MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

Partial Alluvial Valley Floor Determination

For the Otter Creek Watershed In and Adjacent to the Proposed Otter Creek Mine

Industrial and Energy Minerals Bureau, Coal and Uranium Program, P.O. Box 200901, Helena, MT 59620

February 2016

Determination of the presence or absence and extent of a potential alluvial valley floor within and adjacent to the proposed Otter Creek mine.

Table of Contents

I. Regulatory Framework 2

II. Presence or Absence 2

Analysis of Presence or Absence 2

The Otter Creek Valley in the Vicinity of the Proposed Otter Creek Mine 3

Geology and Soils: 4

Hydrology: 5

1. Unconsolidated Streamlaid Deposits 5

Otter Creek 6

Tenmile Creek 8

Fortune Coulee 8

Threemile Creek 9

Gene and Newell Creeks 10

Unnamed Tributaries 10

2. Sufficient Water to Support Agricultural Activities 10

a. The Existence of Current or Historic Flood Irrigation 10

b. Capability of the Area to be Flood Irrigated 11

c. The Existence of Subirrigation 11

Presence or Absence Conclusion 16

References 17

I. Regulatory Framework

The Montana Strip and Underground Reclamation Act § 82-4-201 through 82-4-254, MCA, and its implementing rules, Administrative Rules of Montana (ARM) 17.24.301 through 17.24.1309 ("MSUMRA"), specifically, § 82-4-227(3) (b) (i) MCA], and ARM 17.24.301, 17.24.325, and 17.24.805 set forth the process for identifying an alluvial valley floor (AVF) located in the arid and semi-arid lands of Montana. Any mine proposal or mine related disturbance within a valley holding a stream, or adjacent to and connected to a valley holding a stream, must have an AVF determination. MSUMRA requires protection of identified AVFs from impacts of coal mining that are adverse to agricultural activities or farming.

An AVF determination consists of three separate evaluations. The first evaluation determines the presence and extent or absence of AVFs based on defined criteria. The second evaluation determines the significance of the AVF for adversely affected agricultural or farming operations. The third evaluation determines the essential hydrologic functions of each agriculturally significant AVF.

As explained in detail, below, both geologic and hydrologic criteria must be met to designate an AVF. The key to the existence of an AVF is the presence of both geomorphic characteristics and water availability for agricultural activities or farming.

II. Presence or Absence

Analysis of Presence or Absence

Section 82-4-203(3)(a), MCA, defines an AVF as: "the unconsolidated stream-laid deposits holding streams where water availability is sufficient for subirrigation or flood irrigation agricultural activities." Section 82-4-203(3)(b), MCA, distinguishes "upland areas that are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion and deposits by unconcentrated runoff or slope wash, together with talus, other mass movement accumulation, and windblown deposits" from AVFs. Uplands is further defined in ARM 17.24.301 (136) as "with respect to alluvial valley floors, those geomorphic features located outside the floodplain and terrace complex, such as isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits, and surfaces covered with residuum, mud flows or debris flows, as well as highland areas underlain by bedrock and covered by residual weathered material or material deposited by sheetwash, rillwash, or wind."

Alluvium and colluvium are deposits of materials resulting from erosion and deposition. Alluvium is a general term for materials deposited by water, including gravel, sand, silt, clay, and all the variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated (Brady and Weil). Colluvium is a deposit of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action (Brady and Weil). Both of these processes of transport result in unconsolidated material on the earth's surface.

According to the Dictionary of Geologic Terms, "Colluvial material can consist of alluvium in part also containing angular fragments of the original rocks." Colluvium may be mixed with alluvium. Various

processes may account for this. For example, alluvial stream channel deposits may slide down terrace banks resulting in new colluvial deposits.

The definition of AVF is further clarified as "unconsolidated streamlaid deposits holding streams" as "all flood plains and terraces located in the lower portions of valleys which contain perennial or other streams with channels." ARM 17.24.301(132). This definition of unconsolidated deposits allows for colluvium as defined above to be contained in a terrace or floodplain of an AVF. Therefore, the presence of surface colluvium does not exclude a stream from AVF status. The underlying geology rather than surface deposition dictates a determination of alluvial or colluvial character in a valley floor.

ARM 17.24.325(2)(b) sets forth the procedure for determining the presence or absence of an AVF:

> Based on the investigations conducted under [17.24.325(2)](a), the department shall make a written determination of the extent of any alluvial valley floors within the study area and whether any stream in the study area may be excluded from further consideration as lying within an alluvial valley floor. The department shall determine that an alluvial valley floor exists if it finds that:
> (i) unconsolidated streamlaid deposits holding streams are present; and
> (ii) there is sufficient water to support agricultural activities as evidenced by:
> (A) the existence of current flood irrigation in the area in question;
> (B) the capability of the area to be flood irrigated, based on typical regional agricultural practices, historical flood irrigation, stream-flow, water yield, soils, water quality, and topography; or
> (C) subirrigation of the lands in question, derived from the ground water system of the valley floor; and
> (iii) the valley does not meet the definition of upland areas in ARM 17.24.301.
> (c) If the department determines in writing that an alluvial valley does not exist pursuant to (b), no further consideration of this rule is necessary;

Finally stream valleys "adjacent" to proposed mining operations must be evaluated for the presence or absence of AVFs. "Adjacent" is also a defined term under MSUMRA and means in pertinent part, "the area outside the permit area where a resource or resources, determined in the context in which the term is used, are or could reasonably be expected to be adversely affected by proposed mining operations." § 82-4-203(2), MCA.

The Otter Creek Valley in the Vicinity of the Proposed Otter Creek Mine

Otter Creek is a perennial tributary of the Tongue River in the semi-arid to arid region of southeast Montana. See Map 1, Project Overview. The confluence with the Tongue River is near the town of Ashland, Montana, approximately 7 straight line miles (19 stream miles) downstream from the proposed mine. Otter Creek's drainage basin is approximately 700 square miles. Otter Creek and a number of its tributaries are perennial, intermittent, and ephemeral streams that occupy valleys adjacent to the proposed operations of the Otter Creek mine.

Stream valleys on adjacent lands that may be affected by the proposed operations may be identified by proposed permit boundaries and coal leases obtained by the applicant, Otter Creek Coal, L.L.C. Otter Creek Coal has obtained leases for the state and private coal reserves for a large block within the Otter Creek drainage. The area is broken into proposed mining Tracts 1, 2, and 3. See Map 1, Project Overview. Tract 1 is east of Otter Creek primarily north of Threemile Creek running north to Home Creek and bordered by Custer National Forest (CNF) to the East. Tract 2 is primarily east of Otter Creek and generally bounded by Tenmile Creek to the south, Threemile Creek to the north, and bordered on the east by the CNF. Tract 3 is west of Otter Creek bounded by CNF on the south and west and the Township 3 and 4 South, boundary line to the north. Currently only an application for the Tract 2 area has been submitted; therefore, this AVF determination is limited to Tract 2.

Portions of the Otter Creek valley and valleys of tributaries of Otter Creek in areas within and adjacent to the proposed Otter Creek Mine are located completely within Township 4 South, Range 45 East and in all or portions of Sections 3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 22, 23, 24, 25, and 26. The proposed mining in Tract 2 is on the east side of Otter Creek running between Tenmile Creek at the south to Threemile Creek north of the project.

Three named tributary drainages flow west into Otter Creek; Threemile Creek, Fortune Coulee, and Tenmile Creek. Two named tributaries flow east into Otter Creek; Gene Creek and Newell Creek. Fortune Spring which is also referred to as Fortune Coulee is the only named stream proposed to be mined and reclaimed as a part of Tract 2. There are eight other unnamed tributaries within the proposed mine area. The nameless tributaries fit the upland definition by not having substrata of alluvium and are highland areas outside the terrace complex of Otter, Threemile or Tenmile Creeks. Mine facilities, including the office and maintenance facilities, and railroad, are proposed for areas outside of the Otter Creek valley floor. Two crossings are proposed across the main stem of Otter Creek in Tract 2. One crossing will be used for mine access and a second crossing will be for a conveyor system to transfer coal from the mine area to the railroad loadout. These two corridors will be the only direct surface impacts to the Otter Creek channel and valley floor within the AVF boundary. See Map 2A, Project Detail. Additional mining impacts will be discussed during the hydrologic function analysis.

