed Action would connect the ponds with inter-pond channels with an armored outfall installed as a safety measure which could result in greater long-term stability of the toe ponds. Construction of these channels (especially if deep channels without shallow edges are created) could decrease the available breeding habitat for the western toad (Maxell 2010). No timing restriction on this activity has been identified, and no BMPs have been proposed to mitigate effects on the western toad. Revegetation of the tailings impoundment would increase the amount of upland foraging habitat potentially available over the long-term.

The Agency-Mitigated Alternative proposes to remove the majority of the stockpiled reclamation materials from west of the toe ponds, cover the impoundment with 18 inches of stockpiled soils, revegetate the tailings impoundment, and create inter-pond channels between the toe ponds. This alternative would inventory fish in the ponds, and remove non-native fish species in the toe ponds in coordination with FWP. The removal of non-native fish species could result in greater breeding success for western toads that may use the toe ponds to breed. The Agency-Mitigated Alternative would specify that all of the work in the toe ponds (i.e. creating the inter-pond channels, and fish surveys and removal) would occur between September 1st to March 1st or when juvenile western toads are no longer observed at breeding sites. Channel construction would ensure that a gradual slope between the pond and the new channel would maintain shallow habitat (Maxell 2010).

Under the Agency-Mitigated Alternative, no seasonal restrictions would be applied to soil hauling operations. BMPs would be used to limit sediment impacts to Lake Creek and the toe ponds and to minimize impacts to toads during soil hauling operations. Troy Mine, Inc. would be required to map out potential haul routes and install silt fences properly (*i.e.* bury the lower four inches of the fence material) around the entire perimeter of both the stockpile and haul routes. The silt fences would isolate these areas and restrict toad movement between the toe ponds and Lake Creek during reclamation operation, limiting the loss of toads from crushing by heavy equipment.

Western toads have been documented to have a high fidelity to breeding sites and could be expected to work their way around silt fences until they reach the toe ponds (Maxwell 2010). Culverts would be placed under the haul routes in two or more general locations: 1) between Lake Creek and the toe ponds; 2) between the toe ponds to allow toads to move between ponds; and 3) other areas identified during an agency field review. There would be no seasonal restriction on hauling operations.

The Agency-Mitigated Alternative would reduce the potential effect on western toads and their breeding/metamorphosis habitat at the toe ponds as well as limiting direct loss of individuals from heavy equipment traffic. The placement of the culverts would allow restricted, but continual, western toad movement between Lake Creek and the toe ponds during the breeding/metamorphosis period. Reclamation of the tailing impoundment surface would not negatively affect the western toad and would increase the amount of upland foraging habitat potentially available over the long-term.

The Proposed Action would plant wetland vegetation in a portion of the impoundment area. If a portion of the tailings impoundment were to convert to wetland habitat, the result could be a slight increase in available breeding/metamorphosis habitat. The No Action and Agency-Mitigated alternatives would not create wetland habitat in the tailings impoundment area.

The Proposed Action and Agency-Mitigated Alternative would maintain the decant ponds. During closure, the mine water quality may be suitable for western toads. While the amount of shallow water habitat would be limited, toads may occasionally use the ponds in the future.

None of the alternatives would result in the disturbance of existing upland foraging habitat because reclamation activities focus on revegetating currently disturbed areas. The Proposed Action and Agency-Mitigated Alternative would reclaim the disturbed areas to productive, native-species dominated plant communities and would increase the amount of upland foraging habitat potentially available in the analysis area. The No Action Alternative would not be as successful in establishing a native-species dominated plant community as described in **Section 3.16.2**.

None of the alternatives would affect the availability of coarse downed woody material or snags that may provide cover for toad movement and foraging. On NFSL, reclamation activities are confined to previously disturbed areas, and it is unlikely that they would impact toad burrows. The tailings embankment was previously reclaimed during operations, and it contains some rodent burrows which could serve as over-wintering habitat for toads. Under the No Action and Agency-Mitigated alternatives, the stockpiled material between Lake Creek and the toe ponds would be used to reclaim the tailings impoundment. Some roads would have to be developed on the embankment to allow access to the tailings surface. These roads would impact some existing rodent burrows. The roads would be reclaimed after hauling is completed.

Under the No Action Alternative and the Proposed Action, no additional reclamation work would occur on the undisturbed, previously reclaimed portion of the embankment. Under the Agency-Mitigated Alternative, some of the bare areas on the embankment with little or no soil and vegetation would be recovered with reclamation materials and planted and/or seeded. Some potential burrow sites would be lost. Placement of reclamation materials and revegetation would occur during the non-winter months. Mortality to burrowing toads would be expected to be low.

Reclamation of roads under the No Action and Agency-Mitigated alternatives could include some ditch work where toads may potentially be found. Incidental mortality to toads on these road prisms could occur. No over-wintering burrows would be anticipated in this compacted soil. Road reclamation work under any of the alternatives would not occur near known toad breeding sites and would not be likely to affect breeding habitat through sediment pulses that may enter nearby streams.

Cumulative Effects

Past actions in the analysis area have had both beneficial effects (breeding habitat created in man-made features such as holding ponds along Keeler Creek) and negative effects (timber harvest has decreased foraging habitat and impacted over-wintering habitat). Present and reasonably foreseeable future projects would include vegetation management measures that would protect riparian zones and

wetland areas and that would provide for adequate coarse, downed woody material. These measures would minimize potential effects on foraging and breeding/metamorphosis habitats. For example, less than one acre of breeding area was impacted by road repair work that occurred in 2008 and 2009 along Keeler Creek (KNF 2010). The project occurred after the toad breeding season, and the potential pulse of sedimentation into the creek was planned to be completed prior to the next breeding season. In addition, the majority of reasonably foreseeable future projects that propose winter harvest would not occur until the ground is frozen to at least one inch in depth during the winter, thus minimizing impacts to toad over-wintering habitat (KNF 2010).

None of the alternatives would result in adverse effects to western toad over -wintering, foraging, or to breeding/metamorphosis habitat on NFSL. All alternatives propose reclamation work on currently disturbed sites that are not likely providing habitat. Moreover, proposed revegetation activities for all of the alternatives could improve upland foraging habitat within the Troy Mine Permit Area for the western toad.

Cumulatively, private timber and federal timber harvest activities, road construction, real estate developments, and the creation of openings could all affect upland toad habitat. However, suitable habitat would still occur on NFSL. The No Action Alternative and the Proposed Action would be expected to negatively impact the western toad through mortality and habitat disturbance. The Proposed Action would also create inter-pond channels potentially reducing the amount of breeding habitat. Both alternatives could reduce breeding success at one of three known breeding sites in the analysis area.

The No Action Alternative and the Proposed Action, when considered in association with past, present, and reasonably foreseeable future activities on both public and private lands, would be expected to have adverse cumulative effects that would impact the western toad. The temporary reduction in habitat from these cumulative activities in combination with the long-term increase in habitat from the reclamation activities would not likely result in a declining population trend for this species because abundant habitat is still available adjacent to these areas.

The Agency-Mitigated Alternative would have the least impact when combined with other past, present, and reasonably forseeable future activities in the Lake Creek watershed. Movement to and between the toe ponds during the breeding season would be restricted to the use of culverts until the silt fences were removed. However, there would be no permanent loss of breeding habitat, mortality risk due to hauling operations would be reduced, and there would be the potential for an increased amount of upland habitat following reclamation of the site.

Regulatory Compliance

Forest Plan Consistency: The Agency-Mitigated Alternative meets Forest Plan direction as applicable to the western toad and sensitive species (Pages II-1 #6, #7, II-23). The No Action Alternative and the Proposed Action would not meet Forest Plan direction.

The Agency-Mitigated Alternative would be consistent with Forest Plan riparian standards and guidelines (FP Vol. 1 II-28 thru 33) as amended by INFISH.

All alternatives meet Forest Plan standards for snags and down wood (FP II-1 #8; II-22 and 23 and Appendix 16).

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow NFMA direction to provide diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative would result in a determination of "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* to the population or species of the western toad. This finding is based on the following considerations: 1) no loss of currently available known breeding habitat; 2) temporary loss of upland movement areas due to the removal of stockpiled reclamation materials during hauling operations; 3) the risk of direct mortality during tailings impoundment and road reclamation activities; and 4) suitable habitat would remain in the analysis area and would be distributed across the KNF. Actions as described for the tailings impoundment (specifically the toe ponds) on private property would negatively impact the western toad and its breeding/metamorphosis habitat within the analysis area.

The Proposed Action would result in a determination of "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* to the population or species of the western toad. This finding is based on the following considerations: 1) potential loss of currently available known breeding habitat with the creation of inter-pond channels; 2) retention of reclamation material stockpiles and upland movement areas within the tailings impoundment area; 3) the risk of direct mortality during tailing impoundment and road reclamation activities; and 4) suitable habitat would remain in the analysis area and would be distributed across KNF. Actions as described for the tailings impoundment (specifically the toe ponds) on private property would negatively impact the western toad and its breeding/metamorphosis habitat within the analysis area.

The Agency-Mitigated Alternative would result in a determination of "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* to the population or species of the western toad. This finding is based on the following considerations: 1) no loss of currently available known breeding habitat on NFSL and minimization of habitat loss at the toe ponds; 2) timing restrictions in place to avoid the breeding/metamorphosis period on activities occurring in the toe ponds; 3) restricted movement areas during hauling operations and reclamation activities; 4) reduced risk of direct mortality during tailing impoundment and road reclamation activities; and 5) suitable habitat would remain in the analysis area and would be distributed across KNF. Actions as described for the tailings impoundment (specifically the toe ponds) on private property would temporarily impact the western toad and its breeding/metamorphosis habitat within the analysis area.

3.18.5.11 Wolverine

Wolverine Background

Wolverine population ecology, biology, habitat description, and relationships are described in Banci (1994) and Butts (1992). The above information is incorporated by reference. Wolverine occurrence data originate from recent USFS wildlife observation records, the NRIS database, and from other agencies (FWP). The analysis area for direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

Wolverine observation and monitoring data indicate that one sighting occurred in 2002 and that tracks were seen in 2006 in the vicinity of Spar Lake. Johnson (1999) shows wolverine presence confirmed in seven of the eight planning units on the KNF.

Ruediger (1994) shows the KNF as a primary habitat area for wolverine. Except for denning habitat, wolverines are habitat generalists (Heinz 1996). Modeling of wolverine denning habitat identified 1,784 acres of potential denning habitat in the analysis area, with another 59,329 acres considered as foraging habitat (Johnson 2004b). Johnson (1999) modeled about 12,000 acres of wolverine denning habitat on the KNF and 563,045 acres of foraging habitat.

Environmental Consequences

Direct and Indirect Effects

None of the alternatives would include reclamation activities during the sensitive winter period when wolverines might be denning in deep snows.

Wolverine foraging may be disturbed by human activity and noise. Reclamation activity for all alternatives would take place over approximately two to three years and would require the use of heavy equipment comparable to current mining activities. Reclamation activities would occur in the same locations as current mining activities and would not expand the area of activity into currently undisturbed locations. The effects of road reclamation and use of existing roads for other reclamation activities (*e.g.,* removal of structures, mining equipment, recontouring of slopes, etc.) would not be expected to increase disturbances on wolverines in areas currently receiving regular use from mining activities. None of the alternatives proposes to increase motorized access. All roads identified as restricted within the Troy Mine Permit Area are currently restricted to all motorized activities year -long, including snow vehicles.

None of the reclamation alternatives would include timber harvest activities. Reclamation alternatives would include revegetation of disturbed areas and could increase foraging habitat in the long-term.

Cumulative Effects

Because there would be no direct or indirect effect on wolverine denning habitat from any of the reclamation alternatives, there would be no cumulative effects. Accordingly, there would be no impact on the viability of the wolverine at the Forest scale.

Throughout the analysis area, past, present, and reasonably foreseeable future projects include timber management. The noise from these activities may disturb wolverines, and the resulting changes in vegetative structure may affect available forage habitat. Recreational use such as snowmobile use in areas open to winter travel would continue to affect wolverines from the noise of the activity. Prescribed burning would stimulate forage for prey species the wolverine feeds on. None of the reclamation alternatives would affect the effectiveness of current fire management in the analysis area. Therefore, there would be no cumulative effect on forage habitat.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction for sensitive species (Pages, II -1 #6, #7, II-23).

NFMA: The Proposed Action and Agency-Mitigated Alternative would follow NFMA direction to provide for diverse populations of plant and animal communities by complying with Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all result in a determination of "*May Impact Individuals or their Habitat, But Will Not Likely Contribute to a Trend Towards Federal Listing or Cause a Loss of Species Viability"* to the population or species of the wolverine. This determination is based on the following considerations: 1) noise from the reclamation activities may disturb or cause wolverines to temporarily avoid the area; 2) disturbed areas would be revegetated which would encourage the growth of vegetation that the wolverine's prey base depends upon; 3) no winter denning habitat would be affected by reclamation work; and 4) reclamation activities in elevations above 5,000 feet would not occur during the winter denning season.

3.18.6 Management Indicator Species (MIS)

Federal laws and direction applicable to management indicator species (MIS) include the NFMA (1976) and Forest Service Manual (FSM) 2620. The NFMA specifies that NFSL be managed to provide for diversity of plant and animal communities to meet overall multiple -use objectives. The "specific land area" (scale) for providing diversity is established in the framework as the area covered by a Forest Plan. The KNF Forest Plan goal (Forest Plan p. II-1 #7) is to "maintain diverse age classes of vegetation for viable populations of all existing native, vertebrate, wildlife species… and in sufficient quality and quantity to maintain habitat diversity representative of existing conditions." In addition, the KNF Forest Plan includes this wildlife standard relevant to MIS: "The maintenance of viable populations of existing native and desirable non-native vertebrate species, as monitored through indicator species, will be attained through the maintenance of a diversity of plant communities and habitats" (Forest Plan Vol. 1 p.II-22).

Based on the direction found in the NFMA, Appendix 12 of the Forest Plan identifies MIS as species which are used to represent particular habitats or habitat complexes. Each MIS represents a group of species that share common habitat components which are required for sustained growth and successful

reproduction. Managing the landscape to benefit a specific MIS population would be expected to have corresponding favorable effects on many other wildlife species which they represent. MIS are listed in **Table 3-26**.

Other federal resource laws that provide impetus for managing for viable wildlife populations on public land include the National Wilderness Preservation Act (1964), NEPA (1969), and ESA (1973). Information from landscape assessments conducted in the Columbia River Basin was also reviewed.

Table 3-26. KNF Management Indicator Species

Species	Habitat Represented	Comments
Grizzly Bear (*Ursus arctos horribilis)*	General Forest	See Threatened and Endangered Species Section (**Section 3.18.4.1)**
Gray Wolf (*Canis lupus*)	General Forest	See Threatened and Endangered Species Section (**Section 3.18.4.3**)
Elk *(Cervus elaphus*)	General Forest	See discussion below in MIS section (**Section 3.18.6.1**)
Whitetail Deer (*Odocoileus virginianus*)	General Forest	Represents similar habitat as elk. The elk was chosen for analysis based on criteria described below in the elk MIS section; therefore, whitetail deer will not be considered further.
Bald Eagle (*Haliaeetus leucocephalus*)	Rivers and Lakes	See Sensitive Species Section (**Section 3.18.5.1**)
Mountain Goat (*Oreamnos americanus*)	Alpine	See discussion below in MIS section (**Section 3.18.6.2**)
Peregrine Falcon (*Falco peregrinus*)	Cliffs	See Sensitive Species Section (**Section 3.18.5.8**)
Pileated Woodpecker (*Dryocopus pileatus*)	Snags, Old Growth	See discussion below in MIS section (**Section 3.18.6.3**)

Elk and whitetail deer are two MIS species that represent similar habitat. Summerfield (1991) recommends determining which big game species will be featured in a particular area because winter requirements differ. The following criteria were used to identify the elk as the MIS for general forest habitat in this EIS: 1) Forest Plan direction; 2) the biological potential of the area; 3) state wildlife management objectives; 4) public comments during scoping; and 5) the information contained within the Kootenai Conservation Plan which established management emphasis designations for elk by planning subunit (Johnson 2004a, Appendix H). The analysis area is the Lake Creek watershed which is contained within two PSUs. The Spar PSU has a high emphasis for elk, and the Lake PSU has a moderate emphasis for elk.

