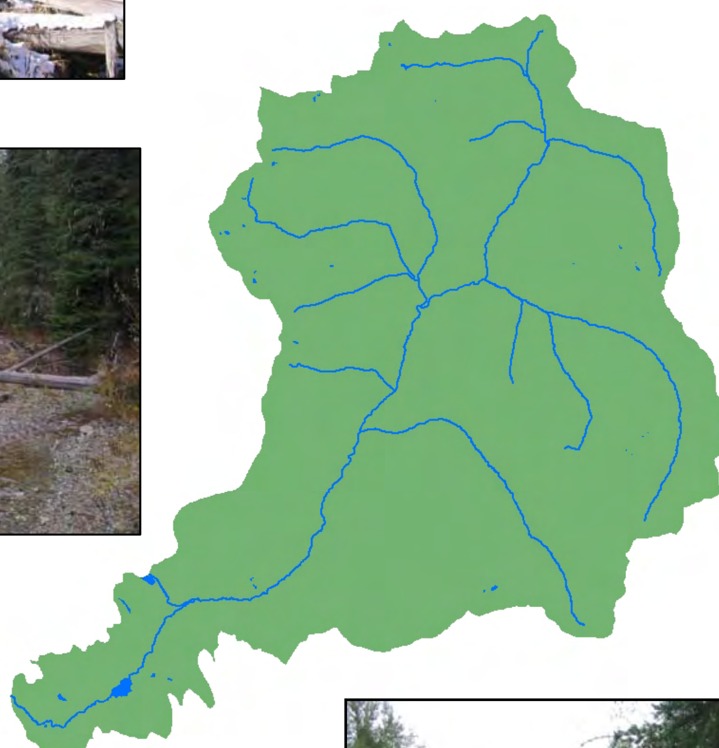
Grave Creek Watershed Water Quality and Habitat Restoration Plan and Sediment Total Maximum Daily Loads

Montana Department of Environmental Quality



March 2005

Significant Contributors

DEQ
Kootenai River Network
River Design Group, Inc.

ERRATA SHEET FOR THE GRAVE CREEK WATERSHED WATER QUALITY AND HABITAT RESTORATION PLAN AND SEDIMENT TOTAL MAXIMUM DAILY LOADS

This TMDL was approved by EPA on May 10, 2005. Several copies were printed and spiral bound for distribution, or sent electronically on compact disks. The photos and maps in the web version of the document were missing and now have been added to the document. If you had received an electronic or hard copy of the document, these photos and maps may already be included in your copy. If you have a bound copy produced from the web version, please note the corrections listed below or simply print out the errata sheet and insert it in your copy of the TMDL document. If you have a compact disk version without the photos and maps, please add this errata sheet to your disk or download the updated version from our website.

Appropriate corrections have already been made in the downloadable version of the TMDL located on our website at: http://deq.mt.gov/wqinfo/TMDL/finalReports.mcpx

The following photos were missing from the web version of the approved document starting on page 146.

- Photo 1: Clarence Creek – Riparian Harvest
- Photo 2: Stahl Creek - Riparian Harvest with No Buffer
- Photo 3: Main Stem Middle - Cut logs In-Stream - Marginal Habitat
- Photo 4: Main Stem Upper - Typical Avalanche Chute
- Photo 5: Lewis - Typical Natural Avalanche Chute
- Photo 6: Main Stem Upper - Road Fill Road Encroachment
- Photo 7: Main Stem Upper - Bank Erosion
- Photo 8: Stahl Creek - Riparian Harvest with No Buffer and with Mass Wasting
- Photo 9: Blue Sky - Riparian Modification and Mass Wasting
- Photo 10: Williams - Road Encroachment and Riparian Harvest with Mass Wasting
- Photo 11: Main Stem Upper - Example of In-Stream LWD Removal
- Photo 12: Main Stem Lower Below Canyon - Bank Erosion and Evidence of Aggradation
- Photo 13: Main Stem Lower Above Canyon – Evidence of Aggradation
- Photo 14: Main Stem Upper - Typical Reach Condition
- Photo 15: Main Stem Upper – Mid-Channel Bar, Evidence of Possible Aggradation
- Photo 16: Main Stem Upper - Check Dam
- Photo 17: Main Stem Upper - Gabion for Fill Slope Protection
- Photo 18: Main Stem Upper - Avalanche Slide - Woody Debris Contribution
- Photo 19: Main Stem Lower Below Canyon – Terrace Erosion
- Photo 20: Main Stem Lower - Bank Armoring
- Photo 21: Fish Passage Barrier on Foundation Creek

The following maps were missing from the original approved document starting after the photos that started on page 146.