A previous AVF determination in the Otter Creek drainage was completed in 1985 (DSL, 1985). The 1985 determination was for a reach of Otter Creek located approximately 8 straight-line miles upstream (south) of the current site in Township 6 South, Range 46 East, MPM, Section 6: SW1/4 SE1/4; and Section 7: W1/2NE1/4, E1/2W1/2, and NW1/4 SE1/4. See Map 1, Project Overview. Although the earlier AVF study determined that the subject reach of Otter Creek qualified as a significant AVF, the reach is sufficiently removed from the proposed action to render that decision irrelevant to this one.

Geology and Soils:

As explained above, the first step in determining the presence or absence of an alluvial valley floor is to identify valleys with streams holding unconsolidated streamlaid deposits. Unconsolidated stream-laid deposits are alluvium. In the Otter Creek drainage, the subject of this evaluation, the parent (source) materials for alluvium are derived from the Tongue River Member of the Fort Union formation. The source materials for these alluvial deposits are sandstone and clinker capped buttes that are underlain by

softer strata (USDA 1980). Through time, the source materials have been eroded and deposited in the drainages and lowlands as alluvium. The alluvium is sorted into finer silts and clays on floodplains that lie over coarser clinker gravels and fine sands. Monitoring well logs may refer to these materials in descriptions of alluvium.

The baseline soil survey indicates that the Otter Creek flood plain is composed of finer textured materials consisting primarily of fine silty to clayey loam soils found in the surface horizons (soil Layers) with coarser loamy textures in the lower horizons. Coarse fragments are few and generally confined to gravel lenses in the deeper horizons (Application C2012018 – 1d). These surface horizons rest on soil with a roughly even mixture of sand, silt, and clay called loam. All of these soil types lie over gravels which occur at the greatest depths in the soil column. This is a typical layering of soil horizons. When water transports earthen materials the largest particles, gravels and then sands, settle out first. As flow slows, smaller and lighter particles settle out. The smallest and lightest particles, silty then clayey particles, settle out last generally to be found in the surface horizons.

Hydrology:

The geomorphology of Otter Creek and its tributaries falls into two general categories. The first category includes the main-stem channels of Otter, Tenmile, and Threemile Creeks, characterized by meanders within a lower gradient valley consisting of alluvium. A second category includes erosional channels represented by upland tributaries like Fortune Coulee, where the channel is characterized by an incision formed on a steeper gradient slope and lacks major depositional zones and meanders. The low gradient valleys support agricultural production adjacent to the active stream channels. In contrast, erosional channels flow through rangeland, where runoff is directed to flood irrigation on the lower gradient valleys, used in stock watering ponds, or not captured for use.

The presence of erosional drainages informs the Department's determination. The Department must identify the characteristics of the AVF that are necessary to preserve the essential hydrologic functions of the AVF throughout the mining and reclamation process. ARM 17.24.325(3)(c)(ii)(A). The agricultural floodplains and terrace areas receiving the erosional channel water are considered in-flow fields and are discussed below in relation to the existence of flood irrigation. Even though an erosional drainage does not contain sufficient alluvium to support agriculture, the seasonal runoff through erosional drainages may be necessary to the essential hydrologic function of an AVF.

1. Unconsolidated Streamlaid Deposits

The presence of unconsolidated streamlaid deposits in Otter Creek and its tributaries may be ascertained by use of maps, field geology, and monitoring well and piezometer drill logs. The monitoring well logs are presented in Appendix A of the permit application; Otter Creek Mine Baseline Report 304E, Monitoring Well Logs (Application C2012018 – 1a). Monitoring well locations are marked on Map 2A, Project Detail. Specific well logs were examined to demonstrate the distribution of alluvial materials throughout the Otter Creek AVF study area.

For the purposes of this presence or absence determination, the reach of Otter Creek from Tenmile to Threemile Creek was considered. These three creeks are directly adjacent and bound three sides of the

proposed mine area. If these drainages are determined to be significant AVFs for farms or ranches, the next step, if necessary, will be to expand the scope of the AVF study area to include more drainages. This reach of Otter Creek includes Threemile Creek, Fortune Coulee, and Tenmile Creek joining from the east, and Gene Creek and Newell Creek joining from the west. Geologic alluvial well log data for individual drainages are discussed, below.

Otter Creek

This determination evaluates information from monitoring well numbers A3, A7, A6 and A1, located in the Otter Creek valley. See Map 2A, Project Detail. Wells are evaluated sequentially from south to north starting at the upstream end near Tenmile Creek and working downstream to Threemile Creek.

Logs for wells A3, A7, A6 and A1 indicate the presence of unconsolidated streamlaid deposits (alluvial material) beginning up to five feet below a soil surface layer. The well log for well number A3 indicates the presence of alluvial material from 5 to 57 feet below ground surface. The well log for well number A7 indicates the presence of alluvium from 5 to 43.5 feet below ground surface. The well log for A6 indicates the presence of alluvium from 5 to 23 feet below ground surface, and the well log for well number A1 indicates alluvium from 2 to 15 feet below ground surface. These well logs indicate the presence of unconsolidated streamlaid deposits in the current Otter Creek valley at a depth and to an extent sufficient to qualify the Otter Creek valley floor for consideration as an AVF upstream, downstream, and throughout the interval where wells A3, A7, A6 and A1 are located. These specific well logs demonstrate the channel length extent of alluvial deposits in the Otter Creek valley floor within the area being considered.

To demonstrate the width of unconsolidated streamlaid deposits, three series of AVF monitoring wells were located across Otter Creek, or a tributary valley. See Map 2A, Project Detail. The monitoring wells are drilled into terraces on either side of the stream channel in the valley floor. For this determination, terrace is a level, or nearly level, plain bordering a river or stream. Rivers or streams sometimes are bordered by terraces at different levels (Brady and Weil, 2010). In eastern Montana river valleys are often characterized by a series of terraces descending in elevation from the valley margins toward the stream channel.

Of the three monitoring well series, two are located within the Otter Creek valley while the third is located in the Threemile Creek drainage downstream of the proposed mine. The two series of monitoring wells located in the Otter Creek valley are identified as AVF 4 and AVF 3, located upstream to the south in section 27, and downstream to the north in section 15, respectively, within the proposed Tract 2 permit boundary. See Map 2A, Project Detail.

Monitoring well series AVF 4 consists of four wells designated AVF 4 – 1 through AVF 4 – 4, which are located on separate valley terraces that differ in surface elevation by 7-feet. Wells AVF 4 – 1 and AVF 4 – 4 are located on terraces that are closer to the Otter Creek channel, while wells AVF 4 – 2 and AVF 4 – 3 are located on higher terraces away from Otter Creek on the east and west margins of the Otter Creek valley, respectively. The four well logs indicate alluvial materials ranging from 4 to 37 feet thick.

Monitoring well series AVF 3 contains four wells identified as AVF 3 – 1 through AVF 3 – 4 that represent multiple terraces spanning the width of Otter Creek. The wells are located laterally east to west across the Otter Creek valley. See Map 2A, Project Detail. The four well logs describe alluvial materials ranging from 14 to 70 feet thick below silty soils with colluvial materials within the channel and terrace complex.

Monitoring well number AVF 3 – 3 is located on the east side of Otter Creek at a surface elevation approximately 10 feet above the terraces closer to Otter Creek which contain well numbers AVF 3 – 1 and AVF 3 – 2. Well number AVF 3 – 4 is located on a terrace to the west side of Otter Creek, 20 feet below the terrace of well number AVF 3 – 3. Monitoring wells AVF 3 – 1 and AVF 3 – 2, near the Otter Creek channel, exhibit 70- and 43-foot thick layers of alluvial materials, respectively. Wells AVF 3 – 3 and AVF 3 – 4 are located away from the main channel on higher terraces of Otter Creek. The well log for well number AVF 3 – 3 indicates an alluvial layer 41 feet thick and well AVF 3 – 4 indicates a 14-foot sand and gravel layer below ground surface. Note the different terminology per monitoring well log here. One well log designates alluvial material where the other refers to it as sand and gravel layers which are alluvial by nature. In all cases these are all evidence of unconsolidated streamlaid deposits in the Otter Creek valley.