3.18.6.1 Elk

Elk Background

Elk population ecology, biology, habitat description, and relationships are described in Murie (1979) and in Toweill and Thomas (2002). The above information is incorporated by reference. Elk population and harvest data come primarily from FWP data. Additional information used is from recent USFS wildlife observation records and from the NRIS database.

Affected Environment

The analysis area for direct, indirect, and cumulative effects to individuals and their habitat is the Lake Creek watershed. The boundary for determining population trends towards viability is FWP big game hunting district #104 (includes both PSUs) and the KNF. The elk population in the hunting district is stable (Brown 2008).

Components typically analyzed for elk include: cover/forage ratios, thermal cover, opening sizes, movement areas, HE and ORD, security, and key habitat components (wallows, wet meadows, and bogs). No vegetation management would occur under any of the alternatives. Therefore, the components of cover/forage ratios, thermal cover or opening sizes, and vegetation management in movement areas will not be further analyzed in this document.

The HE of an area refers to the percentage of habitat that is usable by elk outside of the hunting season and that does not contain open roads. Numerous studies have shown that there is a strong negative correlation between elk use of an area and the density of open roads, even if those roads are only lightly traveled (Frederick 1991).

Management Area 12 (MA 12, non-winter big game habitat) and grizzly bear management both have the most restrictive ORD standards in the Forest Plan at ≤ 0.75 mi/mi^2. This road density translates into a habitat effectiveness value of 68 percent (Lyon 1984). If ORD for the BMU(s) in an analysis area meets the grizzly standard, it also achieves big game management recommendations for the analysis area (Schrenk 1995). Open road density for BMU 3, where project activities would occur, is currently better than Forest Plan standards at 0.57 mi/mi^2 which translates into an HE value of 74 percent.

Security areas are defined as areas that are larger than 250 contiguous acres in size and more than one half mile from an open road (Hillis *et al.* 1991). These areas offer elk refuge through reduced

vulnerability during the hunting season and can greatly influence the age structure and composition of a herd.

The Forest Plan has no standard for security. A panel of state and federal wildlife biologists convened in 1996 and identified security as an important component in elk habitat and that the Hillis *et al.* (1991) method would be used to calculate it (Johnson 2004a, Appendix H-B). This method recommends a minimum of 30 percent of an elk's fall use area be maintained as security habitat. Since elk use in the fall could be any place within the analysis area, the 30 percent minimum is measured against the NFSL acres in the analysis area. Within the analysis area, secure habitat is currently at 59 percent (KNF 2010).

The Forest Plan directs that wet meadows, bogs, and elk wallows will be avoided when building roads. When these previously unidentified areas are located, they are mapped and managed as riparian areas. Management would also follow other KNF riparian management guidelines, Montana Streamside Management Act (HB 731), and INFISH guidelines.

Environmental Consequences

Direct and Indirect Effects

Reclamation activities on the private lands at the tailings impoundment area would create disturbances, however, since mining activities would cease as reclamation activities begin there would be no overall change in on elk disturbance levels.

There would be no timber harvest associated with any of the alternatives, and there would be no new areas disturbed. All reclamation alternatives would revegetate areas disturbed by mining activities. As newly revegetated areas are established, they may provide productive foraging habitat initially, but as the forest cover matures, the quality of the forage would decline.

All three alternatives propose to keep NFSR 4626 gated at the mill site and restricted to motorized traffic above the mill site towards Mt. Vernon. All other roads listed in **Table 2-1** (except NFSR 9003) are either behind gates or on patented and private land and would remain restricted to motorized traffic. Although NFSR 9003 is an open road, the effects of motorized use on this road are negligible due to the proximity to NSFR 4626. The Proposed Action would keep this road in its current condition. The No Action and Agency-Mitigated alternatives would reclaim NFSR 9003.

Both HE and security habitat are based on open roads present within the analysis area. Therefore, no decrease in HE and security habitat would be expected during the Troy Mine reclamation project because no new open roads would be built and reclamation activities would generally occur in the same areas as present mining activities. The one exception is NFSR 4628 which does not receive regular mining use beyond NFSR 4628C which accesses the South Adit. The No Action and Agency-Mitigated alternatives propose stabilization work on this portion of road, and any elk present may experience short-term disturbance as this work is carried out.

None of the alternatives propose activities within currently undisturbed riparian habitat and would follow other KNF riparian management guidelines, the Montana Streamside Management Act (HB 731),

and INFISH guidelines. In addition, none of the alternatives would be expected to impact any unknown special habitat features for elk such as wetlands because these activities would occur in previously disturbed areas.

Cumulative Effects

Past harvest and natural disturbances have provided a variety of vegetation age classes and successional stages across the analysis area, and have succeeded in diversifying the landscape. In some cases, past timber harvests and fires provided habitat conditions favorable for big game such as elk. None of the reclamation alternatives would affect fire suppression effectiveness either.

Open road densities have declined in the past several years as a result of restricting/reclaiming roads through decisions intended to facilitate grizzly bear recovery. Because the Sparring Bulls project would maintain HE at 74 percent and only decrease security habitat from 59 to 56 percent during project actvities, both percentages would remain better than standards (KNF 2010). None of the alternatives would increase motorized access during reclamation of the Troy Mine Permit Area and therefore would not have a negative cumulative effect on elk HE or security habitat.

Basic road maintenance, pre-commercial thinning, mushroom picking, prescribed burning, timber hauling, wildlife habitat improvement projects, and various recreational uses are additional activities that have occurred and would continue to occur within the analysis area. Potential activities that have been restricted beyond the mill/office site during mining activities may increase slightly, but they would likely not extend far beyond the existing gate location because the road would remain restricted to motorized access following completion of reclamation activities. These activities are generally not considered to have adverse impacts on wildlife species but they may incidentally affect wildlife use within some areas on a temporary basis. Overall, they are not likely to affect the viability of this species.

With respect to patented lands, there are no known non-mining related activities proposed at the top of Mt. Vernon. Therefore, no cumulative effects on elk are expected for this parcel of patented property as part of any of the alternatives. Due to the number of roads and homes located around the tailings impoundment area, current conditions for the elk are not expected to change due to reclamation activities. Reclamation activities are not expected to contribute any additional direct effects in the tailings impoundment area, and therefore, there would be no cumulative effect on elk disturbance on these private lands.

Hunter access to Mt. Vernon is already available from the south via NSFR 4628 and from the west via trail #513. Once mining operations cease and reclamation has been completed, use by hunters to access Mt. Vernon from the north side may increase. However, it will continue to be restricted to non-motorized access and would maintain current security habitat within the Troy Mine Permit Area.

All alternatives would establish new vegetation areas through reclamation activities that could provide some productive forage habitat for elk. All of the activities listed above, including reclamation, may disturb elk or cause them to temporarily avoid the area until human actions are finished. However, reclamation alternatives would not create a cumulative effect on potential elk disturbance.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction for big game species and MIS (Pages: II-1 #3, II-2 #12, II-23-23).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide for diverse populations of plant and animal communities by following Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Elk Management Plan Consistency: The reclamation project is located in the Lower Clark Fork Elk Management Unit which is identified in the FWP Statewide Elk Management Plan. The proposed project is consistent with that document.

Statement of Findings

Based on the analysis for elk, the other general forest habitat indicators, and the KNF Conservation Plan (Johnson 2004a), habitat for general forest species should provide sufficient quality and quantity of the diverse age classes of vegetation needed for viable populations. Because sufficient general forest habitat is available, the populations of species using that habitat should remain viable.

3.18.6.2 Mountain Goat

Mountain Goat Background

Detailed mountain goat, ecology, biology, habitat use, status, and conservation are described and summarized in Brandborg (1955) and Joslin (1980). That information is incorporated by reference. Mountain goat occurrence data come from USFS wildlife observation records, the NRIS database, and from other agencies (FWP).

The analysis area for project impacts to individuals and their habitat is the Lake Creek watershed. The boundary for cumulative effects and determining trend and contribution toward viability is FWP Mountain Goat hunting district #100, district #101, and the KNF.

Affected Environment

Alpine habitat is found within the Spar and Lake PSUs. Wildlife observation records show mountain goats are known to use the suitable habitat in these subunits. FWP records for the Mountain Goat hunting district #101 (this district includes the Troy Mine Permit Area) indicate a stable population (Brown 2008).

Harvest records from the 1999 hunting season suggest that a minimum of 40 - 50 mountain goats, currently inhabit the southern portion of the Spar PSU (KNF 2001). These goats are commonly seen along the ridgeline from Spar Peak to the spires east of Mt. Vernon (NRIS), the ridgeline over Little Spar Lake from Spar Peak to Savage Mountain, and the rocky ridgelines near Sawtooth Mountain (KNF 2001). The Mt. Vernon area is also known both as a winter range and as an important spring kidding area (KNF 2001).

Environmental Consequences

Direct and Indirect Effects

The tailings impoundment area is not within mountain goat, habitat and reclamation activities on these private lands would have no direct effects on mountain goat,.

Most of the proposed activities for all the alternatives would take place in areas that currently receive regular use during mining operations. The one exception is NFSR 4628 which does not receive regular mining use beyond NFSR 4628C and accesses the South Adit. The No Action and Agency-Mitigated alternatives propose road storage work along this segment of NFSR. Mt. Vernon and the ridgeline to the west serve as a travel corridor between the spires area and Spar Peak, both of which have known mountain goat ,activity. Disturbance and displacement of mountain goats, would be expected from the road storage activities south of the more regularly used mining operation sites.

Reclamation activities are expected to occur over an approximately two to three year time frame during the snow free period, generally from April to September. For most of the Troy Mine Permit Area, this timeframe would not change the current condition experienced by mountain goats,. The Agency-Mitigated Alternative would specify that road work on the segment of NFSR 4628 from the junction with NFSR 4628C to Ross Creek would take place between April 1 and June 15 to permit spring forage opportunities for the grizzly bear. This timing would also benefit the mountain goat ,which may still be using lower elevation sites during the early spring for forage and kidding areas. The No Action Alternative and the Proposed Action would not include seasonal restrictions for any proposed road work.

None of the alternatives propose to create new roads or to increase motorized access over the top of Mt. Vernon. All roads identified as restricted within the Troy Mine Permit Area are all currently restricted to all motorized activities year-long, including snow vehicles. The Proposed Action would not reclaim any of the existing roads. However, both the No Action and Agency-Mitigated alternatives propose to reclaim several roads within the Troy Mine Permit Area. Reclamation of roads near the top of Mt. Vernon, along with the end of activities related to the current mining operations, would likely enhance goat habitat security by reducing current disturbances from roads.

All of the alternatives would occur within and along already disturbed sites, such as roads; therefore, no vegetation manipulation would result. The Proposed Action and Agency-Mitigated Alternative include revegetating disturbed sites with native plant species mixes and would apply different plant species compositions to different habitat types along an elevational gradient. These alternatives would result in recovery of forested vegetation at a faster rate than the No Action Alternative, providing greater benefits to mountain goat habitat. In the No Action Alternative, the plant species mix proposed for reclamation activities includes non-native species and does not account for differences in habitat type such as elevation. Therefore, the No Action Alternative would have limited benefits to mountain goat, habitat.

Cumulative Effects

Past, present, and reasonably foreseeable future actions include past harvest and natural disturbances which have provided a variety of vegetation age classes and successional stages across the analysis area, diversifying the landscape. In some cases, past timber harvests and fires provided habitat conditions favorable for forage for big game species.

Open road densities have declined in the past several years because roads have been restricted/reclaimed through decisions intended to facilitate grizzly bear recovery. None of the alternatives proposes to increase motorized access during reclamation of the Troy Mine Permit Area and therefore would not create a cumulative effect to mountain goat, disturbance or security related to roads.

Basic road maintenance, pre-commercial thinning, mushroom picking, prescribed burning, timber hauling, wildlife habitat improvement projects, and various recreational uses are all additional activities that would continue to occur within the analysis area. Potential activities that are currently restricted beyond the mill/office site during mine operation may increase slightly, but likely would not extend far beyond the existing gate location because the road would remain restricted to motorized access after completion of reclamation activities. Moreover, these activities are generally not considered to have adverse impacts on wildlife species but may incidentally affect wildlife use within some areas on a temporary basis. Overall, they are not likely to affect the viability of the species.

With respect to patented lands, there are no known non-mining related activities proposed at the top of Mt. Vernon. Therefore, no cumulative effects on goats are expected on this parcel of patented property as part of any alternative. The tailings impoundment area is not within mountain goat, habitat, and therefore, reclamation activities that would occur in this area would not affect the goat. Also, mining activities would cease as reclamation activities begin. There would be no cumulative effect on mountain goat, disturbance from reclamation as both activities would not be occurring at the same time.

Hunter access to Mt. Vernon already occurs from the south via NSFR 4628 and the west via trail #513. Once mining operations cease and reclamation has been completed, use by hunters to access Mt. Vernon from the north side may increase. However, it would continue to be restricted to non-motorized access and would maintain current security areas within the Troy Mine Permit Area.

All of these activities listed above, including reclamation, might disturb a mountain goat ,or cause it to temporarily avoid the area until human actions are finished. The reclamation alternatives would not create a cumulative effect on potential mountain goat, disturbance or mortality.

Regulatory Compliance

Forest Plan Consistency: All alternatives meet Forest Plan direction for big game species and MIS (Pages: II-1 #3, II-2 #12, and II-23-23).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide diverse populations of plant and animal communities by following Forest Plan standards and

guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

None of the alternatives would contribute any cumulative effects to the mountain goat,. None of the alternatives would increase motorized access or disturb new lands in the alpine habitat of Mt. Vernon. The No Action and Agency-Mitigated alternatives would also reclaim several roads, improving the un-roaded nature and security of Mt. Vernon for mountain goats,. The available habitat for alpine species would provide sufficient quality and quantity of the diverse age classes of vegetation needed for viable populations.

3.18.6.3 Pileated Woodpecker

Pileated Woodpecker Background

Pileated woodpecker population ecology, biology, habitat description, and relationships identified by research for the northern Rocky Mountains are described in McClelland (1979, 1977), McClelland and McClelland (1999), McClelland *et al.* (1979), and in Warren (1990). This information is incorporated by reference. Additional research conducted in the Pacific and Inland Northwest that may be relevant includes Bull (1975, 1980, 1987), Bull and Holthausen (1993), Bull and Jackson (1995), Bull and Meslow (1977), Bull *et al.* (1992), Jackman (1974), Mannan (1977), Mellen (1987), Mellen *et al.* (1992), and Thomas (1979).

Pileated woodpecker occurrence data come from recent USFS wildlife observation records, the Region One Landbird Monitoring Program (Avian Science Center, Univ. of Montana), and from the NRIS database. The pileated woodpecker is the indicator species for old growth and snag habitat on the KNF. Habitat for this species has been modeled by using all designated and undesignated old growth habitat and old growth replacement habitat, which has currently been mapped for the KNF (2010).