- Map 1: Vicinity Map
- Map 2: Land Ownership
- Map 3: 2000 Census Population Density

- Map 4: Topography
- Map 5: Landtypes
- Map 6: Hydrography
- Map 7: Irrigation Diversions
- Map 8: Vegetation Land Cover
- Map 9: Forest Management Activities: Number of Harvest Entries
- Map 10: Road System
- Map 11: Rain on Snow Zone
- Map 12: Fish Distribution
- Map 13: Surveyed R1/R4 Reaches and Rosgen Stream Types
- Map 14: In-stream Sediment Sources
- Map 15: Sediment Sources Identified from Air Photo Interpretation

Table of Contents

List of Figures

List of Tables

List of Photos

List of Maps

List of Appendices

EXECUTIVE SUMMARY

This document presents a Water Quality Protection Plan and Total Maximum Daily Loads (TMDLs) for the Grave Creek Watershed in Montana. A TMDL is a pollutant budget identifying the maximum amount of a particular pollutant that a waterbody can assimilate without causing applicable water quality standards to be exceeded. Section 303 of the Federal Clean Water Act and the Montana Water Quality Act (Section 75-5-703) require development of TMDLs for impaired waterbodies that do not meet Montana water quality standards. Section 303(d) also requires identification of impaired waterbodies on a list, referred to as the 303(d) list. This 303(d) list is updated every two years and submitted to the U. S. Environmental Protection Agency (EPA) by the Montana Department of Environmental Quality (MDEQ). The whole length of Grave Creek from Foundation Creek to the confluence with Fortine Creek is identified as an impaired waterbody on Montana's 303(d) list. Table E-1 provides a summary of the water quality and TMDL plan components discussed in further detail below and throughout the document.

Assessment and Impairment Status Update

Grave Creek supports an important bull trout fishery as well as several other native fish including westslope cutthroat trout. The development of this water quality plan and TMDL included an in-depth physical assessment and analysis of water quality in Grave Creek and tributaries to Grave Creek. As part of this assessment phase, TMDL targets and other beneficial use support indicators that must be satisfied to meet Montana Water Quality Standards were developed. These targets and indicators focus on many of the physical stream parameters that can be linked to excess sediment loading and aquatic life or fish habitat limitations. Examples include percent surface or subsurface fine sediment values, pool frequency or pool quality, and the width to depth ratio of the stream. The target and indicator values of concern were developed using a substantial amount of data from "reference" streams throughout western Montana.

Based on the above assessment approach, Grave Creek was identified as having fish habitat limitations with linkages to excess sediment loading. In the lower reaches of Grave Creek the habitat limitations were linked to a lack of pools and low levels of large woody debris. Additional indicators of habitat problems in the lower watershed include an overly wide channel, eroding banks linked to past channelization and past and current stream management practices, and a reduction in function of the riparian corridor linked to current and historical management practices. In the upper, forested portion of Grave Creek, the fish habitat limitations were linked primarily to a lack of pools and a lack of large woody debris. Additional indicators of habitat problems in the upper watershed include low pool depths and sediment loading from mass wasting events linked to previous timber harvest and road construction activities. Similar indicators of fish habitat limitations were also noted for several tributaries to Grave Creek.

The above noted fish habitat limitations were sufficient to justify a sediment impairment determination for Grave Creek, consistent with the 2004 303(d) list, thus requiring development of a sediment TMDL for Grave Creek. The coarse bedload fraction was identified as the primary sediment size of concern. Most of the targets used as indicators of fine sediment impairment were satisfied, particularly in middle and upper parts of Grave Creek and in tributaries. This information was used to assist with the development of restoration objectives and specific sediment TMDL requirements.