These two series of AVF monitoring wells demonstrate the difference in terrace structure in the Otter Creek valley. The AVF 4 series of monitoring wells provides a cross section of alluvium in the Otter Creek valley on terraces with elevations that fall within 7 feet of elevation. The AVF 3 series of monitoring wells demonstrates various extents of alluvium across the Otter Creek valley with terraces varying in elevation by 20 feet. The variability in terrace elevation shows how Otter Creek has altered the initial alluvial deposits. These alterations show how a lower terrace in the alluvium following stream cutting and slope collapse from higher elevation terraces now demonstrates colluvium above alluvium. The layering of colluvium over alluvium in this manner integrates such areas of colluvium for consideration.

In addition to alluvial monitoring wells, 15 shallow alluvial wells, or piezometers, were installed in the Otter Creek floodplain (Application C2012018 – 1c). Installed in August 2013, piezometers are located in 4 separate series spread downstream through the Otter Creek floodplain. See Map 2B, Project Detail. At each series location, 3-4 piezometers are installed across the floodplain perpendicular to streamflow direction. During installation, geologic data were recorded for each piezometer installation, which are summarized below.

Piezometers were installed to depths ranging from 8 to 16 feet below ground surface, and screened in shallow alluvium at intervals ranging from 4 to 16 feet deep. Piezometer drill logs indicate the presence of unconsolidated streamlaid deposits consisting of gravels, sands, silts, and clays in the Otter Creek valley further demonstrating the predominance of those materials in the main stem of Otter Creek.

Geologic and hydrologic characteristics measured in the Otter Creek valley floor indicate extensive unconsolidated alluvial materials. The exploration and monitoring efforts described above show sufficient evidence that the reach of Otter Creek in this evaluation is an alluvial valley floor.

Tenmile Creek

One monitoring well, A4, is located in the main stem channel of Tenmile Creek, and two monitoring well series, B7 in section 36, and B12 in section 31, are located on tributaries north of the main stem channel of Tenmile Creek to the southeast and outside of the proposed mine permit. The tributaries flow north to south toward Tenmile Creek. See Map 2A, Project Detail.

The monitoring well log for well A4 in the Tenmile Creek main stem indicates the presence of alluvial materials from the surface to approximately 68 feet below ground surface. The A4 monitoring well indicates the presence of alluvium upstream of the Otter Creek/Tenmile Creek confluence south of the southern boundary of Tract 2, through Township 5S, Range 45E, Section 1 N1/2 NE1/4. The Geologic map (Application C2012018 – 1f) also indicates alluvial material continuing to the south upstream of well A4 in Tenmile creek.

An unnamed tributary monitoring well series, B12, in section 31, indicates the presence of unconsolidated materials; however, those materials appear to be layers of colluvium and broken sandstone rather than streamlaid or altered alluvium. Accordingly, the deposits described by the B12 series qualify as upland deposits rather than an alluvial valley floor deposit in contrast to those described in Otter Creek, above. The unnamed tributary monitoring wells of the B7 series in section 36 begin in bedrock at the surface. Wells B12 and B7 indicate upland areas rather than unconsolidated streamlaid deposits.

The main stem of Tenmile creek through monitoring well A4 section 1, exhibits unconsolidated streamlaid deposits consistent with AVF criteria. However, alluvium is not present in upland tributaries as demonstrated by B7 and B12 monitoring well series north of Tenmile Creek in sections 36 and 31 respectively. Therefore, unconsolidated streamlaid deposits are predominant only in the main stem of Tenmile Creek. The extent of monitoring well A4 in Section 1, is the known upstream extent of alluvium; however, alluvium may extend beyond this point in the main stem channel.

Fortune Coulee

Fortune Spring drains through Fortune Coulee in sections 25, 26, and the extreme northeastern corner of section 27, into Otter Creek through an erosional channel that is characteristic of upland rather than an alluvial drainage. Fortune Coulee meets the criteria for upland by being a highland erosional channel outside the Otter Creek floodplain and terrace complex because it does not contain any flat lands large enough for agricultural activity or farming.

One monitoring location in section 26 contains two monitoring wells, K-2 and K-6. These wells are located in the upland near the confluence with Otter Creek. Both well logs indicate upland conditions rather than unconsolidated alluvial materials. The surface elevations of the monitoring wells are approximately 60 to 80 feet above the elevation of the Fortune Coulee bottom. The Department recognizes that the geologic map (Application C2012018-1F) indicates alluvial deposits in the Fortune Coulee bottom. However, the drainage is characteristic of upland, and therefore excluded from being an AVF. No alluvial deposit verification wells were required.

Where it meets Otter Creek, Fortune Coulee is a source of surface water used for flood irrigation; thus, it is included as waters contributing to Otter Creek AVF enhancement. In this case, Fortune Coulee acts as a conduit to provide water to agricultural fields in the Otter Creek valley, though does not support an AVF within its drainage area. Fortune Coulee will be evaluated as a source that may support the essential hydrologic function of the Otter Creek AVF in the Hydrologic Functionality analysis.

Threemile Creek

Threemile Creek is located north of the mine disturbance and straddles the boundary of Tracts 1 and 2. Threemile Creek is fed by a number of north-flowing tributaries that originate to the south, inside Tract 2. The drill log for monitoring well A5, located at Township 4S, Range 45E, Section 12 NW1/4 NW1/4, indicates the presence of unconsolidated streamlaid deposits to a depth of 28 feet where bedrock is encountered. In the 28 feet above bedrock there is a layer of sand and gravel from 12 to 26 feet. The surface 12-foot layer consists of silty clay mixed with sand and gravel noted to be wet at 5 feet. These layers represent unconsolidated alluvial deposits.

Upland monitoring well series B6 is in Section 12 in an unnamed north-flowing tributary. This tributary contains a reservoir and is the largest north flowing feeder stream of Threemile Creek within Tract 2. The B6 well series show that the geologic material consists of colluvium at the surface and various layers of siltstone and mudstone down to bedrock. Here the colluvium is not associated with any unconsolidated alluvial deposition.

Lateral extent of unconsolidated materials is indicated by a series of alluvial monitoring wells located in the Threemile Creek drainage near the confluence with Otter Creek. This series of monitoring wells, numbered AVF 6 – 1 through AVF 6 – 5, are all located on terraces with elevations ranging from 3,036 to 3,046 feet. The well logs indicate interbedded colluvium and alluvium surface layers up to ten feet deep. The interbedded colluvium disappears below ten feet and alluvium is found 10 to 66 feet below ground surface. These monitoring points indicate sufficient alluvium to meet the AVF criteria.

Well logs located in the main stem of Threemile Creek through Section 12 indicate unconsolidated streamlaid deposits consistent with AVF criteria. Monitoring site B6, located in a side tributary of Threemile Creek, Section 12, indicates beddings of siltstone and shale with colluvium. This site indicates a lack of alluvial material outside the main channel of Threemile Creek. There are at least three other unnamed tributaries flowing south to north into Threemile Creek. All of these unnamed tributaries are upland erosional channels outside of the Threemile Creek floodplain and terrace complex and meet criteria for upland. Additionally, there is no evidence of agricultural activities or of flat areas of sufficient size to support agricultural activities or farming in these drainages.

Threemile Creek geologic and hydrologic data discussed above indicates sufficient unconsolidated alluvial materials to determine the main stem of Threemile Creek an AVF. The extent of monitoring well A5 in Section 12 is the known upstream extent of alluvium; however, alluvium may extend beyond this point in the main stem channel.

Gene and Newell Creeks

Gene and Newell Creeks flow into Otter Creek from the west in Township 4S, Range 45E, Sections 34 and 22 respectively. These drainages are highland erosional channels that lie outside the Otter Creek floodplain and terrace complex. They are characterized by a lack of unconsolidated streamlaid deposits and do not qualify as AVFs. These drainages provide surface runoff used for irrigation of the agricultural fields associated within the Otter Creek AVF and will be evaluated as sources that may support the essential hydrologic function of the Otter Creek AVF in the Hydrologic Functionality analysis.