The PPI for the woodpeckers on the KNF has been calculated by Johnson (2003). The procedure used is based on the assumption that all currently mapped effective and replacement old growth habitat (both designated and undesignated) is providing suitable habitat to support nesting territories. This assumption also includes the premise that all suitable habitat is spatially distributed across the landscape in a pattern that can be incorporated into individual nesting territories. The procedure was based on territory sizes of pileated woodpeckers as described in research by McClelland (1977) for northwest Montana, and by Thomas (1979) and Bull and Holthausen (1993) for northeast Oregon. For the PPI analysis on the KNF (Johnson 2003), replacement old growth habitat was defined as habitat that had some old growth characteristics but did not meet the Forest Plan (1987) definition of old growth, or the definition found in Green *et al.* (1992 errata corrected 2004).

Effective old growth habitat was modeled as supporting one nesting pair per 600 acres, with replacement old growth habitat supporting one nesting pair per 1000 acres. The difference in territory size is based on research that suggests that higher quality habitat can support a breeding pair with fewer acres (McClelland 1977; Bull and Holthausen 1993). Also, allowing for larger territory sizes when habitat

becomes fragmented appears reasonable, because territory sizes up to 2,600 acres have been reported for western Oregon (Mellen *et al.* 1992). Of course, there are numerous and complex interrelated factors that influence the actual size of the home range territory (McClelland 1977).

Potential effects of the reclamation alternatives are primarily evaluated on the basis of potential impacts to designated and undesignated old growth habitat.

The analysis area for direct, indirect, and cumulative impacts to individuals and their habitat is the Lake Creek watershed. The boundary for determining trends towards viability is the KNF.

Affected Environment

The modeled minimum PPI for the pileated woodpecker on the Kootenai National Forest is 425 nesting or breeding pairs (Johnson 2003). It is within the calculated historic range of variation for the minimum PPI of 335 to 554 breeding pairs (Johnson 1999).

Old growth characteristics within the analysis area are described in **Section 3.16.4**. Approximately 6,045 acres of effective old growth habitat (both designated and undesignated) and about 3,848 acres of replacement habitat (both designated and undesignated) are found within the analysis area. Existing pileated woodpecker nesting territories would likely encompass a large portion of this old growth habitat. Based solely on the quantity of old growth habitat available, the analysis area could support about 34 nesting territories (PPI) (KNF 2010). A small portion of this old growth habitat is found within the Troy Mine Permit Area (88 acres, representing 3.3 percent of permit area) (**Section 3.10.4.3**).

There are currently 9,893 acres of old growth on federal land being maintained for old growth dependent species (*i.e.*, pileated woodpecker) within the Spar PSU (KNF 2010). Distribution is good within the analysis area and provides adequate habitat for both plant and animal species needing the old growth ecosystem. The Spar PSU also contains habitat for obligate cavity nesters, such as the pileated woodpecker (approximately 75 percent of the planning subunit) (KNF 2010).

Breeding bird point count surveys have been conducted on the KNF since 1994. In this program, transects consisting of multiple bird monitoring points are set up within a wide range of habitats which are distributed geographically across the KNF. This survey technique is not specifically designed to census woodpecker species, although all migratory and resident bird species detected by specialists trained in bird identification are recorded at each point on each transect. The rate of detection can vary greatly from year to year, especially for a wide-ranging species like the pileated woodpecker that may or may not be anywhere near a given point on a given day. During the 1994-2002 period, the pileated woodpecker was tallied 204 times at the 2,638 individual points surveyed (USFS 2003).

Environmental Consequences

Direct and Indirect Effects

There is a limited quantity of old growth habitat located within the Troy Mine Permit Area primarily along creek drainages. Reclamation activities are not expected to occur in or to impact these areas of old growth habitat potentially used by pileated woodpeckers. Also, woodpeckers using these stands are

tolerant of current mining operations and would experience similar activities from the reclamation work. Thus, there would be no effects to the woodpeckers.

Because no alternatives propose impacts to old growth stands within the Spar and Lake PSUs or with the Troy Mine Permit Area, there would be no change in the quantity of old growth forest habitat for pileated woodpeckers, and the analysis area would continue to meet Forest Plan standards for old growth. All alternatives would re-establish forested vegetation within the Troy Mine Permit Area. Re-establishment of forested cover would create the possibility of old growth within the mine permit area on NFSL after 150+ years. In this sense, the alternatives may be considered an improvement over the existing condition, though the chance of old growth establishment on this site cannot be determined with any accuracy.

Natural successional processes would continue throughout existing old growth stands and throughout stands containing old growth attributes used by pileated woodpeckers. Habitat would be provided for pileated woodpecker nesting pairs that find suitable feeding and breeding conditions provided by the structural features and overall environment within these stands. There would be no change in PPI in the analysis area.

Cumulative Effects

None of the three alternatives would have any effect on old growth habitat used by pileated woodpeckers and, therefore, would result in no cumulative effects to old growth.

Past, present, and reasonably foreseeable future projects are not expected to impact the pileated woodpecker. Timber management activities and watershed improvement work anticipated in the analysis area would not affect the pileated woodpecker (KNF 2010). Therefore, there would be no cumulative effects on pileated woodpecker from any of the reclamation alternatives.

Regulatory Compliance

Forest Plan Consistency: All alternatives are consistent with Forest Plan direction applicable to the pileated woodpecker and MIS (Pages: II-1 #7, #8, and II-22-23).

All alternatives are consistent with Forest Plan direction for old growth below 5,500 feet (FP Vol. 1 II -1 #7; II- 7; II-22 and 23; Appendix 17; and Kootenai FSM 2432.22 Supplement No. 85).

All alternatives meet Forest Plan standards for snags and down wood (FP II -1 #8; II-22-23 and Appendix 16).

NFMA: The Proposed Action and Agency-Mitigated Alternative would comply with NFMA direction to provide diverse populations of plant and animal communities by following Forest Plan standards and guidelines (Johnson 2004a). The No Action Alternative would not comply because of its use of introduced grasses and forbs.

Statement of Findings

The No Action Alternative, Proposed Action, and Agency-Mitigated Alternative would all have "*No Impact"* on the pileated woodpecker. Based on the analysis for pileated woodpecker, designated and undesignated old growth habitat, and old growth replacement habitat within the analysis area, none of the alternatives would have an impact on snag and old growth habitat.

3.18.7 Migratory Birds

Migratory birds are protected under the Migratory Bird Treaty Act. Executive Order #13186 (January 10, 2001) "Responsibilities of Federal Agencies to Protect Migratory Birds" was issued to support the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Acts, the Fish and Wildlife Coordination Act, the Endangered Species Act, and the National Environmental Policy Act. This order requires federal actions on migratory birds to be part of the environmental analysis process. On January 17, 2001, the USFS and the USFWS signed a Memorandum of Understanding (MOU) to complement this Executive Order, and another MOU was signed on February 23, 2009 between the USFS and the USFWS.

NFMA requires that Forest plans "provide for the diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives."

Affected Environment

Neotropical migratory birds are those bird species that migrate to more northerly latitudes to breed on the KNF each summer. Each fall, these species migrate south for the winter months to avoid harsh weather and to find more abundant food sources. Of the approximately 205 bird species known to occur on KNF as breeders, migrants, winter visitors, or as transients, about 70 species could be classified as neotropical migratory land birds.

Environmental Consequences

Responses of migratory birds to reclamation activities would depend upon their individual habitat preferences and needs. None of the alternatives would disturb new areas but they would revegetate existing disturbed areas. Some species prefer forest cover and closed canopy habitats (*e.g.,* brown creeper, golden-crowned kinglet, hermit thrush), and others prefer more open grass, forb, and shrub habitats (*e.g.,* American kestrel, calliope hummingbird, chipping sparrow). Still other bird species prefer to use edge habitats along the boundaries of forested and more open areas (*e.g.,* dark-eyed junco, western tanager, Townsend's warbler). Over time, the reclamation activities would return disturbed areas to a more forested cover type which would also reduce the existing distinct edge habitats that occur within the Troy Mine Permit Area.

MIS selected to represent those species that use general forest habitat conditions would also represent the habitat needs for migratory birds. Maintaining suitable habitat conditions for general forest MIS species would also maintain sufficient habitat for neotropical migratory land birds.

Regulatory Compliance

There are no specific goals or standards for migratory land birds in the Forest Plan. However, it does contain the goal to "maintain diverse age classes of vegetation for viable populations of all existing

native, vertebrate, wildlife species" (Forest Plan, Vol. 1, II-1, goal #7). All alternatives would be consistent with the Forest Plan because a wide range of successional habitats would continue to be available. The alternatives would be in compliance with the Executive Order titled "Responsibilities of Federal Agencies to Protect Migratory Birds." In addition, as habitat for MIS species would be maintained in the analysis area and across the KNF, their habitat would contribute to the maintenance of habitat and populations of neotropical migratory bird species.

3.19 Other Required Disclosures

3.19.1 Environmental Justice

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority and Low Income Populations requires federal agencies address any potential for disproportionately high or adverse effects to these populations. The analysis of Environmental Justice in this EIS follows the CEQ's guidance on Environmental Justice, (CEQ 1997), the EPA's guidance on Environmental Justice (EPA 1998, 1999) and the U.S. Department of Agriculture's regulation on Environmental Justice (USDA 1997b). Using these guidance documents, the following steps were taken: identification of minority and low-income populations within the analysis area, assessment of effects of the project alternatives on these populations, and determination if the effects would be disproportionately high and adverse. The U.S. Department of Agriculture's regulation indicates an effect on a minority or a low-income population is disproportionately high and adverse if the adverse effect is appreciably more severe or greater in magnitude than the adverse effect that will be suffered by the non-minority population and/or non-low-income population.

See **Section 3.12** for a complete analysis of demographic conditions within the analysis area. Findings of the analysis in **Section 3.12** indicate that minority populations within the analysis area (Lincoln County) are smaller than those of the State of Montana and the U.S. as a whole. Minority populations include American Indians, and the analysis area is located within lands encompassed by the Hellgate Treaty of 1855 (see Section 3.5, American Indian Consultation). There is a higher percentage of the population within the analysis area that is below the poverty line than in the State of Montana as a whole.

None of the proposed reclamation alternatives would have adverse effects on minorities or low-income populations. All proposed reclamation alternatives would result in improved access to public lands for non-motorized recreational use, which would benefit all populations and would not be a disproportionately high or adverse effect on any minority or low-income population.

3.19.2 Important Farmland, Rangeland, and Forest Lands

The Farmland Protection Policy Act and USDA Departmental Regulation No. 9500-3 provide for the protection of important farmland, prime forest land, and prime rangeland. The USDA regulation, 7 CFR Part 658, implements the Farmland Protection Policy Act. Lands administered by the Forest Service in the analysis area do not include any important farmlands or prime range lands, and the definition of prime forest land does not apply to lands within the KNF. The proposed reclamation alternatives would return public lands to some level of recreational use, which is a key goal of the KNF Forest Plan.

Reclamation would also return private lands to timber production, wildlife habitat, and recreational land uses.

3.19.3 Energy Requirements and Conservation Potential

All of the proposed reclamation alternatives would require less energy than existing operations at the Troy Mine. The number of workers commuting to the area and heavy equipment use during implementation of the proposed reclamation alternatives would be less than existing operations, requiring less energy. Once reclamation activities are completed, there would be substantially less energy use than current operations, as the only long-term activities would entail water quality monitoring that only require a small number of trips into the analysis area each year. Energy requirements for these long-term monitoring activities would be insignificant. Petroleum fuel use would be similar among the proposed reclamation alternatives, and would be minimal following completion of reclamation activities.

3.19.4 Urban Quality and the Design of the Built Environment

While the analysis area is not urban, the scenic quality has been altered. With implementation of the proposed reclamation alternatives, existing mine infrastructure would be demolished and removed, adits would be sealed, and disturbed areas would be regraded, covered with growth media, and revegetated. Previously disturbed, non-scenic mining lands would be returned to a condition more consistent with the surrounding forest lands.

3.19.5 Irreversible and Irretrievable Commitment of Resources

An irreversible commitment of resources refers to the loss of future options. It applies primarily to non-renewable resources, such as minerals or cultural resources, and to those factors that are renewable only over long time spans, such as soil productivity. Examples of an irreversible commitment of resources include extinction of a threatened or endangered species, disturbance of a cultural site, loss of land production, and use of natural resources. Irretrievable commitments represent the loss of production, harvest, or use of renewable resources. For example, production or loss of agricultural lands would be an irretrievable commitment of resources, but may not be irreversible.

Implementation of the proposed reclamation alternatives would result in the irretrievable commitment of fossil fuels, including diesel and gasoline fuels consumed by construction equipment.

Chapter 4 Consultation and Coordination

This chapter provides a list of those persons responsible for preparation of the EIS. It also provides a list of agencies, organizations, and persons to whom copies of the draft EIS were distributed.

4.1 Preparers and Contributors

4.1.1 Forest Service

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Gautreaux, Russ	Minerals Staff	B.S., Natural Resource Management	30 years
Harlow, Dick	IDT District Coordinator	B.S., Forestry	31 years
Hauge, Kristen	Archaeologist	B.A., Anthropology	20 years
Kroeger, Wayne	Transportation Planner	Associate Degree Engineering/Drafting	34 years
Lacklen, Bobbie	IDT Project Coordinator/Geologist	B.A., Geology	25 years
McDougall, Leslie	Weeds, Vegetation, Old Growth	B.S., Forestry	24 years
McKay, John	Contract Geologist	B.A., Geology	30 years
Mohar, Kathy	Environmental Coordinator	B.A., Business	17 years
Newgard, Kris	Hydrology, Transportation	B.S., Civil Engineering	25 years
Rockwell, Mandy	Wildlife	M.A., Natural Resources	6 years
Sestrich, Clint	Fisheries Biologist	M.A., Fish and Wildlife Management	6 years
Timmons, Becky	Heritage/American Indian	M.A., Anthropology B.A., Anthropology	31 years

4.1.2 Department of Environmental Quality

Name	Responsibilities	Education	Experience
Boettcher, Lisa	Reclamation Specialist	M.S., Geology and Geological Engineering B.S., Geology	21 years
Castro, James	Geochemist	Ph.D., Geochemistry M.S., Physical Chemistry	34 years

Name	Responsibilities	Education	Experience
Corsi, Emily	IDT Project Coordinator/MEPA	M.S., Natural Resources Conservation B.A., Politics	4 years
Dreesbach, Catherine, P.E.	Mining Engineer	M.S., Mining Engineering M.S., Environmental Engineering B.S., Physics	13 years
Jepson, Wayne	Hydrogeology	M.S., Geology B.A., Earth Sciences	19 years
McCullough, Warren	QC Review	M.S., Economic Geology B.A., Anthropology	35 years
Plantenberg, Patrick	Reclamation Specialist	M.S., Range Science/Reclamation Research B.S., Plant and Soil Science/Recreation Area Management	36 years
Rolfes, Herb	Permitting	M.S., Land Rehabilitation B.A., Earth Space Science, A.S., Chemical Engineering	24 years
Strait, James	Cultural Resources	M.A., Archaeology B.S., Anthropology	15 years

4.1.3 EIS Consultant Team

Name/Firm	Responsibilities	Education	Experience
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Jespersen, Jamie CDM	NEPA/MEPA	B.A., Civil Engineering	3 years
Mullen, Pat AMEC	NEPA/MEPA and Biological Resources	M.A., Zoology/Wildlife Biology B.S., Biology	23 years
Pfister, Laura AMEC	Social Resources	M.S., Resource Administration and Management B.S., Economics and Environmental Studies	13 years
Pozega, Gwen CDM	Project Manager	B.S., Engineering Science	13 years
Stenberg, Kate CDM	NEPA/MEPA	Ph.D., Wildlife Science/Regional Planning M.Admin., Environmental Administration B.A., Biology – Environmental Studies	25 years

Name/Firm	Responsibilities	Education	Experience
Stordahl, Darrel, P.E. CDM	Project Manager / Engineer	M.S., Environmental Engineering B.S., Mining Engineering	23 years
Vavra, Matt AMEC	Biological and Physical Resources	M.S., Geographical Information Systems B.S., Wildlife Biology	8 years
Whiting, Kent CDM	Geochemistry	M.S., Geochemistry B.S., Geology	20 years

4.2 Consultation and Coordination with Agencies, Organizations, and Individuals

On October 25, 2007, approximately 20 individuals and 68 government organizations, elected officials, or private interest groups were mailed a copy of the scoping information. In addition to federal, state, tribal, and local agencies, either a hard copy, electronic copy, or a summary of the Draft EIS has been sent to those organizations or individuals who requested a copy of this document. A copy of this Draft EIS can also be viewed at the following locations:

- DEQ website at http://deq.mt.gov/eis.mcpx
- USFS website at http://www.fs.fed.us/r1/kootenai/projects/projects/project.shtml?project=22452
- Supervisor's Office, Kootenai National Forest, Libby, Montana
- Three Rivers Ranger Station, Troy, Montana
- Montana Department of Environmental Quality, Lee Metcalf Building, Helena, Montana
- Montana State Library, Helena, Montana
- Mansfield Library, University of Montana, Missoula, Montana
- Lincoln County Library, Libby, Montana
- Troy Public Library, Troy, Montana

4.2.1 Federal, State, Tribal, or Local Agencies

Scoping material and a copy or summary of the Draft EIS were sent to the following federal, state, tribal or local agencies. Please note that a single asterisk (*) represents those agencies who received only a copy or summary of the Draft EIS. Triple asterisk (***) represent those agencies who received a letter notification of availability with the web address to access the Draft EIS; all other federal, state, tribal or local agencies received both scoping and Draft EIS materials.