Restoration Objectives

Restoration objectives, including a sediment TMDL and sediment load allocations were developed at the watershed scale to address the sediment sources in the Grave Creek Watershed. These sources include mass wasting linked to historical timber harvest, erosion from roads, future timber harvest activities, and bank erosion along lower Grave Creek linked to existing or past management of the channel and riparian areas. Coarse sediment loads that may remain in the channel from past activities where BMPs were not fully implemented is a concern. Restoration objectives were also developed to address dewatering since it was concluded that the lack of water during summer months in particular water years with below average mean annual precipitation, is an impairment condition in lower Grave Creek consistent with the most recent 2004 303(d) list.

It is important to note that fish habitat concerns and sediment contributions associated with the upper watershed were attributed to past or historical forest management practices. The current Kootenai National Forest (KNF) management of the upper watershed is facilitating recovery of the system and related improvements to fish and aquatic life habitat. This management includes application of timber harvest best management practices (BMPs) for water quality protection, and protection of riparian zones. In the lower portions of the watershed along private lands, many of the problems are also linked to past activities such as channelization of Grave Creek. Many landowners, agency personnel, and other stakeholders, including the Kootenai River Network (KRN) are working toward improved water quality in the lower watershed and have implemented several water quality improvement projects.

It is also important to note that the Montana State law promotes a voluntary approach toward implementation of the restoration objectives. State law also recognizes that timber harvest and other activities can continue in a watershed where there is an impaired waterbody like Grave Creek, as long as such activities are accomplished in a way that is protective of the watershed and consistent with the restoration objectives. These important aspects of Montana State Law are supported by the Montana Department of Environmental Quality and incorporated into this document.

Implementation and Monitoring

Implementation and monitoring strategies linked to the targets and restoration objectives are incorporated into this document. Implementation focuses on a continuation of many of the ongoing water quality protection activities in the watershed, both on private lands and on lands under KNF ownership. The KRN, KNF, private landowners and other agencies and stakeholders play an important role in effective implementation of this plan and water quality protection and restoration.

The monitoring strategy focuses on tracking progress toward meeting TMDL targets and other goals. An important component of the monitoring strategy is to assist with adaptive management to address uncertainties that tend to exist when developing numeric goals and applying them to TMDL targets and load allocations. The monitoring strategy also includes tracking implementation projects and pursuing a better understanding of the water quality and fish habitat capabilities and limitations in the Grave Creek Watershed.

Table E-1: Water Quality Plan and TMDL Summary Information.

Impaired Waterbody Summary	• Grave Creek: fish habitat and other habitat alteration problems linked to excess sediment/sedimentation; flow alterations (dewatering)
Impacted uses	• Cold-water beneficial use negatively impacted via loss of habitat and from dewatering • Recreational use negatively impacted in lower Grave Creek from dewatering
Pollutant Source Categories	• Timber Harvest: Mass wasting near streams from historical riparian harvest and other ground disturbing activities; historical channelization along lower Grave Creek for log drives; forest roads • Private Lands Development and Agriculture on Private Lands: Riparian disturbances (grazing, other agriculture); stream encroachment from structures and agricultural activities; historical channelization for land development; private roads. • Recreation: Forest and other roads
TMDL Target Development Focus	• Acceptable pool frequency values • Acceptable macroinvertebrate measures • Acceptable measures of percent fines in riffles and spawning substrate • Acceptable width to depth ratios
Supplemental (Target) Indicators	• Sinuosity and other channel dimensions in lower Grave Creek • Large woody debris levels • Pool depth or other measures of pool quality • Fish data • Visual observations and professional judgment • Stream stability ratings • Existing and historical loading above naturally occurring levels and other land use indicators • Trend data (future addition when data is available)
Other Use Support Objectives (non-pollutant & non-TMDL)	• Improve levels of large woody debris • Minimum flow goals in lower Grave Creek • Eliminate unnatural fish passage barriers based on fishery goals