Unnamed Tributaries

There are 8 unnamed drainages located within Tract 2. These drainages can be identified as narrow branched valleys on Maps 2A and 2B. Some of these are the drainages mentioned in the discussions for Tenmile and Threemile creeks. The others are tributaries to Otter Creek. In all cases they meet criteria for upland in that they are highland erosional channels outside the terrace structure of the AVF streams they flow to and do not contain streamlaid deposits. Another distinction of these drainages is the lack of agricultural activity or farming. These eight drainages are all considered Upland.

2. Sufficient Water to Support Agricultural Activities

After identifying stream and tributary reaches that qualify for classification as an AVF on the basis of the presence of unconsolidated streamlaid deposits, the presence of irrigation sufficient to support agricultural activities or farming must be determined. See § 82-4-203(3)(a), MCA; 17.24.325(2)(b). The three criteria to determine if there is sufficient water to support agricultural activities or farming are discussed in the following text (subsections a-c). Discussion of water resource utility is withheld for inclusion as Section III, Hydrologic Functionality, which will be completed in subsequent Departmental documentation.

a. The Existence of Current or Historic Flood Irrigation

Flood irrigation is defined as "supplying water to plants by natural overflow or the diversion of flows, so that the irrigated surface is largely covered by a sheet of water." ARM 17.24.301(44). By contrast, "subirrigation" which is addressed in detail, below, generally means "the supplying of water to plants from a sub-surface zone where water is available and suitable for use by vegetation." ARM 17.24.301(118).

Surface water management structures such as dams and spreader and containment dikes indicate the existence of current or historic flood irrigation. Appendix D (Application C2012018 – 1b) includes photos of existing water management structures along the portion of Otter Creek included in the study area. The spreader dikes generally disperse water from tributaries feeding Otter Creek. The containment dikes have the potential to hold water from three sources: (i) from the spreader dikes as in-flow; (ii) as floodwater from the Otter Creek drainage; (iii) and/or precipitation and snowmelt from the immediate field or areas up-gradient of these fields. Containment dikes can be found along almost the entire stretch of Otter Creek from Tenmile Creek to Threemile Creek and continue downstream to Ashland, MT. In some instances there are also secondary, and tertiary dikes between subsequent benches above the Otter Creek channel. By holding and directing water for agricultural activity or farming, these water management structures are evidence of existing flood irrigation practices, as discussed above.

There are several areas along the Otter Creek valley floor in and adjacent to Tract 2 where unconsolidated deposits are present beneath flood irrigated lands. This directly meets the requirements of presence of an AVF in that both unconsolidated alluvial deposits are present and flood irrigation is present. These areas of flood irrigation are shown on Map 3.

b. Capability of the Area to be Flood Irrigated

The presence of containment dikes discussed above indicates existing flood irrigation. Fields at the base of tributaries to Otter Creek are discussed in the Baseline Report 325A (Application C2012018 – e) and act as in-flow fields – receiving surface flow from adjacent tributaries or upland areas. This is evident through documentation of flood irrigation structures on all named tributaries included above, (Tenmile, Gene, Newell, and Threemile Creeks along with Fortune Coulee), as well as unnamed ephemeral tributaries feeding either side of Otter Creek. These flood irrigation structures are considered evidence of flood irrigation for fields underlain by unconsolidated streamlaid deposits. As these demonstrations of flood irrigation are occurring above alluvial deposits, these areas are AVF's.

c. The Existence of Subirrigation

Areas with unconsolidated streamlaid deposits that are sub-irrigated also qualify as AVF's. Subirrigation occurs when groundwater is close enough to the surface to support agricultural activities or farming. This happens when water reaches the root zone of the plants being grown. "Subirrigation means, with respect to alluvial valley floors, the supplying of water to plants from a sub-surface zone where water is available and suitable for use by vegetation." ARM17.24.301 (118).

The portion of Otter Creek that is subirrigated was defined by the area where water was available to the root zone of the plants in the agricultural fields. This was determined by the depth of the active root zone of those plants, and the thickness of the capillary fringe. Capillary fringe is the zone above the water table that has the potential to carry moisture useful to plants.

Well data collected as part of the Otter Creek AVF investigation suggest alluvial water levels ranging from 1 to 52 feet in depth to water. Piezometer data showed groundwater depths ranging from 4 to 11 feet below ground surface, except for piezometer series AVF 8, which were dry at 17 feet below ground surface. An area where water is less than 14 feet below the surface is considered to be within the zone of subirrigation for alfalfa (Dollhopf, et al., 1982). The fields along the stretch of Otter Creek under consideration as an Alluvial Valley Floor consist primarily of introduced grass species having much shorter root systems than alfalfa, and therefore a shallower depth to water will be required to provide subirrigation.

According to Appendix J of baseline report 325A (Application C2012018 –1d), the maximum rooting depths observed in the Otter Creek cropland fields ranged from 30 to 82 inches, with an average of 57 inches. The 57 inch average rooting depth is rounded to 60 inches (5 feet) for ease in discussions. This five foot depth will be considered the depth to which roots can utilize water in this area.

When evaluating the depth to useful groundwater, the thickness of the capillary fringe needs to be considered. However, the thickness of a capillary fringe is difficult to determine. Capillary fringe refers to the ability of water to rise in the soil column above the water table due to capillary action. Pore sizes

of the material above the water table determine the thickness of the capillary fringe. Based on the soils data collected as part of the AVF investigation, a site-specific capillary fringe was established. This process took into consideration the depth of each soil textural class and their proportional grain size to determine the capillary rise possible for these alluvial soils.

TABLE 2.3

Typical Height of Capillary Fringe

Material	Grain Size (mm)[a]	Pore Radius (cm)[b]	Capillary Rise (cm)	
			Source A[a]	Source B[b]
Gravel				
Coarse	…	0.4	…	0.38
Fine	2–5	…	2.5	…
Sand				
Very coarse	1–2	…	6.5	…
Coarse	0.5–1	0.05	13.5	3.0
Medium	0.2–0.5	…	24.6	…
Fine	0.1–0.2	0.02	42.8	7.7
Silt				
	0.05–0.1	0.001	105.5	150
	0.02–0.05	…	200	…
Clay	…	0.0005	…	300

Source: [5, 6].

Note: Calculation for capillary rise initiates in metric units from Table 2.3. Final results are in feet for consistency.

Capillary rise was determined based on soil texture and Table 2.3 above (Kuo 2014). Soil samples collected at each of the piezometer locations in the AVF study area were analyzed for their soil texteral class. Each soil textural class is comprized of percentages of sand, silt, and clay, equaling 100 percent. Each of the textural components has a capillary rise associated with it as evidenced in the table above.

Loam is a type of soil that can generally be defined as having 42% sand, 42% silt, and 16% clay. Using the table, sand has a capillary rise of 24.6 cm, silt a rise of 150 cm, and clay a rise of 300 cm. The weighted average capillary rise for loam is calculated as 42% times 24.6 cm (10.332cm), 42% times 150 cm (63cm), and 16% times 300 cm (48-cm) resulting in approximately 121 cm.

These numbers were then calculated as a percentage of the entire soil profile to create a weighted average. For example, transect five, site 1, has a 279 cm soil profile of which 63% (175 cm) is silty clay loam and 37% (104 cm) is loam. Using these soil textures, a capillary rise is calculated using 63% times 188.5 cm (118cm) and 37% times 121 cm (45 cm). The two are then added together to give a weighted average capillary rise of 163 cm. This process was done for each piezometer location resulting in a minimum rise of 104 cm, a maximum of 194 cm, and an average of 146 cm in rise. This 146 cm was then rounded to 152 cm (30.48 cm equals 1 foot) for ease in calculations which converts to a 5-foot capillary rise.

By applying this average, the Department expects subirrigation will occur when the water level is less than or equal to 10 feet below ground surface (approximately 5-foot rooting depth and approximately 5-foot capillary fringe). Map 3, AVF Water Utilization, identifies areas within the AVF study area that have alluvial groundwater within 10 feet of the surface. This establishes the existence of subirrigation according to Subirrigation part (d)[1] in the AVF study area. Map 3 limits areas that qualify as AVFs based on the extent of subirrigation.