Advisory Council on Historic Preservation(***)
Bureau of Land Management
City of Libby
City of Troy
Coeur d'Alene Tribe
Confederated Salish and Kootenai Tribes
Environmental Protection Agency
Environmental Quality Council (***)
Federal Aviation Administration (***)
Federal Highway Administration (*)
Kalispel Tribe
Kootenai National Forest

Kootenai National Forest Tribal Liaison
Kootenai Tribe of Idaho
Lincoln County Commissioners
Lincoln County Library (*)
Mansfield Library, University of Montana
Montana Bureau of Mines and Geology
Montana Dept of Commerce
Montana Dept of Environmental Quality
Montana Dept of Natural Resources and Conservation
Montana Dept of Revenue
Montana Dept of Transportation (*)
Montana Fish Wildlife and Parks
Montana Natural Heritage Program
Montana Office of the Governor
Montana State Library (*)
Montana Tech Library
Northwest Power Planning Council (***)
Sanders County Commissioners
SHPO
Troy Public Library
U.S. Army Engineers (***)
U.S. Army Corps of Engineers
USDA APHIS PPD/EAD (***)
USDA Natural Resources Conservation Service (***)
USDA National Agricultural Library (***)
U.S. Dept of Agriculture
USDI Office of Environmental Policy and Compliance (***)
USCG Environmental Impact Branch Marine (***)
U.S. EPA Office of Federal Activities
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey National Center (***)
U.S. Navy Office of Chief of Navy Operations (***)
Valley County Road Department
Wheatland County

4.2.2 Organizations and Businesses

Scoping material and a copy or summary of the Draft EIS were sent to the following organizations and businesses. Please note that a single asterisk (*) represents those organizations and businesses who received only a copy or summary of the Draft EIS; all others received both scoping and Draft EIS materials.

Alliance for the Wild Rockies
AMEC
Athens Investments, Inc.
Cabinet Back Country Horsemen
Cabinet Resource Group (*)
Camp, Dresser and McKee, Inc.
Clark Fork Coalition
Daily Inter Lake
Earthworks
Genesis, Inc.
Kootenai Valley Record
Lower Yellowstone Irrigation Project
Lincoln County Coalition
Montanians for Multiple Use
Montana Chapter American Fisheries Society
Montana Environmental Information Center (MEIC)
Montana Historical Society
Montana Mining Association
Montana Mountain Valley, LLC
Montana Trout Unlimited
Montana Wilderness Association
National Wildlife Federation
Northwest Properties, LLC
Northwest Mining Association
Rock Creek Alliance
Scotchmans Peak Wilderness (*)
Sierra Club
Society of American Foresters
The Lands Council (*)
The Western News
Troy Snowmobile Club (*)
Western Environmental Trade Association (WETA)
Wildwest Institute
Yaak Valley Forest Council

4.2.3 Individuals

Scoping material and a copy or summary of the Draft EIS were sent to the following individuals. Please note that a single asterisk (*) represents those individuals who received only a copy or summary of the Draft EIS. Double asterisk (**) represent those individuals who received scoping documents only; all other individuals received both scoping and Draft EIS materials.

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Allan Layer (*)
Aubyn Curtiss, Montana State Senator
Bruce Clark (*)
Carole Wright
Chas V. Vincent, Montana State Representative
Clint Jensen (*)
Colleen Hinds (*)
Darcy O'Bleness
Dasios Fotula
David Reid
Debbie Lyman (*)
Dennis Rehberg, U.S. Representative
Derek Feeback (*)
Dick Artley (*)
Don Weatherby
Donald Baney (*)
Donald Davis (*)
Doug Parker
Earlene Jellesed (*)
Floyd Beck (*)
Gerald A. Bennet, Montana State Representative (*)
Glenn Knodle (*)
Hannah Hernandez
Harvey H. Fredericksen (*)
James Hill (*)
Janine Price (*)
Jeff Franke (*)
Jim Elliot, Montana State Senator
Joe Madaski (*)
John Norris
Jon Sonju, Montana State Representative (*)
Jon Tester, U.S. Senator
Joshua Peterson (*)
Judy Hutchins
Julie Waters-Barcomb (*)
Keith O'Bleness
Kevin and Brenda Goe (*)
Linda Newstrom (*)
Lloyd Doney (*)
Max Baucus, U.S. Senator
Neil Newton
Pat Ingraham (**)
Paul D. Kukay (*)
Paul Coon (*)
Ralph Heinert
Ray Remp (**)
Ray Sampson
Richard Greene
Robert Jenkins
Robert Winstrom (*)
Ron Cotton
Ruby Miller (*)
Steve Gibson
Steve Lloyd (*)
Steve Prieve (**)
Tom Bamford
Toria Hasz (*)

Chapter 5 Index

access road, ES-8, 1-7, 2-1, 2-2, 2-28, 2-30, 2-42, 2-43, 2-58, 3-4, 3-81, 3-125, 3-126, 3-127, 3-129, 3-130, 3-131

adit, ES-3, ES-5, ES-6, ES-8, ES-9, ES-13, ES-15, ES-17, 1-3, 1-6, 1-7, 2-6, 2-12, 2-18, 2-19, 2-20, 2-27, 2-33, 2-36, 2-39, 2-42, 2-43, 2-44, 2-45, 2-52, 2-53, 2-54, 2-58, 2-59, 2-61, 2-62, 3-1, 3-4, 3-8, 3-20, 3-22, 3-38, 3-39, 3-41, 3-63, 3-100, 3-123, 3-129, 3-130, 3-141, 3-165, 3-234, 7-1, 7-3

attenuation, vi, ES-10, 2-12, 2-13, 2-15, 2-16, 2-27, 2-45, 2-46, 7-1, 8-7, 8-4

bald eagle, 20, 3-169, 3-194, 3-195, 3-196, 3-197, 3-222, 6-1, 8-5, 8-11, 8-15

best management practices, 2-28, 2-50, 2-58, 3-9, 3-10, 3-20, 3-21, 3-113, 6-1, 7-1

black-backed woodpecker, ES-20, 3-198, 3-199, 8-1, 8-12

black-backed woodpecker, 3-194, 3-197, 3-198

BMPs. See best management practices

bond, 1, 1-6, 1-9, 1-10, 2-14, 2-16, 2-24, 2-25, 2-28, 2-43, 2-56, 2-61, 3-37, 3-148

borrow area, ES-10, ES-11, ES-12, 2-1, 2-2, 2-14, 2-25, 2-27, 2-34, 2-47, 2-48, 2-51, 2-52, 2-56, 2-60, 3-8, 3-14, 3-21, 3-39, 3-117, 3-118, 3-120, 3-140, 3-141, 3-142, 3-143, 3-146, 3-147

borrow source. See borrow area

Bull Lake, ES-1, 1-2, 3-3, 3-18, 3-44, 3-103, 3-106, 3-162, 3-163, 3-202

bull trout, 3-18, 3-20

Canada lynx, 3-171, 3-183, 3-184

Coeur d'Alene salamander, 3-194, 3-200, 3-201, 8-2

Common loon, 3-194, 3-201, 3-202

copper, vi, 9, 1-1, 1-3, 2-12, 2-13, 2-15, 2-27, 2-45, 3-4, 3-5, 3-20, 3-37, 3-162

decant pond, ES-10, ES-12, 1-7, 2-2, 2-12, 2-13, 2-14, 2-16, 2-19, 2-20, 2-21, 2-22, 2-23, 2-28, 2-46, 2-52, 2-54, 2-61, 2-62, 3-39, 3-41, 3-75, 7-1, 8-7

development rock, ES-10, 2-19, 2-44, 2-47, 2-51, 2-52, 2-53, 2-58, 3-39

elk, 3-169, 3-170, 3-221, 3-222

employment, 3-108, 3-109, 8-15

Endangered Species Act (ESA), 1-9, 3-4, 3-18, 3-169, 3-171, 6-1

environmental justice, 3-108, 3-109, 3-233

fisher, 3-194, 3-203

flammulated owl, 3-194, 3-206

floodplain, 2-39, 3-3, 3-92, 3-99, 3-153

National Forest System Road (NFSR), ES-8, 1-9, 2-1, 2-30, 2-43, 2-50, 3-103, 3-105, 3-127, 3-129, 3-130, 3-131, 3-134

gray wolf, 3-171, 3-188, 3-221

grizzly bear, 3-4, 3-97, 3-126, 3-127, 3-169, 3-171, 3-173, 3-175, 3-221

groundwater quality. See water quality

harlequin duck, 3-194, 3-208

hydraulic plug, 9, 2-12, 2-19, 2-27, 2-44, 2-45, 2-52, 2-53, 2-58, 2-62, 3-39

income, 3-108, 3-109, 3-111, 3-112, 3-233

infiltration pond, 2-22, 2-53, 2-59, 7-3

interior redband trout, 3-19

iron, 2-15, 2-17, 2-61, 3-37

Kootenai River, 2-53, 3-16, 3-18, 3-49, 3-195, 3-196

Lake Creek, ES-10, 17, 1-2, 1-8, 2-13, 2-15, 2-17, 2-22, 2-23, 2-38, 2-39, 2-46, 2-47, 2-53, 3-1, 3-2, 3-5, 3-10, 3-17, 3-18, 3-19, 3-22, 3-23, 3-24, 3-25, 3-26, 3-39, 3-44, 3-92, 3-93, 3-96, 3-99, 3-102, 3-103, 3-105, 3-106, 3-113, 3-116, 3-118, 3-121, 3-125, 3-126, 3-160, 3-170

load-out facility, 2-6, 2-35, 2-37, 2-60, 3-6, 3-8, 3-9, 3-10, 7-2

macroinvertebrate, 10, 2-22, 2-23, 2-38, 2-46, 7-3

Management Indicator Species (MIS), 3-168, 3-221, 6-2

mill site, vi, ES-8, ES-14, ES-15, 2-1, 2-6, 2-12, 2-16, 2-21, 2-24, 2-27, 2-29, 2-33, 2-42, 2-43, 2-48, 2-50, 2-51, 2-56, 2-58, 2-59, 2-60, 2-61, 3-7, 3-8, 3-22, 3-109, 3-113, 3-116, 3-117, 3-119, 3-141, 3-144, 7-2, 8-5

mine water, vi, ES-5, ES-6, ES-7, ES-9, ES-10, ES-ES-12, 13, 1-7, 2-2, 2-6, 2-12, 2-13, 2-15, 2-18, 2-19, 2-20, 2-21, 2-23, 2-36, 2-39, 2-44, 2-46, 2-50, 2-52, 2-53, 2-54, 2-58, 2-61, 2-62, 3-1, 3-20, 3-22, 3-24, 3-25, 3-75, 8-2, 8-3

mountain goat, ES-20, 3-190, 3-222, 3-226, 3-227, 3-228, 8-1

MPDES, 2-13, 6-2

MT 56, ES-1, 1-2, 2-1, 2-2, 3-3, 3-5, 3-10, 3-103, 3-106, 3-127, 3-162, 3-163, 3-164, 3-166, 3-167, 6-2

Mt. Vernon, ES-8, 2-30, 2-43, 3-106, 3-126, 3-129, 3-134, 3-163, 3-164

nitrate, 2-2, 2-38, 3-20, 3-37

nitrogen, ES-9, 2-45, 3-5, 3-116

northern bog lemming, 3-195

northern leopard frog, 3-195

noxious weed, ES-11, 1-11, 2-26, 2-49, 3-2, 3-3, 3-135, 3-136, 3-137, 3-138, 3-140, 3-141, 3-142, 3-143, 3-144, 3-145, 3-146, 3-148, 3-149, 3-150, 3-156, 7-3, 8-10

office/shop, ES-3, 1-3, 2-1, 2-3, 2-5, 2-6, 2-21, 2-24, 2-27, 2-29, 2-33, 2-49, 2-51, 2-60, 3-117, 3-141, 3-144

ore body, 2-6, 2-45, 3-37, 6-1

patio, ES-6, ES-7, ES-8, ES-10, ES-15, 2-6, 2-19, 2-27, 2-33, 2-36, 2-39, 2-42, 2-43, 2-44, 2-47, 2-48, 2-52, 2-58, 3-37, 3-39, 3-100, 7-3

peregrine falcon, 3-194, 3-209, 3-210, 3-222

pileated woodpecker, 3-222, 3-229, 3-231

pipeline, ES-3, ES-9, ES-12, ES-13, ES-17, 1-3, 1-7, 2-6, 2-12, 2-14, 2-16, 2-20, 2-21, 2-27, 2-43, 2-44, 2-48, 2-50, 2-51, 2-53, 2-54, 2-58, 2-60, 3-22, 3-23, 3-24, 3-25, 3-75, 3-124, 3-141, 3-144

portal, ES-3, ES-9, ES-10, 1-3, 1-6, 2-6, 2-19, 2-20, 2-25, 2-33, 2-36, 2-39, 2-43, 2-44, 2-45, 2-47, 2-48, 2-54, 3-4, 3-20, 3-39, 3-100, 3-129, 7-3

power line, ES-3, ES-12, 1-3, 2-2, 2-6, 2-27, 2-32, 2-48, 2-51, 2-60, 3-162

Quonset hut, 2-2, 2-29, 2-51, 2-60

reclamation material, ES-7, ES-10, ES-14, 16, 20, 21, 23, 2-12, 2-47, 2-55, 3-1, 3-14, 3-20, 3-26, 3-36, 3-79, 3-114, 3-115, 3-116, 3-118, 3-119, 3-120, 3-121, 3-134, 3-143, 3-147, 3-148, 3-149, 3-150, 3-151, 3-156, 3-215, 3-217, 3-218

recreation, ES-8, 1-2, 2-30, 2-43, 2-47, 3-8, 3-9, 3-18, 3-91, 3-96, 3-98, 3-99, 3-100, 3-101, 3-102, 3-103, 3-105, 3-106, 3-107, 3-123, 3-124, 3-125, 3-127, 3-130, 3-164, 3-165, 3-170, 4-2

recreational. See recreation

revegetation, ES-5, ES-7, ES-8, ES-9, ES-10, ES-11, 15, 17, 19, 1-7, 2-14, 2-18, 2-22, 2-26, 2-28, 2-42, 2-43, 2-44, 2-47, 2-48, 2-49, 2-55, 2-56, 2-57, 2-62, 3-1, 3-8, 3-22, 3-23, 3-37, 3-39, 3-41, 3-100, 3-116, 3-119, 3-121, 3-123, 3-135, 3-140, 3-141, 3-144, 3-145, 3-146, 3-147, 3-148, 3-149, 3-150, 3-166