As part of the Alluvial Valley Floor determination request, Otter Creek Coal submitted a series of infrared photos taken at various dates. Plate 13D (Application C2012018 – 1f) was flown in September of 2011. Subirrigation may also be identified through aerial infrared photography during the dry portion of the growing season. This aerial photo map shows moisture enhanced conditions on many fields within the study area. In-flow fields, described above, also appear to show increased moisture in this photo. This suggests that the tributaries support agricultural activity and farming in Otter Creek by serving as a source of enhanced moisture conditions beyond the normal growing season.

Furthermore, pressure transducers with continuous recorders were installed in two piezometers. Pressure transducers monitor and record water levels, and were used to monitor alluvial aquifer depths in piezometers AVF 4 – P1 and AVF 7 – P4. Piezometer AVF 4 – P1 is located on the western edge of the Otter Creek floodplain and adjacent to the Fortune Coulee confluence. Piezometer AVF 7 – P4 is located near the middle of the Otter Creek floodplain, west of the stream channel and just upstream of the Threemile Creek confluence. These pressure transducers were set to record water pressure at 2-hour intervals; this water pressure is internally converted by the transducer to water depth. Following data download, recorded water depths were correlated to surveyed groundwater elevations, producing a long term, high frequency dataset of shallow groundwater levels. Continuous groundwater elevations from pressure transducers installed in AVF 4 – P1 and AVF 7 – P4 are presented in Figures 1 and 2 for the monitoring period March 2014 to September 2015 (Application C2012018 – 1c supplement).

---

1. **"Subirrigation"** means, with respect to alluvial valley floors, the supplying of water to plants from a sub-surface zone where water is available and suitable for use by vegetation. Subirrigation may be identified by:

   (a) diurnal fluctuation of the water table, due to the differences in nighttime and daytime evapotranspiration rates;

   (b) increasing soil moisture from a portion of the root zone down to the saturated zone, due to capillary action;

   (c) mottling of the soils in the root zone;

   (d) existence of an important part of the root zone in the capillary fringe or water table of an alluvial aquifer; or

   (e) an increase in streamflow or a rise in ground water levels, shortly after the first killing frost on the valley floor.

Figure 1. Summary graph of groundwater elevations in piezometer AVF7-P4 from March, 2014 to September, 2015.

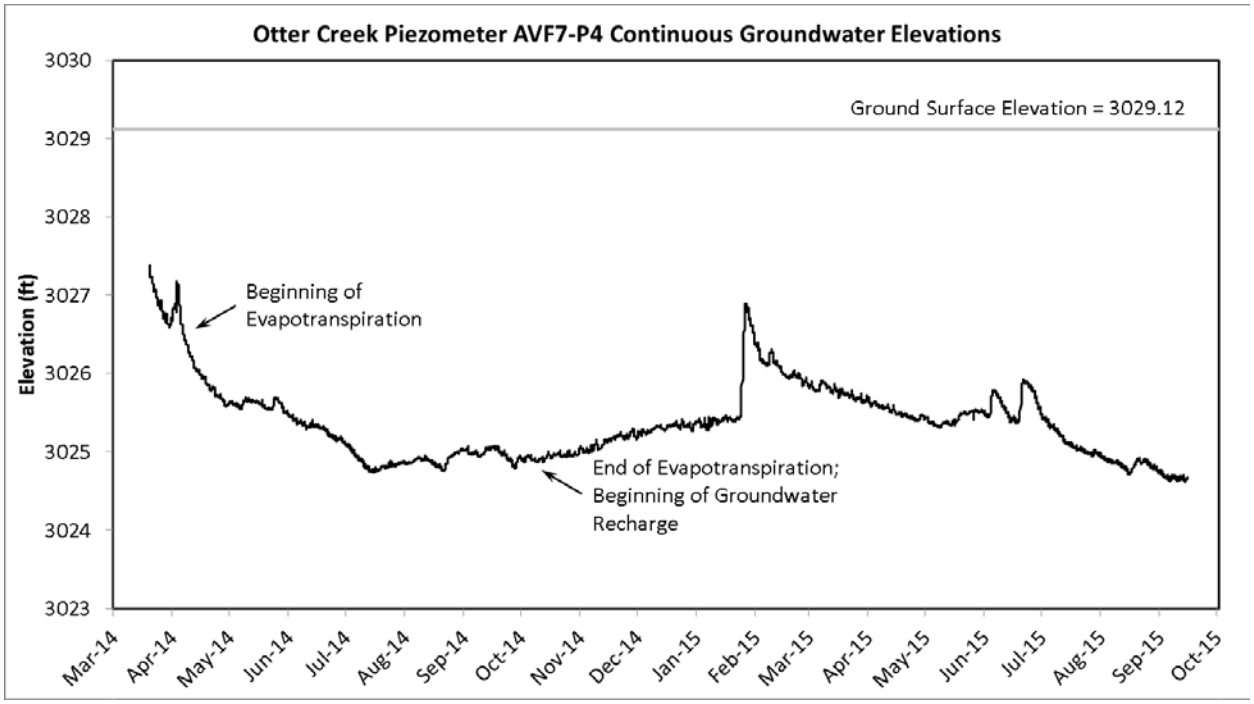
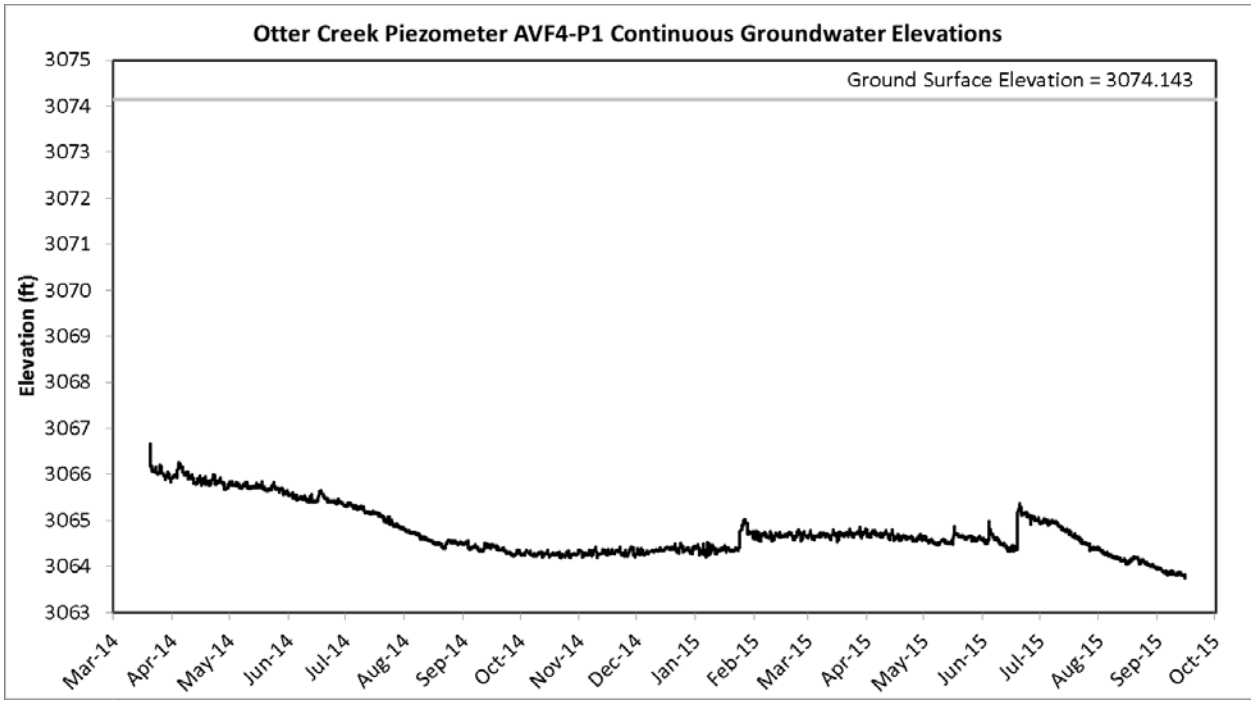