Ross Creek, 2-13, 2-23, 3-17, 3-19, 3-102, 3-103, 3-105, 3-121, 3-127, 3-129, 3-162, 3-163, 3-164, 3-198

soil, 2-14, 2-16, 2-23, 2-24, 2-25, 2-26, 2-29, 2-33, 2-34, 2-39, 2-42, 2-43, 2-47, 2-48, 2-49, 2-51, 2-52, 2-54, 2-56, 2-58, 2-59, 3-8, 3-12, 3-14, 3-15, 3-19, 3-37, 3-39, 3-41, 3-42, 3-97, 3-98, 3-112, 3-113, 3-114, 3-115, 3-116, 3-118, 3-120, 3-121, 3-126, 3-140, 3-143, 3-144, 3-147, 3-148, 3-149, 3-154, 4-2, 7-1, 7-4, See soil

Soil, ES-7, 2-13, 2-23, 2-39

Spalding's catchfly, 3-152, 3-153

Spar Lake, ES-8, 2-30, 2-43, 3-7, 3-100, 3-101, 3-102, 3-103, 3-105, 3-106, 3-127, 3-162

Stanley Creek, ES-1, ES-6, ES-12, 17, 1-2, 1-3, 2-17, 2-20, 2-21, 2-23, 2-29, 2-36, 2-37, 2-44, 2-50, 2-51, 2-54, 2-60, 2-62, 3-1, 3-17, 3-18, 3-20, 3-22, 3-24, 3-25, 3-44, 3-75, 3-100, 3-121, 3-129

stockpile, ES-7, ES-10, ES-14, ES-18, 2-2, 2-13, 2-14, 2-23, 2-24, 2-33, 2-34, 2-39, 2-47, 2-51, 2-56, 2-59, 3-14, 3-37, 3-39, 3-113, 3-116, 3-118, 3-120, 3-121, 3-139, 3-140, 3-143, 3-147, 3-149

tailings facility. See tailings impoundment

tailings impoundment, ES-3, ES-7, 1-3, 1-6, 2-1, 2-2, 2-4, 2-6, 2-12, 2-13, 2-14, 2-16, 2-17, 2-20, 2-21, 2-22, 2-24, 2-33, 2-39, 2-42, 2-43, 2-44, 2-45, 2-47, 2-48, 2-50, 2-51, 2-52, 2-53, 2-54, 2-56, 2-58, 3-3, 3-4, 3-6, 3-7, 3-8, 3-9, 3-14, 3-22, 3-26, 3-37, 3-39, 3-40, 3-92, 3-113, 3-116, 3-118, 3-120, 3-123, 3-124, 3-138, 3-141, 3-143, 3-144, 3-145, 3-146, 3-147, 3-148, 3-165

toe pond, 1-6, 2-1, 2-2, 2-13, 2-14, 2-22, 2-23, 2-24, 2-25, 2-34, 2-36, 2-37, 2-38, 2-45, 2-46, 2-47, 2-53, 2-55, 2-56, 2-60, 3-116, 3-120, 3-121, 3-141, 3-145, 3-146

Townsend's big-eared bat, 3-211

trail, 3-2, 3-102, 3-103, 3-105, 3-106, 3-161, 3-164, 3-176

Troy Mine Permit Area, 3-8, 3-9, 3-10, 3-26, 3-39, 3-91, 3-98, 3-102, 3-124, 3-127, 3-142, 3-143, 3-145, 3-146, 3-152, 3-155, 3-159, 3-160, 3-166, 3-168, 3-171, 3-198, 3-230

water howellia, 3-152, 3-153

water line, ES-13, 1-7, 2-6, 2-20, 2-21, 2-44, 2-53, 3-23

water quality, 1-8, 1-10, 1-11, 1-12, 2-9, 2-12, 2-13, 2-17, 2-18, 2-19, 2-22, 2-23, 2-36, 2-38, 2-39, 2-44, 2-46, 2-50, 2-53, 2-55, 2-61, 2-62, 3-

1, 3-15, 3-19, 3-20, 3-22, 3-23, 3-24, 3-25, 3-26, 3-99, 3-126, 3-129, 7-1

water treatment, 1-10, 2-12, 2-18, 2-36, 2-45, 2-54, 2-61, 3-1, 3-5, 3-124

western toad, 3-194, 3-213

westslope cutthroat trout, 3-19, 3-20, See

wetland, ES-10, ES-11, 1-10, 1-12, 2-14, 2-21, 2-26, 2-28, 2-46, 2-47, 2-48, 2-49, 2-52, 2-56, 3-140, 3-143, 3-144, 3-145, 7-4

white sturgeon, 3-18

whitetail deer, 3-222

wolverine, 3-195, 3-219

Chapter 6 List of Acronyms

Acronym	Acronym Description
ACHP	Advisory Council on Historic Preservation
AIRFA	American Indian Religious Freedom Act
ARD	Acid Rock Drainage
ARM	Administrative Rules of Montana
ARPA	Archaeological Resources Protection Act
BA	Biological Assessment
BAA	Bear Analysis Area
BLM	Bureau of Land Management
BMPs	Best Management Practices
BMU	Bear Management Unit
CAA	Clean Air Act
CDM	Camp, Dresser & McKee, Inc.
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second
CRG	Cabinet Resource Group
cy	cubic yards
CYE	Cabinet-Yaak Ecosystem
CYRZ	Cabinet-Yaak Recovery Zone
dBA	decibel
DEQ	Montana Department of Environmental Quality
DN	Decision Notice
DNRC	Montana Department of Natural Resources and Conservation
DPS	Distinct Population Segment
DSL	Montana Department of State Lands
EA	Environmental Assessment
EIS	Environmental Impact Statement
EOB	East Ore Body
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FONSI	Finding of No Significant Impact
FP	Forest Plan
FWP	Montana Department of Fish, Wildlife & Parks
GIS	Geographic Information System
gpm	gallons per minute
HDPE	High-Density Polyethylene
HE	Habitat Effectiveness
IDT	Interdisciplinary Team
INFISH	Inland Native Fish Strategy
IRA	Inventoried Roadless Area
KNF	Kootenai National Forest
kPa	kilopascal
kV	kilovolt
LAUs	Lynx Analysis Units
MA	Management Area
MAQB	Montana Air Quality Bureau
MBEWG	Montana Bald Eagle Working Group
MCA	Montana Code Annotated
MEPA	Montana Environmental Policy Act

MIS	Management Indicator Species
ML	Metals Leaching
MMRA	Metal Mine Reclamation Act
MNHP	Montana Natural Heritage Program
MVUM	Motor Vehicle Use Map
MOU	Memorandum of Understanding
M.P.	Mile Post
MPDES	Montana Pollution Discharge Elimination System
MT 56	Montana Highway 56
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NBEMG	National Bald Eagle Management Guidelines
NCDE	Northern Continental Divide Ecosystem
NEPA	National Environmental Policy Act
NFMA	National Forest Management Act
NFS	National Forest System
NFSL	National Forest System Lands
NFSR	National Forest System Road
NHPA	National Historic Preservation Act
NPS	Non-point Source
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NRLMD	Northern Rockies Lynx Management Direction
NWMT	Northwest Montana recovery area
OMRD	Open Motorized Route Density
ORD	Open Road Density
PCE	Primary Constituent Element
PLSS	Public Land Survey System
PM	Particulate Matter
PPI	Potential Population Index
PR	Project Record
PSD	Prevention of Significant Deterioration
PSU	Planning Subunit
RHCA	Riparian Habitat Conservation Area
RMR	Rock Mass Rating
ROD	Record of Decision
SIP	State Implementation Plans
SHPO	State Historic Preservation Office
SWCP	Soil and Water Conservation Practices
SWPPP	Storm Water Pollution Prevention Plan
TCP	Traditional Cultural Property
TMRD	Total Motorized Route Density
U.S.	United States
USC	United States Code
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VQOs	Visual Quality Objectives
VRUs	Vegetation Response Units

Chapter 7 Glossary

adfluvial	Describing fish that live in lakes and migrate into rivers or streams to spawn.
adit	A horizontal opening driven into the side of a hill or mountain to access an ore deposit.
allochthonous	Said of rocks or materials formed elsewhere than their present place.
alluvial or alluvium	The general name for all sediments, including clay, silt, sand, gravel, or similar unconsolidated material deposited in a sorted or semi-sorted condition by a stream or other body of running water.
alluvial fan	Coarse material forming a fan-shaped deposit at the base of a ravine or drainage.
ambient	Existing or present.
anadromous	Describing fish that live primarily in the ocean but breed in fresh water.
angle-of-repose	The maximum (steepest) angle at which a loose material will remain stable.
attenuation	Reduction in the concentration of a constituent of concern achieved by natural physical, biological, or chemical processes.
baseflow	Groundwater inflow to streams.
bedload	Coarse particles transported on the bed of a stream; sand, gravel, cobbles, boulders.
best management practices (BMPs)	Activities or structural improvements that improve and/or control non-point source pollutants.
borrow materials	Geological materials such as rock or soil dug from one location to provide materials for another location.
cation exchange capacity	A measure of the chemical process in which cations are exchanged between a solid, such as zeolite, and a solution, such as water. Cations are elemental metals that are ionized in solution.
common ions	A water analysis that typically reports concentrations of calcium, magnesium, sodium, potassium, sulfate, chloride, hardness, total dissolved solids, alkalinity, and conductivity.
concentrate	Ore that has been processed into a more concentrated form suitable for refining.
conspecific populations	Populations of plants or animals that belong to the same species.
Core	Grizzly bear core habitat
cultivar	A variety of a plant developed from a natural species and maintained under cultivation.
debris flow	A fast moving, high density, liquefied landslide.
debris torrent	A rapid surge of water, mud, and rocks down a steep creek; a channelized debris flow.
decant pond	A basin used to hold process water for a sufficient period of time to allow solids to settle from suspension.
degradation	The process by which water quality is lowered in the natural environment.
development rock	Rock other than ore that is removed from an underground mine.

diagenesis	Changes undergone by a sediment after its initial deposition such as compaction, cementation, and replacement that occur under conditions of pressure and temperature that are normal in the outer part of the earth's crust. Excludes weathering and metamorphism.
dike	a. A bank usually of earth constructed to control or confine water. b. A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.
drift	A horizontal mine tunnel
embeddedness	The degree to which coarse particles (sediments) are surrounded by fine sediments.
empirical	Derived from experiment or observation.
endangered species	A species threatened with extinction.
endemic	Restricted to or native to a particular area or region.
euhedral	A mineral grain that is completely bounded by its own rational faces, and whose growth has not been restrained or interfered with by adjacent grains.
extirpation	Complete removal or destruction.
fault	A fracture in the earth's crust accompanied by a displacement of one side of the fracture with respect to the other.
forb	An herb other than a grass.
glacial-fluvial deposits	Materials deposited by glacial meltwater; outwash deposits.
glacial outwash	Sediment deposited by glacial meltwater, generally layered.
glacial till	Sediment deposited in contact with glacial ice, generally unlayered.
gradient	Slope, generally with respect to streams or groundwater.
herbaceous	Having the qualities of an herb.
historic properties	Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term includes properties of traditional religious and cultural importance to an Indian tribe or Native Hawaiian organization and that meet the National Register criteria (36 CFR Part 800 Protection of Historic Properties, Section 800.16 Definitions (1)).
hydraulic head	Potential energy contained in a water mass, produced by elevation, pressure, and velocity.
interclastic	Said of material that is introduced between rock fragments.
interspecific competition	Competition between species for resources.
lacustrine	Pertaining to, produced by, or inhabiting a lake or lakes.
lithostatic	Said of pressure within rocks.
loadout facility	A location other than the mill site, used for the loading, unloading, handling, or mixing of ore concentrate for shipment by rail.
lode-mining claim	A claim located upon deposits of mineral which are erected in or surrounded by hard rock, such as veins, fissures, lodes, and disseminated ore bodies. There are two types of claims: lode and placer. A placer claim is located in loose or unconsolidated material.

macroinvertebrate	Stream insects that are a primary food source for fish and are sensitive to metals concentrations in surface water.
Management Situation 1	Habitat contains grizzly bear population centers and habitat components needed for the survival and recovery of the species. Management decisions will favor the needs of the grizzly. Habitat maintenance and improvement and grizzly/human conflict minimization will receive the highest management priority.
Management Situation 3	Areas where grizzly bear presence is possible but infrequent. Developments such as campgrounds, resorts, or other high human use associated facilities, and human presence result in conditions which make grizzly presence untenable for humans and/or grizzlies. Grizzly habitat maintenance and improvement are not management considerations in these areas. Grizzly/human conflict minimization is a high priority management consideration.
metapopulation	A group of spatially separated populations of the same species which interact at some level.
metasedimentary	Partly metamorphosed sedimentary rock.
mitigation	An action to alleviate, avoid, eliminate, or replace the impact to the surrounding environment.
morphology	Form and structure.
moving window analysis	A GIS modeling routine which converts linear road maps into a map of road densities based on a selected pixel (cell) size. Road density is the amount of road found within a circular "window" of a selected area (*e.g.* 1 mi^2) centered on each pixel.
non-attainment area	A geographic area in which the level of a criteria air pollutant is higher than the level allowed by the federal standards.
noxious weeds	Physically harmful or destructive weeds as identified by the legislature.
ore	Rocks or minerals that can be mined, processed and delivered at a profit.
patented land	A parcel of land which the federal government sold to a claim holder and whose ownership can be transferred to other private parties. The minerals contained within the land also belong to the claim holder.
infiltration pond (percolation pond)	A basin constructed to allow fluids to infiltrate or trickle through a permeable media for the purpose of disposal.
piezometer	Small wells used to locate the water table and obtain groundwater measurements.
portal	The surface entrance to an adit.
portal patio crest	The patio is the normally level area formed in front of a mine opening by spreading development rock from the mine. The crest of the patio is formed by the top of the steep slope on the downhill side of the patio.

Primary Constituent Element (PCE)	The physical and biological features that are essential to the conservation of the species and that may require special management considerations or protection. These features are the PCEs laid out in the appropriate quantity and spatial arrangement for conservation of the species.
reclamation	The process of returning mined land to a viable post-mining contour, use, or condition.
redox	Redox is an abbreviation for reduction-oxidation potential. Redox potential is a measure (in volts) of the affinity of a substance for electrons.
roaded	An area with road access.
scour	An erosional process resulting from flowing water or ice.
shadow area	The area of land overlying the mine workings.
sill	A tabular igneous intrusion between rock layers.
slump	Down slope movement of geologic materials.
specific conductance	A measure of the electrical properties of a solution. Solutions containing salts can transmit electrical current whereas pure water cannot.
stochastic	A process that is non-deterministic; having a random element.
subsidence (mining induced)	Sinking down of part of the earth's surface due to mining.
subsiding	Sinking.
substrate	The base on which an organism lives.
syncline	In structural geology, a syncline is a downward-curving fold, with layers that dip toward the center of the structure.
tailings	Sand-sized or small material leftover from the milling process after the recoverable minerals have been removed from the ore.
talus slope	A sheet of rock debris mantling a slope.
threatened species	Having an uncertain chance of continued survival; likely to become an endangered species.
turbidity	A measure of the amount of suspended solids in water.
unconsolidated	Uncemented particles not lithified into rock.
waste rock	Rock that is uneconomical to mill but must be removed to gain access to an ore body. Waste rock also often comes from underground excavations for facilities, such as shops, explosives magazines, etc. Also referred to as “development rock”.
waters of the U.S.	All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce such as intrastate lakes, rivers, streams (including intermittent streams), wetlands, wet meadows, or natural ponds.
weathering	The physical and chemical breakdown of rock materials into smaller particles or chemical constituents (ions).
wetland	Areas where land is covered, often intermittently, with shallow water or contain soil saturated with moisture for a defined portion of the year.

Chapter 8 References

Agapito, J.F.T., and Associates, Inc. 1991. Evaluation of subsidence potential, Montanore Project, Noranda Minerals Corp. Submitted to IMS Inc.

ASARCO. 1994. Rock Creek Project Rock Mechanics Analysis. Prepared by Dave Young.

Balla, John. 1993. Geology of the Rock Creek Deposit, Sanders County, Montana: Program and Abstracts, Belt III, August 14-21, 1993, 2 pp.

Balla, John. 2000. Geologic comparison of the Troy Mine/Spar Lake deposit and Rock Creek Mine/Rock Lake deposit northwest Montana, unpublished report, for U. S. Forest Service, Kootenai National Forest, Libby, MT.

Banci, V. 1994. Wolverine. Chapter 5 *In* Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. (tech. eds.). The Scientific Basis for Conserving Forest Carnivores American Marten, Fisher, Lynx and Wolverine in the Western United States. General Technical Report RM-254. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. 184 pp.

BC Research. 1976. Determination of the Acid Generation Potential of Tailing from the Troy Deposit, Project Report No. 1 1-1 576, June 1976.

Behnke, R. J. 1992. Native trout of western North America. Am. Fish. Soc. Monograph No. 6. 275 pp.

Bennett, E.H. 1984. A Hypothesis concerning the Genesis of Ore bodies in the Coeur d'Alene Mining District, Idaho. Idaho Geological Survey Technical Report 84-7, November 1984, 39 pp.

Bissell, G. 2004. Third Annual Common Loon Report (2002-2004). Montana Department of Fish, Wildlife and Parks. 20 pp.

Bissell, G. 2005. Third annual common loon report (draft). Unpublished report. March 2005. Montana Department of Fish, Wildlife and Parks, Region One, 490 North Meridian Road, Kalispell, MT 59901.

Bonn, Joanne, B. Dixon, E. Kenney, and D. Pengeroth. 2007. Black-backed woodpecker northern region overview: key findings and project considerations. USDA Forest Service, Missoula, MT. 41 pp

Bowen, Robert, and Gunatilaka, Ananda. 1975. Copper: its geology and economics, Department of Geology, School of Mines, University of Zambia, Lusaka, Zambia. Publisher, John Wiley and Sons, NY.

Brandborg, S.M. 1955. Life history and management of the mountain goat in Idaho. Wildlife Bulletin No. 2. Idaho Department of Fish and Game. Boise, ID. 142 pp.

British Columbia Acid Mine Drainage Task Force. 1989. Draft acid rock drainage technical guide. Prepared by Steffen, Robertson, and Kirsten (B.C.), Inc.

Brown, J. 2008. Personal communication, April 22, 2008.

Bull, E.L. 1975. Habitat utilization of the pileated woodpecker, Blue Mountains, Oregon. M.S. thesis, Oregon State University. Corvallis, OR.

Bull, E.L. 1980. Resource partitioning among woodpeckers in northeastern Oregon. Ph.D. dissertation, University of Idaho. Moscow, ID.

Bull, E.L. 1987. Ecology of the pileated woodpecker in northeastern Oregon. Journal of Wildlife Management. 51(2):472-481.

Bull, E.L. and R.S. Holthausen. 1993. Habitat use and management of pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management. 57: 335-345.

Bull, E. L., and J. E. Jackson. 1995. Pileated Woodpecker (*Dryocopus pileatus*). In *The Birds of North America, No. 148* (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA. and The American Ornithologists' Union, Washington, DC.

Bull, E.L. and E.C. Meslow. 1977. Habitat requirements of the pileated woodpecker in northeastern Oregon. Journal of Forestry. 75(6):335-337.

Bull, E. L., A. L. Wright, and M. G. Henjum. 1990. Nesting habitat of Flammulated Owls in Oregon. Journal of Raptor Research. 24: 52-55.

Bull, E.L., R.S. Holthausen, and M.G. Henjum. 1992. Roost trees used by pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management. 56 (4): 786-793.

Buterbaugh, G.L. 1991. Biological Opinion on the effects to grizzly bears and grey wolf from the implementation of proposed timber harvest in the Grouse Keeler Timber Sale (Compartment 40), KNF. Libby, MT. USDI Fish and Wildlife Service. Denver, CO. July 22.

Butts, T.W. 1992. Wolverine (*Gulo gulo*) Biology and Management: A literature review and annotated bibliography. USDA Forest Service, Region 1, Missoula, MT. 106 pp. plus attachments.

Call and Nicholas Inc. (CNI). 2005. Memorandum on Troy Sinkhole Evaluation. July 28, 2005.

Call and Nicholas Inc. (CNI). 2006. Memorandum on Troy Sinkhole Evaluation. Dec 01.

Carlson, J. 2010. Personal Communication. Kootenai National Forest, Libby, MT.

Cassirer, E.F., C.R. Groves, and D.L. Genter. 1994. Coeur d'Alene salamander Conservation Assessment. USDA Forest Service, Region 1. Missoula, MT. 55 pp.

Caton, Elaine L. 1996. Effects of fire and salvage-logging on a cavity-nesting bird community in northwestern Montana. Ph.D. Thesis, University of Montana, Missoula, MT. 115 pp.

Cherry, M.B. 1997 (unpublished). The Black-backed and Three-toed Woodpeckers: Life History, Habitat Use, and Monitoring Plan. Gallatin National Forest. Bozeman, MT. 22 pp.

Christensen, A.G. and M.J. Madel. 1982. Cumulative effects analysis process – Grizzly bear habitat component mapping. KNF. Libby, MT. 38 pp.

Christy, R.E., and S.D. West. 1993. Biology of bats in Douglas-fir forests. USDA Forest Service. Pacific Northwest Research Station. General Technical Report. PNW-GTR 308. 28 pp.

Claar, J.J., N. Anderson, D. Boyd, M. Cherry, B. Conard, R. Hompesch, S. Miller, G. Olson, H. Ihsle Pac, J. Waller, T. Wittinger, and H. Youmans. 1999. Carnivores. Pages 7.1-7.63 *In* Joslin, G. and H. Youmans, coordinators. Effects of recreation on Rocky Mountain wildlife: A Review for Montana. Committee on Effects of Recreation on Wildlife. Montana Chapter of the Wildlife Society. 307 pp.

Clark, A. L. 1971. Stratabound copper sulfides in the Precambrian Belt Supergroup, northern Idaho and northwestern Montana: I.M.A.-I.A.G.O.D. Meeting, Japan, 1970, Proceedings, pages 261-267

Clark, J.R. 2000. Endangered and Threatened Wildlife and Plants: Determination of Threatened Status for the Contiguous U.S. Distinct Population Segment of the Canada Lynx and Related Rule; Final Rule. USDI Fish and Wildlife Service. *Federal Register*, March 24. Vol. 65:58. pages 16051-16086.

Corn, P., P. Hendricks, T. Koch, B. Maxell, C. Peterson, and K. Werner. 1998. Unpublished letter to Forest Service Region 1 Species at Risk Task Group: subject – Boreal toad (*Bufo boreas boreas*) listing as a sensitive species for all Region 1 Forests. 8 pp.

Cullen M., Pakalnis R., Galovich K. 2002. "Protecting the Quinsam Coal Mine Access Road from Subsidence Damage" Proceedings Canadian Institute of Mining, Metallurgy, and Petroleum, Annual General Meeting.

DEQ. 2008a. MDEQ Hard Rock Program Operating Permit – Field Inspection Report dated October 9, 2008. Troy Mine Operating Permit No. 00093.

DEQ. 2008b. Blowing dust at Genesis mine. Personal email November 3, 2008.

DEQ. 2010. MDEQ Hard Rock Program Operating Permit – Field Inspection Report dated September 29, 2010. Troy Mine Operating Permit No. 00093.

DEQ and USFS. 2008. Memorandum of Understanding on Fostering Collaboration and Efficiencies to Address Water Quality Impairments on National Forest System Lands in Montana between the Montana Department of Environmental Quality and Northern Region, U.S.D.A. Forest Service. Signed March 17, 2008.

Department of Labor and Industry. 2010a. Demographic and Economic Information for Lincoln County, Montana. September 2010.

Department of Labor and Industry. 2010b. Demographic and Economic Information for Sanders County, Montana. September 2010.

Department of Labor and Industry. 2010c. Demographic and Economic Information for the State of Montana. September 2010.

Department of State Lands and USFS, Kootenai National Forest. 1978. *Draft Environmental Impact Statement, Proposed Plan of Mining and Reclamation, Troy Project – ASARCO, Lincoln County, Montana*, Volume 1 and 2.

Dolan, P.M. 1994. The common loon (*Gavia immer*) in the Northern region: biology and management recommendations. USDA USFS Region 1. Lolo NF. Missoula, MT 76 pp.

DuBois, Kristi. 2008. 2007 Bald Eagle Nesting Season Summary. Montana, Fish, Wildlife and Parks. Missoula, Montana. 3 pp.

EPA. 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety (EPA/ONAC 550/9-74-004). March.

EPA. 1979. Protective Noise Levels (Condensed Version of EPS Levels Document). Supplement of "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA/ONAC 550/9-74-004.

EPA. 1992. Mine Site Visit: Asarco/Troy Mine, May 1992. U.S. EPA, Office of Solid Waste, 401 M Street S.W., Washington, D.C. 20460.

EPA. 2009. EPA Identifies Noise Levels Affecting Health and Welfare. http://www.epa.gov/history/topics/noise/01.htm

Erickson, Larry. 2010. Personal Communication, Troy Mine, Inc. Exploration and Technical Services Manager. September.

Evars, D.C. 2004. Status assessment and conservation plan for the common loon (*Gavia immer*) in North America. U.S. Fish and Wildlife Service, Div. of Migratory Bird Management, Hadley Massachusetts. 95 pp.

Federal Highway Administration (FWHA). 2007. Roadside Revegetation: An Integrated Approach to Establishing Native Plants. FHWA-WFL/TD-07-005. November.

Frederick, G.P. 1991. Effects of forest roads on grizzly bears, elk and gray wolves: a literature review. USDA Forest Service, Kootenai NF. Libby, MT. 53 pp.

Fish, Wildlife and Parks. 2004. Montana statewide elk management plan. Wildlife Division, Helena, MT. 404 pp. Weblink: http://fwp.mt.gov/FwpPaperApps/hunting/ElkPlanFinal.pdf

GARD guide. 2008. website: (http://www.gardguide.com)

Genesis, Inc. 2006. Genesis Incorporated Troy Mine Revised Reclamation Plan. March 2006.

Genesis, Inc. 2008. Revised soil quantity estimates. L. Erickson (Genesis) to H. Rolfes (MT DEQ). Jan 22, 2008.

Genesis, Inc. 2009. PM-10 Monitoring, Request for Approval of Proposed Site Location. Letter prepared for DEQ.

Genesis, Inc. 2010. Troy Mine – PM10 Ambient Air Monitoring Station. Letter prepared for MT DEQ.

Golder Associates. 1989. Report to Echo Bay Mines on Surface Subsidence as a Result of Mining the Overlook Orebody. Prepared by M. Cullen.

Graham, R.T., A.E. Harvey, M.F. Jurgensen, T.B. Jain, J.R. Tonn, and D.S. Page-Dumroese. 1994. Managing coarse woody debris in forests of the Rocky Mountains. Research Paper INTRP-477. USDA Forest Service Intermountain Research Station. Ogden, UT. 12 pp.

Grant, Gordon E.; Lewis, Sarah L.; Swanson, Frederick J.; Cissel, John H.; McDonnell, Jeffrey J. 2008. Effects of forest practices on peak flows and consequent channel response: a state-of-science report for western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-760. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 pp.

Green, P.P., J. Joy, D. Sirucek, W. Hann, A. Zack, and B. Naumann. 1992. Old-Growth Forest Types of the Northern Region (errata corrected 2005). USDA Forest Service, Region 1, Missoula, MT.

Griffith, J. S. 1988. Review of competition between cutthroat trout and other salmonids. American Fisheries Society Symposium 4:134-140.

Grindal, S.D. 1995. Habitat use by bats in fragmented forest. pp. 260-272 in: Bats and Forests Symposium. R. Barclay and R. Brigham Eds. British Columbia Ministry of Forests, Victoria, B.C. 291 pp.

Hammond, C. 2009. Montana bald eagle management guidelines. FWP in cooperation with Mont. Bald Eagle Working Group. Kalispell, MT. 11 pp.

Hansen, J.A., P.G. Welsh, J. Lipton, and D. Cacela. 2002. Effects of copper exposure on growth and survival of juvenile bull trout. Transactions of the American Fisheries Society. 131:690-697.

Hargrave, P.A., A.R. English, M.D. Kerschen, G.W. Liva, J.D. Lonn, J.P. Madison, J.J. Metesh, R. Wintergerst. 1999. Abandoned-Inactive Mines of the Kootenai National Forest-Administered Land. Montana Bureau of Mines and Geology. Open File Report MBMG 395. Prepared for the USDA Forest Service Region 1.

Harlow, Dick. 2010. Kootenai National Forest *Three Rivers* Ranger District; Personal Communication, September.

Harrison, J.E. 1972. Precambrian belt basin of northwestern United States: its geometry, sedimentation and copper occurrences. Geological Society of America Bulletin. 83:1,215-1,240.

Harrison, J. E., Cressman, E. R., and Wipple, J. W. 1983. Preliminary Geology and Structure Map of Part of the Kalispell Two Degree Quadrangle, Montana: U.S. Geological Survey, Open-File Report 83-502.

Hayes, T.S. 1983. Geologic studies on the genesis of the Spar Lake strata-bound copper-silver deposit, Lincoln County, Montana. Dissertation for Ph.D submitted to the Department of Applied Sciences, Stanford University, Stanford. November 1983. Typescript.

Hayes, T. S. 1990. A preliminary study of thermometry and metal sources of the Spar Lake strata-bound copper-silver deposit, Belt Supergroup, Montana. U.S.G.S. Open File Report 90-0484.