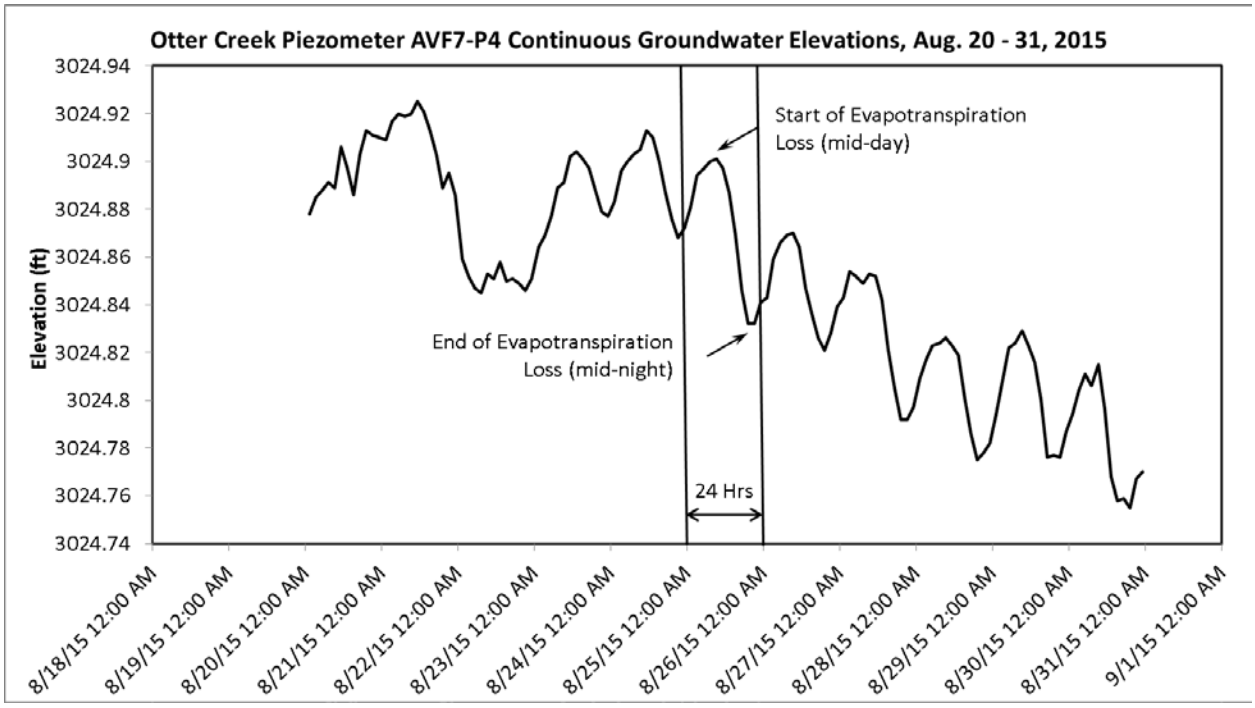
Figure 2. Summary graph of groundwater elevations in piezometer AVF4-P1 from March, 2014 to September, 2015.



Both summary graphs, Figures 1 and 2, indicate fluctuations in groundwater elevations which vary seasonally. These seasonal fluctuations are characteristic of shallow groundwater systems, where groundwater levels are dependent on recharge and loss due to atmospheric conditions. In both summary graphs, groundwater levels reach their maximum following winter and early spring

precipitation events that create recharge (rain or snowmelt). Through late spring and summer, these high levels decline as a result of evaporation and vegetative transpiration (Evapotranspiration; ET). Starting in early fall, ET rates start to decline due to shorter days, cooler temperatures, and vegetation senescence (hibernation or frost kill). Thus, groundwater levels start to recover in the fall as ET markedly declines. Fall recovery is evident in AVF 7 – P4 during October and November 2014 (Figure 1). This seasonality is less evident in AVF 4 – P1, possibly because the groundwater level is generally 10 feet below the ground surface, which, as previously discussed, is considered the maximum depth to water to support sub-irrigation. However, groundwater elevations from the adjacent AVF 4 – 3 alluvial well do indicate seasonality over a long time period (Application C2012018 – 1c supplement), and drier conditions in recent years may be having an impact on this well. Regardless, the seasonality of groundwater levels in AVF 7 – P4 is highly indicative of a shallow groundwater system with subirrigation, again consistent with the presence of an AVF.

Figure 3. Diurnal fluctuations in piezometer AVF7-P4 from August 20 to 31, 2015.



In addition to these seasonal fluctuations in groundwater levels, daily fluctuations captured by the pressure transducers were also analyzed to determine the presence of ET or subirrigation. For example, in August at AVF 7 – P4, daily fluctuations in groundwater levels are also evident (Figure 3). These daily fluctuations, referred to as diurnal fluctuations, are indicative of ET of shallow groundwater and have been used to estimate ET rates in numerous studies (summarized in Gribovszki et al. 2010). During daylight hours, when ET is actively occurring, groundwater levels continually decline as water is lost to the atmosphere. During night hours, after ET has ceased, groundwater levels recover as recharge from adjacent areas occurs. This process continues through the growing season.

These diurnal fluctuations evident in the AVF 7 – P4 piezometer are further evidence that subirrigation is occurring in the Otter Creek floodplain. While the pressure transducer data are not definitive for the entire watershed, it is additional evidence of subirrigation in the Otter Creek floodplain. Also, the comparison of data between AVF 7 – P4 and AVF 4 – P1 further indicates that a groundwater depth of 10-feet or less is a reasonable depth for subirrigation. The strong seasonality and diurnal fluctuations are more pronounced in AVF 7 – P4 (less than ten feet below ground surface) than in AVF 4 – P1 (generally near 10 feet below ground surface). Thus, this additional analysis confirmed that sub-irrigation is occurring in areas of the Otter Creek valley where groundwater is less than 10 feet from the surface.

Presence or Absence Conclusion

Analysis of the relation between the presence of agricultural crops, flood irrigation, and sub-irrigation in the reach of Otter Creek between Tenmile and Threemile Creeks demonstrates the presence of an AVF within the boundaries shown on Map 4, AVF Extent. This map shows areas within the Otter Creek valley that have unconsolidated streamlaid deposits and are either flood irrigated or subirrigated. Multiple monitoring well logs and piezometers indicated that extensive alluvial deposits are contained in the Otter Creek valley and its tributaries. The valley bottom is currently being farmed by several different operations and these operators are often utilizing flood irrigation structures. In the Otter Creek valley, these consist of containment dikes to keep surface runoff from entering the main-stem channel and spreader dikes to direct surface water from small tributaries of Otter Creek to these agricultural fields. Many of these fields also utilize water through subirrigation, or groundwater with the potential to influence the root zone of the plants above them. For Otter Creek, this happens when groundwater is ten feet or less below the ground surface. This set of data discussed above demonstrates that Otter Creek is an Alluvial Valley Floor system. The AVF extent is shown on Map 4, AVF Extent.

References

Application C2012018: Otter Creek Coal permit studies cited

1. Hydrometrics, Inc., Simpson & Assoc., and Westech Environmental Services Inc.; Otter Creek Mine Environmental Baseline Report 325A Alluvial Valley Floor Identification and Analysis
    a. Hydrometrics, Inc.; Appendix C: Alluvial Well Hydrographs, September 2014.
    b. Simpson & Associates, LLC; Appendix D: Photos of Surface Water Runoff Management Structures, September, 2013
    c. Hydrometrics, Inc.; Appendix I, AVF Piezometer Installation and Monitoring Report, September 2014
        Supplement: pressure transducer data, September 2015
    d. Otter Creek Coal Project Alluvial Valley Floor Detailed Soils Report Using Piezometer Transects Powder River County, Montana, July 2014
    e. WESTECH Environmental Services, Inc.; Appendix K: 2013 AVF Vegetation Report
    f. Plates_BR325A_ AVF Determination
2. Hydrometrics, Inc.; Appendix A Otter Creek Mine Baseline Report 304E Monitoring Well Logs

American Geologic Institute. Dictionary of Geological Terms, Revised Edition. Anchor Press 1976

Brady, Nyle C., Weil, Ray R., 2010. Elements Of The Nature And Properties Of Soils, Third Edition, Prentice Hall/Pearson

DSL, 1985. Alluvial Valley Floor Decision Document – For a Portion of Otter Creek within the Custer National Forest. Montana Department of State Lands, Reclamation Division, Capital Station. March 1985

Dollhopf, D. J., J.D. Goering, C.J.Levine, S.A. Young and E.L. Ayers, 1982. Crop response to subirrigation in alluvial valley systems, Montana Agricultural Experiment Station, Reclamation Research Program, MSU, Bozeman, Research Report 900.