Hayes, T.S. and Balla, John C. 1986. Troy Mine, Proterozoic sediment-hosted stratiform copper deposits of upper Michigan and Belt Supergroup of Idaho and Montana: Geological Association of Canada, Mineralogical Association of Canada, Canadian Geophysical Union, Joint Annual Meeting, Ottawa '86, Field Trip 1 : Guidebook, 72 pp.

Hayes, T.S. and M.T. Einaudi. 1986. Genesis of the Spar Lake stratabound copper-silver deposit, Montana: Part I controls inherited from sedimentation and preore diogenesis. Economic Geology. 81:1899-1931.

Hayward, G.D. and J. Verner (tech. eds.). 1994. Flammulated, western, and great gray owls in the United States: A technical conservation assessment. General Technical Report RM-253. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. 214 pp. 3 maps.

Heinemeyer, K.S. and J.L. Jones. 1994. Fisher biology and management in the western United States: a literature review and adaptive management strategy. USDA Forest Service, Region 1. Missoula, MT. 109 pp.

Hendricks, P., K. A. Jurist, D. L. Genter, and J. D. Reichel. 1995. Bat survey of the Kootenai National Forest, Montana 1994. Report to USDA, Forest Service, Kootenai National Forest, Libby, MT. Montana Natural Heritage Program, Helena MT 59620.

Hendricks, P., K.A. Jurist, D.L. Genter, and J.D. Reichel. 1996. Bats of the Kootenai National Forest, Montana. Report to USDA Forest Service, KNF, Libby, MT. Montana Natural Heritage Program. Helena, MT. 99 pp.

Heinz, G. (Technical Editor). 1996 (unpublished). Wolverine (*Gulo Gulo*). Kootenai National Forest, Libby, MT 4 pp.

Hillis, J. Michael, M. J. Thompson, J. E. Canfield, L. J. Lyon, C. L. Marcum, P. M. Dolan, and D. W. McCleery. 1991. Defining elk security: the Hillis paradigm. Pages 38-43 in A. G. Christensen, L. J. Lyon and T. N. Lonner, comps., Proc. Elk Vulnerability Symp., Montana State Univ., Bozeman. 330 pp.

Hutto, R.L. 1995. The composition of bird communities following stand-replacement fires in northern Rocky Mountain conifer forests. Conservation Biology. 9:1041-1058.

Hydrometrics. 2009. Troy Mine October 29, 2009, Tailings Spill Monitoring Report.

Interagency Grizzly Bear Committee (IGBC). 1990. CEM – A model for assessing effects on grizzly bears. USDA Forest Service, U.S. Fish and Wildlife Service, BLM, Idaho Department of Fish and Game, Montana Fish, Wildlife, and Parks, Wyoming Fish and Game, National Park Service, Washington Department of Wildlife. Missoula, MT. 24 pp.

Interagency Grizzly Bear Committee. 1998. Selkirk/Cabinet-Yaak grizzly bear recovery areas: Interim Access Management Rule Set. Approved 12/1/98 by Selkirk/Cabinet-Yaak Subcommittee. 10 pp.

Jackman, S.M. 1974. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. M.S. thesis, Oregon State University, Corvallis, OR.

Johnson, W.J. 1999 (unpublished). Sensitive Species Status Summary: KNF. USDA Forest Service. Libby, MT. 36 pp.

Johnson, W. J. 2002. Historical access management in a small population of grizzly bear. Workshop on recovering small grizzly population, December 2002. Unpublished report. USDA Forest Service, Kootenai NF, Libby, MT. 2 pp.

Johnson, W.J. 2003. Old growth and Pileated Woodpecker: Analysis update. Unpublished report. USDA Forest Service, Kootenai NF. Libby, MT. 4 pp.

Johnson, W.J. (editor). 2004a (unpublished). A Conservation Plan Based on the 1987 KNF Land Management Plan as Amended. KNF Wildlife-Fish-Botany (WFB) Steering Group KNF. Libby, MT. 17 pp. plus appendices.

Johnson, W.J. (editor). 2004b (unpublished). Wolverine and Fisher Hierarchical Approach to Conservation on the KNF. USDA Forest Service, KNF Wildlife-Fish-Botany (WFB) Steering Group Kootenai NF. Libby, MT. 8 pp.

Johnson, W.J. 2007. In defense of Wakkinen and Kasworm (1997) paper as “best science” in the Selkirk and Cabinet-Yaak Grizzly Bear Ecosystems. Unpublished Report, USDA Forest Service, KNF. Libby, MT. 8 pp

Joslin, G. 1980. Mountain Goat Habitat Management Plan for the Cabinet Mountains, Montana. Montana Fish, Wildlife and Parks, Helena, MT. 122 pp.

Kasworm, W. 2008. Personal communication, May 7, 2008.

Kasworm, W. 2010. Personal GIS data from W. Kasworm.

Kasworm, W. and S. Knick. 1989. Shooting mortality in small populations of grizzly bears. Wildlife Society Bulletin. 17:11-15.

Kasworm, W. and T. Manley. 1988. Grizzly bear and black bear ecology in the Cabinet Mountains of northwest Montana. Montana Fish, Wildlife and Parks. Helena, MT.
122 pp.

Kasworm, W. F., H. Carriles, T. G. Radandt, M. Proctor, and C. Servheen. 2009. Cabinet-Yaak grizzly bear recovery area 2008 research and monitoring progress report. U.S. Fish and Wildlife Service, Missoula, MT. 76 pp.

Kennecott Copper Corporation. 1970. Interoffice Memorandum, September 8, 1970;

Kiffney, P.M., and W.H. Clements. 1994. Effects of heavy metals on a macroinvertebrate assemblage from a Rocky Mountain stream in experimental microcosms. Journal of the North American Benthological Society. 13(4):511-523.

Kirk, Lisa. 2003. Rock Creek Project 2003 Geochemistry Review: Prepared for United States Forest Service, Kootenai National Forest.

Klohn Crippen. 2000. Troy Mine Conceptual Tunnel Plug Study. October.

Knight Piésold and Co. 2007. Report on Phase 2 Program on Stability Analyses, Capacity Review and Recommendations for Ongoing Raises.

KNF. 1978 to present. Bald Eagle Monitoring Records. Kootenai National Forest, Libby, Montana.

KNF. 1994. Aquatic Biota Information Systems (ABIS). U.S.D.A. Kootenai National Forest, Libby, Montana.

KNF. 2001. Spar and Lake Subunits Forest Health Project; Record of Decision and Environmental Impact Statement. Kootenai National Forest, Three Rivers RD, Troy, MT.

KNF. 2003. Ownership: Government and Private of the Kootenai National Forest [GIS data]. Available online: http://www.fs.fed.us/r1/kootenai/maps/gis/index.shtml. [Accessed March 2008].

KNF. 2004a. Roads Analysis Report – Mt. Vernon, Troy Mine (Revett/Genesis). U.S. Department of Agriculture, Forest Service, Kootenai National Forest, Libby, MT.

KNF. 2004b. Social Assessment: Kootenai National Forest, Update: 2003. U.S. Department of Agriculture, Forest Service, Kootenai National Forest, Libby, MT.

KNF. 2007. Record of Decision Kootenai National Forest Invasive Plant Management.Kootenai National Fores, Libby, MT. April.

KNF. 2008a. Roads Analysis Report – Mt. Vernon, Troy Mine (Revett/Genesis), 2008 Amendment. U.S. Department of Agriculture, Forest Service, Kootenai National Forest, Libby, MT.

KNF. 2008b. Forest Plan Monitoring and Evaluation Reports Fiscal Year 2007. USDA Kootenai National Forest. Libby, MT. (Monitoring Item C-6) pp. 36-38.

KNF. 2009a. Motor Vehicle Use Map Project Decision Notice and Finding of No Significant Impact. U.S. Department of Agricultural, Forest Service, Kootenai National Forest. Libby, MT.

KNF. 2009b. Forest Plan Monitoring and Evaluation Report FISCAL YEAR 2008. USDA Kootenai National Forest, Libby, MT. July.

KNF. 2010. Sparring Bulls Draft Environmental Impact Statement. Three Rivers Ranger District, Kootenai National Forest, Lincoln County, MT. http://a123.g.akamai.net/7/123/11558/abc123/forestservic.download.akamai.com/11558/www/nepa/60156_FSPLT1_022721.pdf

KNF and DEQ. 2001. Final Environmental Impact Statement for the Rock Creek Project. U.S.D.A. Forest Service, Northern Region, Kootenai National Forest. September.

KNF and DEQ. 2009. Draft Environmental Impact Statement for the Montanore Project. U.S.D.A. Forest Service, Northern Region, Kootenai National Forest. February.

KNF, Lolo National Forest, and Idaho Panhandle National Forest. 2009. Draft Supplemental Environmental Impact Statement, Forest Plan Amendments for Motorized Access Management Within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones. http://www.fs.fed.us/r1/kootenai/projects/projects/project.shtml?project=24882

Kunz, T.H., and R.A. Martin. 1982. *Plecotis townsendii*. Mammalian Species. No. 175. pp. 1-6.

Land and Water Consulting, Inc. 2004. Assessment of Fate and Transport of Copper in Decant Pond System – Troy Mine. Lincoln County, Montana. Prepared for Revett Mining Company. January 2004.

Lange, I. M., and Sherry, R. A. 1983. Genesis of the sandstone (Revett) type of copper-silver occurrences in the Belt Supergroup of northwestern Montana and northeastern Idaho: in Geology, v. 11, p. 643-646, November 1983.

Laudon, K. 2010. Personnal communication with M. Rockwell, KNF, dated September 24, 2010.

Leirfallom, J. 1970. Wolf management in Minnesota. *in*: Jorgensen, S.E., L.E. Faulkner, and L.D. Mech (eds.). Proceeding symposium on wolf management in selected areas of North America. USDI Fish and Wildlife Service. 50 pp. *In* Frederick, G. P. 1991. Effects of Forest Roads on Grizzly Bears, Elk, and Gray Wolves: A Literature Review. USDA Forest Service, KNF, 506 U.S. 2 West. Libby, MT. 53 pp.

Liknes, G.A. and P.J. Graham. 1988. Westslope cutthroat trout in Montana: life history, status, and management. American Fisheries Society Symposium. 4:53:60.

Lincoln County. 2004. Integrated Noxious Weed Management Plan http://www.lincolncountymt.us/weeds/index.html

Lincoln County. 2009. Personal Communication.

Lincoln County. 2010. Personal Communication with Planning Department.

Linkhart, B.D. 2001. Life history characteristics and habitat quality of flammulated owls (*Otus flammeolus*) in Colorado. Ph. D. Dissertation. University of Colorado, Boulder, CO. 221 pp.

Linkhart, B.D. and R.T. Reynolds. 1997. Territories of flammulated owls (*Otus flammeolus*): is occupancy a measure of habitat quality? Pages 250-254 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and Conservation of owls in the Northern Hemisphere. USDA Forest Service General Technical Report NC-190.

Linkhart, B.D., R.T. Reynolds, and R.A. Ryder. 1998. Home range and habitat of breeding flammulated owls in Colorado. Wilson Bulletin. 110(3):342-351.

Mack, C., J. Rachael, J. Holyan, J. Husseman, M. Lucid, B. Thomas. 2010. Wolf conservation and management in Idaho; progress report 2009. Nez Perce Tribe Wolf Recovery Project, P.O. Box 365, Lapwai, Idaho; Idaho Department of Fish and Game, 600 South Walnut, Boise, Idaho. 67 pp. http://www.fws.gov/mountain-prairie/species/mammals/wolf/annualrpt09/Idaho-Wolf-Progress-Report-2009.pdf

Mannan, R.W. 1977. Use of snags by birds, Douglas-fir region, western Oregon. M.S. thesis, Oregon State University, Corvallis, OR.

Maxell, B.A. 2000. Management of Montana's Amphibians: A Review of Factors that may present a Risk to Population Viability and Accounts on the Identification, Distribution, Taxonomy, Habitat Use, Natural History and the Status and Conservation of Individual Species. A Report (#43-0343-0-0224) to Northern Regional Office, USDA Forest Service. Missoula, MT 59807. 161 pp.

Maxell, B.A. 2010. Personal communication of B. Maxell, Montana Natural Heritage Program, with M. Rockwell, KNF, December 10.

Maxell, B.A., J.K. Werner, P. Hendricks, and D. Flath. 2003. Herpetology in Montana: A history, status summary, checklists, dichotomous keys, accounts for native, potentially native and exotic species, and indexed bibliography. Northwest Fauna 5. Society for Northwestern Vertebrate Biology. Olympia, WA. 138 pp.

McClelland, B.R. 1977. Relationship between hole-nesting birds, forest snags, and decay in western larch-Douglas-fir forests of the northern Rocky Mountains. Ph.D. dissertation, University of Montana. Missoula, MT. 495 pp.

McClelland, B.R. 1979. The pileated woodpecker in forests of the northern Rocky Mountains, pp. 283-299 *In* The role of insectivorous birds in forest ecosystems*,* Dickson, James G., R.N. Conner, R.R. Fleet, J.C. Kroll, and J.A. Jackson, (editors), Academic Press, New York, NY.

McClelland, B.R., and P.T. McClelland. 1999. Pileated woodpecker nest and roost trees in Montana: links with old-growth and forest health. Wildlife Society Bulletin. 27(3):846-857.

McClelland, B.R., S.S. Frissell, W.C. Fisher, and C.H. Halvorson. 1979. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. Journal of Forestry. 77 (8):480-483.

McIntyre, J.D. and B.E. Rieman. 1995. Westslope cutthroat trout. *In*: Young, M.K., technical editor. Conservation assessment for inland cutthroat trout. General Technical Report RM-256. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO.

McMaster, K. 1995. Amended Biological Opinion on Kootenai Forest Plan to include an Incidental Take Statement. Letter to R. Schrenk, Forest Supervisor. USDI Fish and Wildlife Service. Helena, MT. July 27. 15 pp.

Mellen, T.K. 1987. Home range and habitat use of pileated woodpeckers, western Oregon. M.S. thesis, Oregon State University, Corvallis, OR.

Mellen, T.K., E.C. Meslow, and R.W. Mannan. 1992. Summertime home range and habitat use of pileated woodpeckers in western Oregon. Journal of Wildlife Management 56 (1): 96-103. Memorandum to Job File No. 388, Spar Lake Project, 22 pp.

Montana Bald Eagle Working Group. 1991. Habitat management guide for bald eagles in northwestern Montana. USDA, Forest Service, Missoula MT. 29 pp.

Montana Bald Eagle Working Group. 1994. Montana bald eagle management plan. 2nd edition. Bureau of Reclamation. 104 pp.

Montana Bald Eagle Working Group. 2010. Montana Bald Eagle Management Guidelines: An Addendum to Montana Bald Eagle Management Plan, 1994, Montana Fish, Wildlife and Parks, Helena, Montana. http://fwpiis.mt.gov/content/getitem.aspx?id=44181

Montana Natural Heritage Program (MNHP). 1993. *Plecotus townsendii*, Townsend's big-eared bat. Vertebrate Characterization Abstract. 5 pp.

Montana Peregrine Institute. 2010. Data table: Montana Peregrine-Watch 2010 (territories active in 2009), Revised 8/13/2010. http://montanaperegrine.org/Activity__Productivity-2010.html

Murie, O.J. 1979. The elk of North America. Teton Bookshop. Jackson, WY. 376 pp.

Murphy and Lehnhausen. 1998. Density and foraging ecology of woodpeckers following a stand replacement fire. Journal of Wildlife Management. 62(4):1359-1372.

O'Connor, T. and M. Hillis. 2001 (unpublished report). Conservation of Post-fire habitat, blackbacked woodpeckers and other woodpecker species on the Lolo National Forest. Lolo National Forest. Missoula, MT.

Parametrix Environmental Research Lab. 2009. Final Annual Report – Year 24. Prepared by Parametrix, Albany, OR. August 2009.

Peng, S.S. 1992. Surface Subsidence Engineering. Society of Mining, Metallurgy, and Exploration. Littleton, CO. 161 pp.

Perkins, J.M. and T. Schommer. 1991. Survey protocol and an interim species conservation strategy for *Plecotus townsendii* in the Blue Mountains of Oregon and Washington. Wallowa- Whitman National Forest, P.O. Box 907, Baker City, OR. 23 pp.

Pierson, E.D., M.C. Wachenhut, J.S. Altenbach, P. Bradley, P. Call, D.L. Genter, C.E. Harris, B.L. Keller, B. Lengus, L. Lewis, B. Luce, K.W. Navo, J.M. Perkins, S. Smith, and L. Welch. 1999. Species conservation assessment and strategy for Townsend's big-eared bat (*Corynorhinus townsendii townsendii* and *Corynorhinus townsendii pallescens*). Idaho Conservation Effort, Idaho Department of Fish and Game. Boise, ID.

Powell, H.D. 2000. The influence of prey density on post-fire habitat use of the black-backed woodpecker. M.S. thesis, University of Montana, Missoula, MT. 99 pp.

Powell, R.A. and W.J. Zielinski. 1994. Fisher. Chapter 3 *In*: Ruggiero, Leonard F., K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. (tech. eds.). 1994. The Scientific Basis for Conserving Forest Carnivores American Marten, Fisher, Lynx and Wolverine in the Western United States. General Technical Report RM-254. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. 184 pp.

Powers, L.R., A. Danle, P.A. Gaede, C. Rodes, L. Nelson, J.J. Dean, and J.D. May. 1996. Nesting and food habits of the flammulated owl (*Otus flammeolus*) in south-central Idaho. Journal of Raptor Research. 30:15-20.

Redpath Engineering. 1991. Supplemental information in support of the environmental impact statement. Prepared for Noranda Minerals Corp.

Reel, S., W. Schassberger, and W. Ruediger. 1989. Caring for our natural community. Region 1. Threatened, Endangered, and Sensitive Species Program. USDA Forest Service, Region 1, Wildlife and Fisheries. 309 pp.

Reichel, J. and D. Flath. 1995. Identification of Montana's amphibians and reptiles. Montana Outdoors. 26(3):15-34.

Rieman, B.E. and K.A. Apperson. 1989. Status and analysis of salmonid fisheries: westslope cutthroat trout synopsis and analysis of fishery information, Idaho Department of Fish and Game.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report INT-302, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Rogers, R. and J. Sumner. 2004. Montana peregrine falcon survey. Montana Department of Fish, Wildlife, and Parks, Bozeman, MT. 32 pp.

Ross, A. 1967. Ecological aspects of the food habits of insectivorous bats. Proc. Western Foundation of Vertebrate Zoology. 1:205-264.

Ruediger, B.J. 1994 (unpublished). Wolverine, Lynx, and Fisher habitat and distribution maps, draft hierarchical approach and draft conservation strategies. USDA Forest Service 2670 letter 9/14/1994. Region 1, Missoula, MT. 5 pp. plus attachments.

Ruggiero, L.F., G.D. Hayward, and J.R. Squires. 1994. Viability Analysis in Biological Evaluations: Concepts of Population Viability Analysis, Biological Population, and Ecological Scale. Conservation Biology. 8(2):64-372

Ruggiero, L.F., K.B. Aubry, S.W. Buskirk (and others). 2000. Ecology and Conservation of Lynx in the United States. University Press of Colorado. Boulder, CO. 480 pp.

Saskatchewan Environment and Public Safety. 1992. Mine Rock Guidelines, Design and Control of Drainage Water Quality. Report 93301, Mines Pollution Control Branch. (Steffen, Robertson, Kirsten, Inc. preparer). April.

Schrenk, R. L. 1995. Grizzly bear analysis/Forest Plan standards for fire recovery projects. Internal 1950 memo, May 30, 1995. USDA Forest Service, Kootenai NF, Libby, MT. 5 pp.

Servheen, C., J.S. Waller, and P. Sandstrom. 2003. Identification and management of linkage zones for grizzly bears between the large blocks of public land in the northern Rocky Mountains. USDI Fish and Wildlife Service, University of Montana, Missoula, MT. 89 pp.

Sime, Carolyn A., V. Asher, L. Bradley, K. Laudon, N. Lance, and M. Ross, and J. Steuber. 2010. Montana gray wolf conservation and management 2009 annual report. Montana Department of Fish, Wildlife & Parks. Helena, MT. 173 pp. Available at: http://www.fws.gov/mountain-prairie/species/mammals/wolf/annualrpt09/2009_MT_Wolf_Annual_Report_03-11-10.pdf

Skaar, D. 1989. Montana common loon management plan. For: Flathead National Forest. Kalispell, MT. 61 pp.

Steffen, Robertson, Kirsten, Inc. (SRK). 2005. Independent Technical Report on the Troy Cu-Ag Project, MT. Toronto, ON, January.

Summerfield, R.L. 1991. Coordinating Big game and Grizzly bear standards. Internal 2600 memo, December 2. USDA Forest Service. Libby, MT. 4 pp.

Summerfield, B., W. Johnson, and D. Roberts. 2004. Trends in road development and access management in the Cabinet-Yaak and Selkirk grizzly bear recovery zones. Ursus 15(1) Workshop Supplement: pp. 115-122.

Summit Envirosolutions. 1996. Interim report of findings hydrologic and hydrogeologic assessment, ASARCO Troy Mine, Troy MT.

Summit Envirosolutions. 1999. Site Instrumentation Status Report Troy Tailings Impoundment, Lincoln County, MT.

Tetra Tech and R Squared. 2006. Final Geotechnical Assessment Report Sinkhole Development at the Troy Mine and Implications for the Proposed Rock Creek Mine Lincoln and Sanders Counties, MT. June.

Thiel, R.P., S. Merrill, and L.D. Mech. 1998. Tolerance by denning wolves, *Canis lupus*, to human disturbance *In:* Joslin, G. and H. Youmans, coordinators. Effects of recreation on Rocky Mountain wildlife: A Review for Montana. Committee on Effects of Recreation on Wildlife. Montana Chapter of the Wildlife Society. 307 pp.

Thomas, J.W. (tech. ed.). 1979. Wildlife Habitats in Managed Forests, the Blue Mountains of Oregon and Washington. USDA Forest Service, Agricultural Handbook No. 553. Wildland Management Institute. Washington, DC.

Thomas, D.W. and S.D. West. 1991. Forage age associations of bats in the Washington Cascade and Oregon Coast Ranges. In: Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-285. Portland, OR. pp. 295-303.

Thunstrom, Eric. 2006. Air Quality Permit #3788-00 Application issued to Mines Management Inc., Montanore Mine.

Toweill, D.E. and J.W. Thomas. (eds.). 2002. North American elk: ecology and management. Smithsonian Institution Press. Washington, DC. 962 pp.

U.S. Bureau of Labor Statistics. 2010. Local Area Unemployment Statistics Information and Analysis, States and selected areas: Employment status of the civilian non-institutional population, 1976 to 2009 annual averages.

U.S. Census Bureau. 2010. State and County QuickFacts.

USDI Fish and Wildlife Service (USFWS). 1978. Recovery plan for the eastern timber wolf. U.S. Gov. Printing Office, Washington, D.C. 79 pp. IN: Frederick, Glenn P. 1991. Effects of Forest Roads on Grizzly Bears, Elk, and Gray Wolves: A literature review. USDA Forest Service, Kootenai NF, Libby, MT. 53 pp.

USDI Fish and Wildlife Service (USFWS). 1984. American Peregrine Falcon Rocky Mountain/Southwest Population Recovery Plan. Prepared in cooperation with the American Peregrine Falcon Recovery Team. USFWS, Denver, CO. 105 pp.

USDI Fish and Wildlife Service (USFWS). 1987. Northern Rocky Mountain Wolf Recovery Plan. U.S. Fish and Wildlife Service, Denver, CO. 119 pp.

USDI Fish and Wildlife Service (USFWS). 1993. Grizzly bear recovery plan. Missoula, MT. 181 pp.

USDI Fish and Wildlife Service (USFWS). 1995. Endangered and threatened wildlife and plants; final rule to reclassify the bald eagle from endangered to threatened in all of the lower 48 States. 50 CFR Part 17. *Federal Register*, Vol. 64, No. 128, July 12th. pp. 35999-36010.

USDI Fish and Wildlife Service (USFWS). 1999a. Endangered and threatened wildlife and plants; proposed rule to remove the bald eagle in the lower 48 states from the list of endangered and threatened wildlife. 50 CFR Part 17. *Federal Register*, Vol. 64, No. 128, July 6th. pp. 36454-36464.

USDI Fish and Wildlife Service (USFWS). 1999b. Final rule to remove the American peregrine falcon from the federal list of endangered and threatened wildlife. *Federal Register* August 25, 1999. pp. 46541-46557

USDI Fish and Wildlife Service (USFWS). 2001. U.S. Fish and Wildlife Service March 6, 2001 Concurrence letter from Mark R. Wilson, on maps of threatened and endangered species potential distribution on the Kootenai National Forest. 2 pp. (plus attachments). U.S. Fish and Wildlife Service, Montana Ecological Services Field Office, Helena, MT 59601.

USDI Fish and Wildlife Service (USFWS). 2007a. Supplement to the Biological Opinion on the Effects to Grizzly Bears, Bull Trout, and Bull Trout Critical Habitat from the Implementation of Proposed Actions Associated with Plan of Operations for the Revett RC Resources Incorporated Rock Creek Copper/Silver Mine. Montana Ecological Services Field Office. 169 pp.

USDI Fish and Wildlife Service (USFWS). 2007b. National Bald Eagle Management Guidelines. 23 pp.

USDI Fish and Wildlife Service (USFWS). 2007c. Biological opinion on the effects of the northern Rocky Mountains lynx amendment on the distinct population segment (DPS) of Canada lynx (*Lynx canadensis*) (lynx) in the contiguous United States. U.S. Fish and Wildlife Service, Montana Ecological Services Field Office, Helena, MT. 59601.

USDI Fish and Wildlife Service (USFWS). 2007d. Biological Opinion on the effects of the Northern Rocky Mountains NRLMD on the Distinct Population Segment (DPS) of Canada Lynx (*Lynx Canadensis*) (Lynx) in the contiguous United States. USFWS Helena, MT. 95 pp.

USDI Fish and Wildlife Service (USFWS). 2009. Endangered and Threatened Wildlife and Plants; Final Rule To Identify the Northern Rocky Mountain Population of Gray Wolf as a Distinct Population Segment and To Revise the List of Endangered and Threatened Wildlife. *Federal Register.* April 2, 2009. pp. 15123-15188.

USDI Fish and Wildlife Service (USFWS). 2010. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States; Final Rule. *Federal Register*. Docket No. FWS-R1-ES-2009-0085.

USFS. 1977. Unpublished data.

USFS. 1986. ROS Book. U.S. Department of Agriculture, Forest Service, Washington Office.

USFS. 1987. Kootenai National Forest Forest Plan, Vol. 1. Northern Region, Forest Service, USDA. September.

USFS. 1995. Environmental Assessment: Decision Notice and Finding of No Significant Impact. Interim Strategies for managing fish-producing watersheds in eastern Oregon and Washington, Idaho, western Montana and portions of Nevada. USDA, Forest Service, Intermountain, Northern, and Pacific Northwest Regions.

USFS. 2001. FSM 2000 – National Forest Resource Management Zero Code 2080 – Noxious Weed Management. USDA Forest Service, Region 1. Missoula, MT.

USFS. 2003. Northern Region Landbird Monitoring Program. Summary report for pileated woodpecker, winter wrens, and brown creeper for the Region and KNF. Unpublished summary report compiled by Jock Young, January 2003, Missoula, MT. 4 pp.

USFS. 2004. Draft Environmental Impact Statement Northern Rockies Lynx Amendment National Forests in Montana, parts of Idaho, Wyoming and Utah Bureau of Land Management Units in Idaho and parts of Utah. USDA Forest Service, USDI Bureau of Land Management. Northern Region, Missoula, MT. 416 pp. Available at: http://www.fs.fed.us/r1/planning/lynx.html.

USFS. 2007. Final Environmental Impact Statement, Northern Rockies Lynx Management Direction. USDA Forest Service, Northern Region. Missoula, MT. March.

USFS. 2008. Draft Supplemental Environmental Impact Statement Forest Plan Amendments for Motorized Access Management Within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones Kootenai, Lolo, and Idaho Panhandle National Forests, Montana and Idaho.

USFS. 2009a. The Forest Service Manual. National Office, Washington, DC.

USFS. 2009b. Meeting Notes: Grizzly Bear Access Amendment-Level 1 Meeting, Bears Outside Recovery Zone (BORZ) Review, August 20, Kootenai, National Forest, Libby, MT.

USFS. 2010. Selkirk and Cabinet-Yaak grizzly bear recovery zones 2009 annual monitoring summary report. Idaho Panhandle, Kootenai, Lolo, and Colville National Forests. 9 pp.

U.S. Geological Survey, 1996. Ground Water Atlas of the United States, Montana, North Dakota, South Dakota, Wyoming. Available at http://pubs.usgs.gov/ha/ha730/gwa.html.

Vinkey, R. 2003. An Evaluation of Fisher (*Martes pennanti*) Introductions in Montana. Missoula, MT: University of Montana. M.S. thesis. 97 pp.

Wakkinen, W. and W. Kasworm. 1997. Grizzly Bear and Road Density Relationships in the Selkirk and Cabinet-Yaak Recovery Zones. Idaho Department of Fish and Game (Bonners Ferry, ID) and USFWS. Libby, MT. 28 pp.

Warren, N. (tech. ed.). 1990. Old-growth habitats and associated wildlife species in the northern Rocky Mountains. USDA Forest Service, Missoula, MT. 47 pp.

Werner, J. K., and J.D. Reichel. 1994. Amphibian and reptile surveys of the Kootenai National Forest, 1994. Montana Natural Heritage Program, Helena MT. 104 pp.

Werner, J.K. and J.D. Reichel. 1996. Amphibian and reptile monitoring/survey of the Kootenai National Forest: 1995. Helena, MT: Montana Natural Heritage Program. 115 pp.

Werner, J.K., B.A. Maxell, P. Hendricks, and D. Flath. 2004. Amphibians and Reptiles of Montana. Mountain Press Publishing Company. Missoula, MT. 262 pp.

Whitaker, J.O., C.E. Maser, and L.E. Keller. 1977. Food habits of bats of western Oregon. Northwest Sci. 51:46-55.

Whittaker, B.N. and D.J. Reddish. 1989. Subsidence: Occurrence, Prediction and Control. Elsevier Science Publishers, Amsterdam.

Wright, V. 1996. Multiscale analysis of flammulated owl habitat use: owl distribution, habitat management, and conservation. M.S. thesis. University of Montana, Missoula, MT. 91 pp.

Wright, V., S.J. Hejl, and R.L. Hutto. 1997. Conservation implications of a multi-scale study of flammulated owls (*Otus flammeolus*) habitat use in the northern Rocky Mountains, USA. pp. 506-516. *In* J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and Conservation of owls of the Northern Hemisphere. USDA Forest Service General Technical Report NC-190.

Young, David, K. 1993. Rock Mechanics Analysis, for ASARCO Incorporated, Rock Creek Project, September 9, 1994.