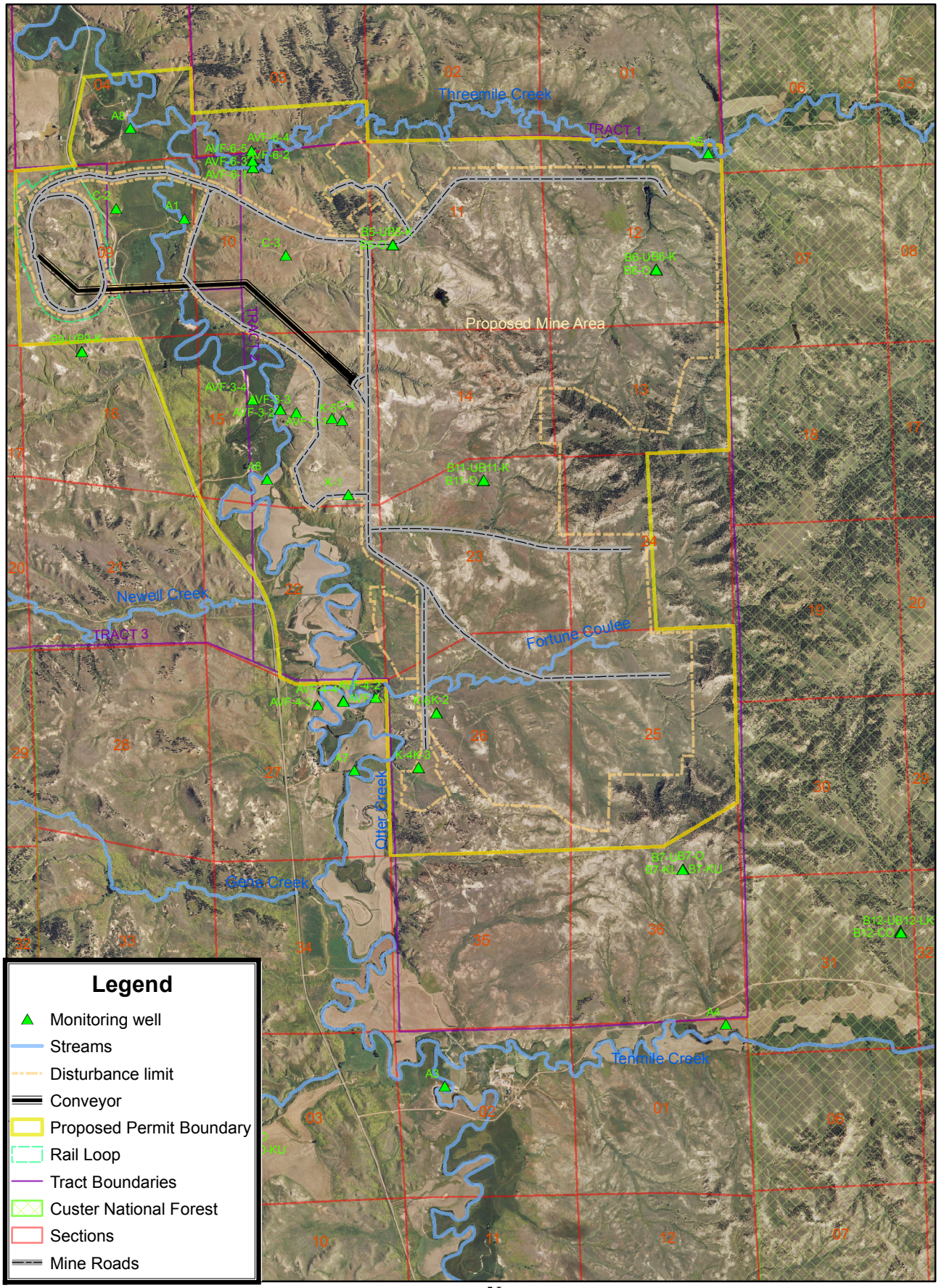
Gribovszki, Z., J. Szilágyi, and P. Kalicz (2010), Diurnal fluctuations in shallow groundwater levels and streamflow rates and their interpretation: A review, J. Hydrol., 385(1–4), 371–383, doi:10.1016/j.jhydrol.2010.02.001.

Kuo, Jeff, *Practical Calculations for Groundwater and Soil Remediation*, 2d ed., Taylor and Francis Group, Boca Raton, FL, 2014, p. 30.

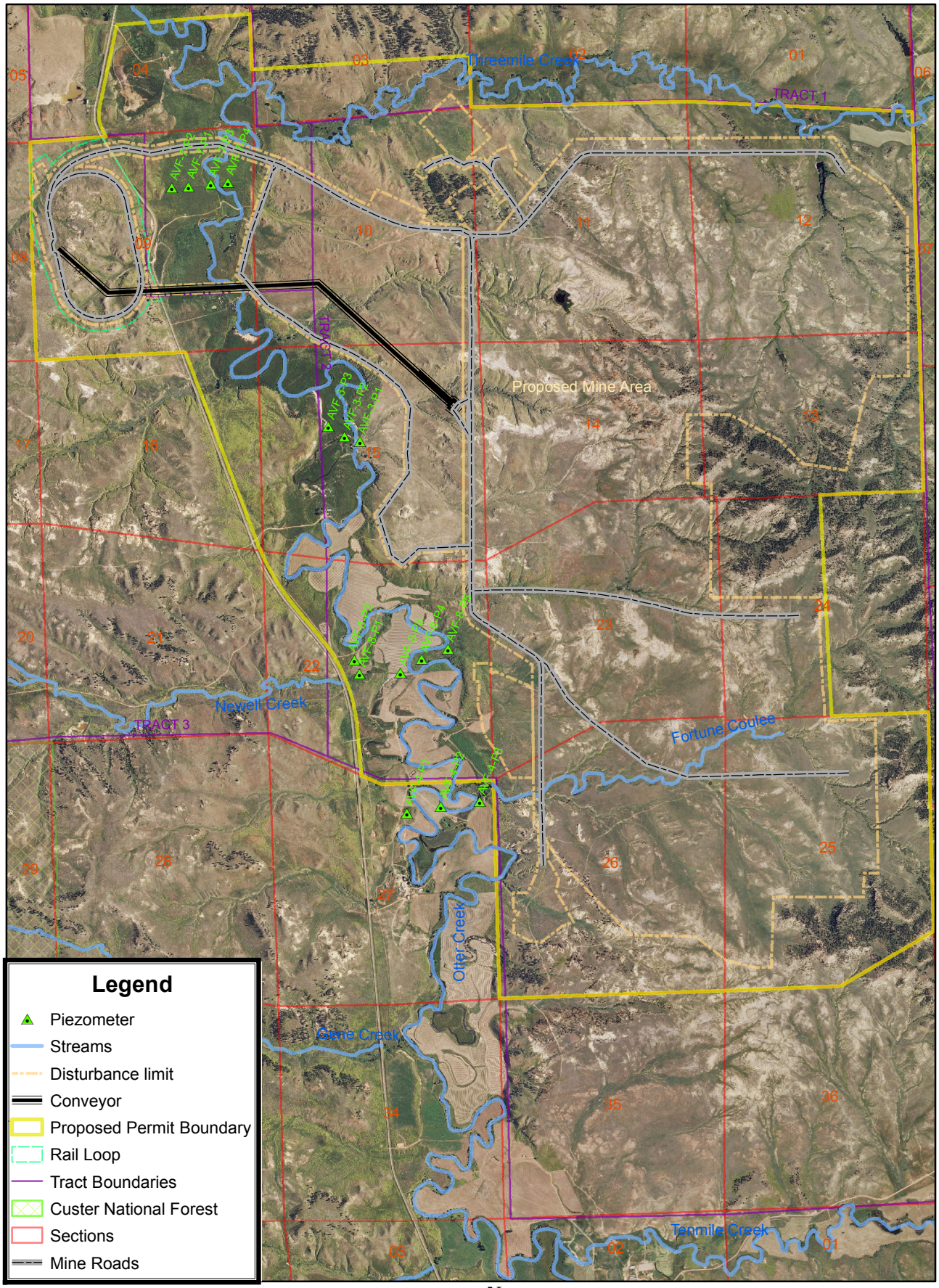
USDA, 1980.; Geological Parent Materials of Montana Soils. Montana Agricultural Experiment Station, Montana State University – Bozeman, MT and USDA Soil Conservation Service. pp 74-81.

Map 1
Project Overview

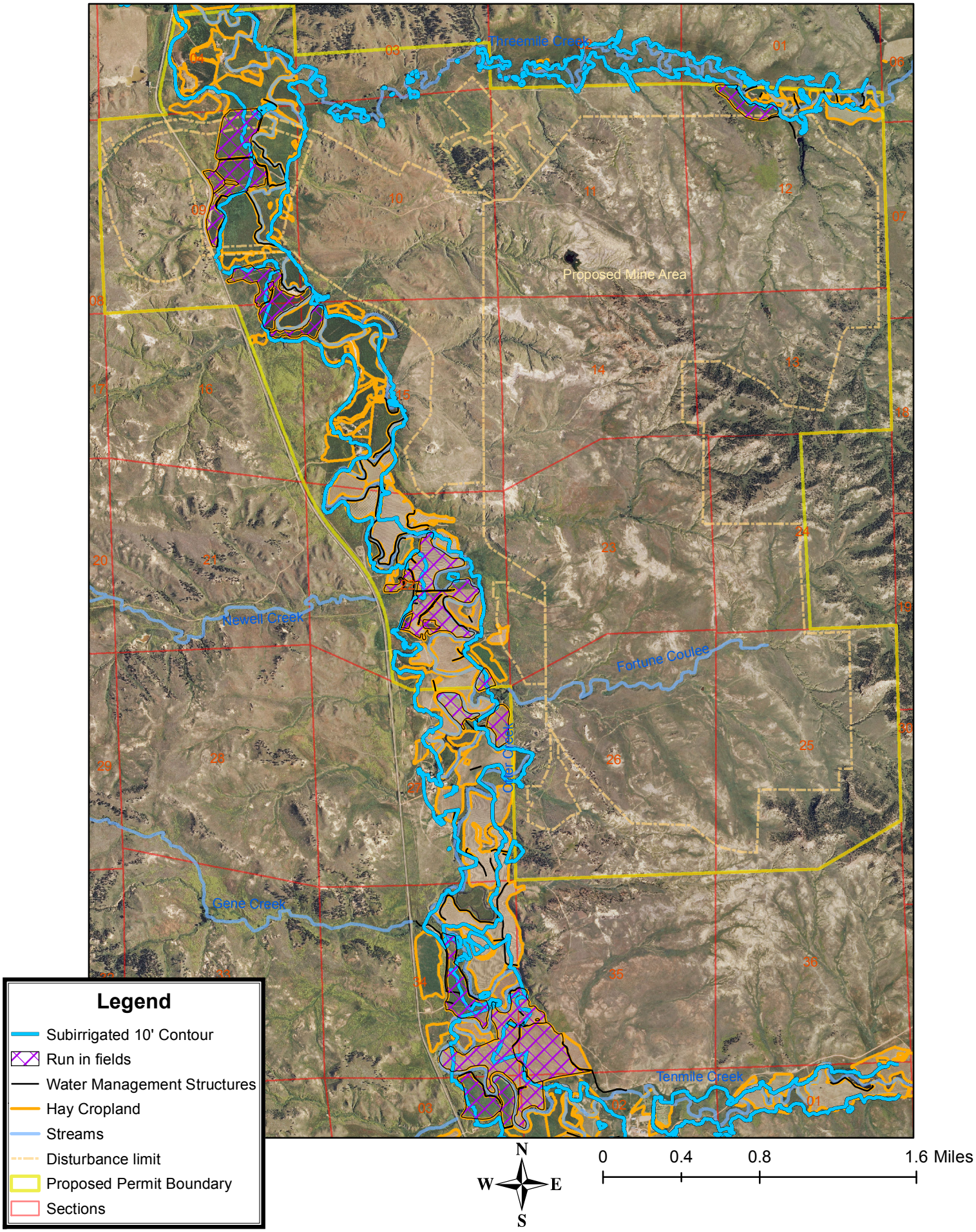
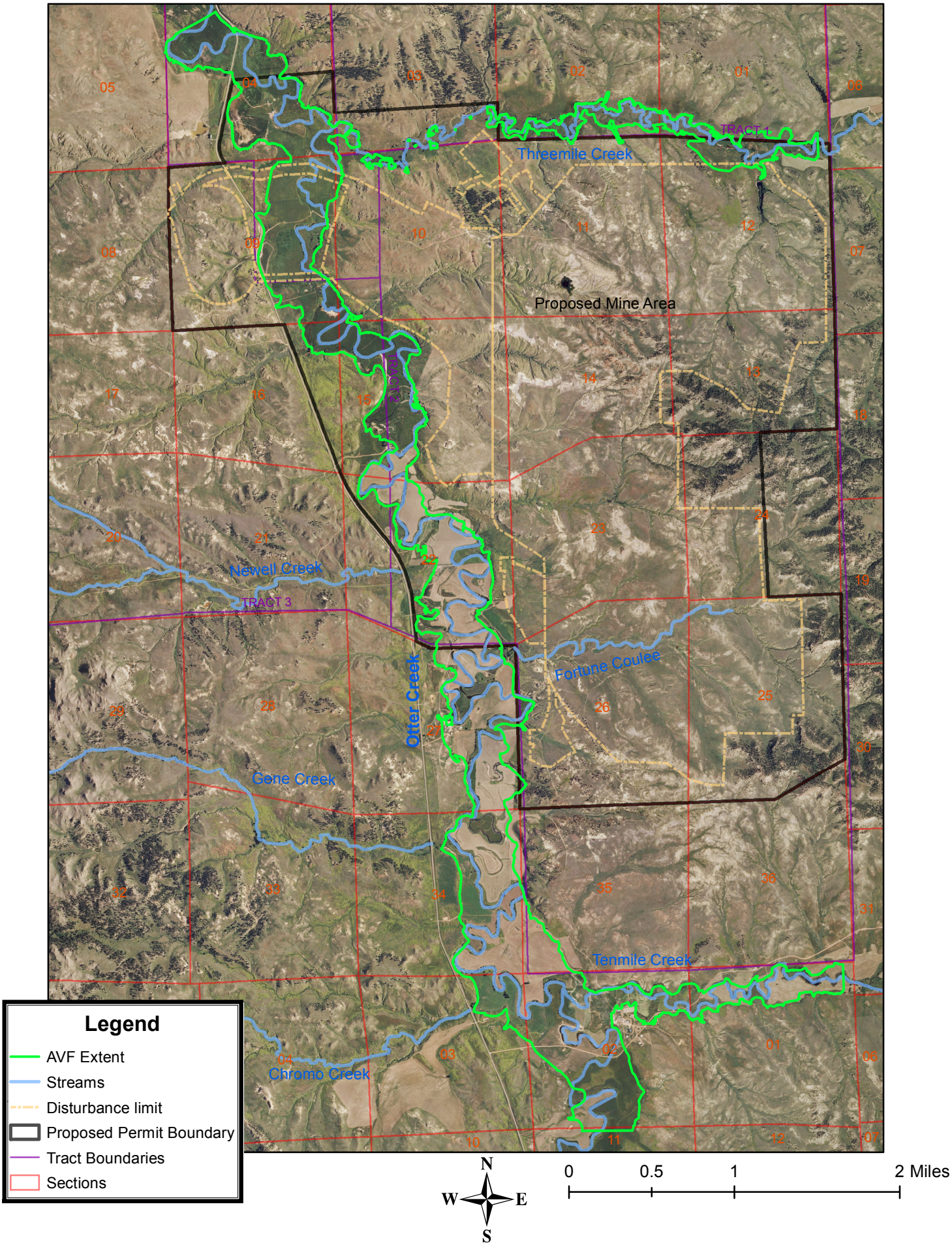
Map 2A
Project Detail



Map 2B
Project Detail



Map 3
AVF Water Utilization



Map 4
AVF Extent