Table E-1: Water Quality Plan and TMDL Summary Information.	
Grave Creek Total Sediment TMDL	• Based on a percent reduction determination for sediment loading from the two major existing controllable sources: bank erosion along lower Grave Creek and mass wasting sites in the upper parts of the watershed • Total of 1 sediment TMDL developed in this plan (1 waterbody – pollutant combination)
Allocation Strategies	• 63% reduction in bank erosion rates in lower Grave Creek • No increase in road related surface erosion and limited increases on private lands in conjunction with BMP implementation • Facilitate recovery of human-induced mass wasting sites, estimated as a 50% reduction in sediment loading over time • Continue with BMPs and other reasonable land, soil and water conservation practices to keep sediment loading from existing and future forest activities at acceptable levels • Manage the stream corridor to facilitate transport of excess historical sediment loads through the system (not a "formal" TMDL load allocation important load consideration)
Other Restoration Objectives	• Improve large woody debris recruitment potential through protection of riparian areas on all lands • Pursue cooperative approaches to improve flow conditions during low flow periods in lower Grave Creek • Evaluate and possibly address potential fish passage problem on Foundation Creek

SECTION 1.0
INTRODUCTION

1.1 Document Description

This document is a water quality and habitat restoration plan (WQHRP) that includes total maximum daily load (TMDL) submittals. The focus is on habitat and sediment related impairments in the Grave Creek TMDL Planning Area (Map 1). The primary objective is to develop an approach to restore and maintain the physical, chemical, and biological integrity of streams in the sub-basin. Restoration and maintenance of these aspects of the integrity of the nation’s waters is the objective of the Clean Water Act, which requires the development of TMDLs. Furthermore, attaining this level of watershed function will ensure full support of beneficial uses consistent with Montana Water Quality Act.

The Grave Creek TMDL Planning Area, also referred to as the Grave Creek Watershed in this document, is located in the northwest part of Montana within Lincoln County. The Grave Creek Watershed size is 74.2 square miles, with elevations ranging from 2,700 ft at the confluence with Fortine Creek to over 7,500 ft at the watershed divide. Most of the watershed originates on the Kootenai National Forest with the headwaters of the drainage occurring in the roadless Ten Lakes Scenic Area. The Watershed Characterization in Section 2.0 provides additional detail about this area.

The Grave Creek Planning Area contains one stream segment listed on Montana’s 2004 list of impaired waters (303(d) list) with probable causes of impairment that are primarily associated with sediment-related pollutant conditions and fish habitat alterations. Water quality concerns within the lower reaches of Grave Creek justify an assessment and protection approach that incorporates all of the Grave Creek Watershed. Therefore, several tributaries to Grave Creek were also evaluated within this document.

Montana State law defines an impaired water as a water or stream segment for which sufficient, credible data indicate that the water or stream is failing to achieve compliance with applicable water quality standards (Montana Water Quality Act, Section 75-5-103). Compilation of this list by states is a requirement of section 303(d) of the Federal Clean Water Act. Both Montana State Law (Montana Water Quality Act; Section 75-5-703) and the Clean Water Act require development of TMDLs for waters on this list where a pollutant results in impairment. This plan also includes restoration strategies where habitat or other conditions impair a beneficial use but a clear link to excess sediment or other pollutant is lacking.

TMDL development and water quality restoration planning is essentially a problem-solving process. The first steps include assessment of the health of 303(d)-listed streams and identification of causal mechanisms responsible for impairment. Numerical reference parameters provide the basis for TMDL target development and for determining the degree to which stream conditions depart from desired conditions. This deviation from desired conditions provides much of the basis for validating impairment conditions. Where impairment is validated, restoration objectives are developed to define conditions that, if implemented, would result in meeting the restoration objectives lead to full support of beneficial uses.

Based on these analyses, watershed planners, in collaboration with stakeholders, can develop a specific strategy or set of solutions to meet the restoration objectives and remedy the identified problems. This results in a comprehensive plan to restore the bodies of water to a condition that meets Montana's water quality standards and supports designated beneficial uses.

1.2 Stakeholder and Agency Coordination

While state law directs the Montana Department of Environmental Quality (MDEQ) to develop TMDLs for impaired waterbodies, numerous local groups are collaborating in the process to ensure stakeholder involvement and to increase the overall quality, acceptance, and ongoing implementation of the plan. In 2002, MDEQ requested Kootenai River Network's (KRN) involvement and assistance with TMDL development in the Grave Creek and Tobacco River TMDL Planning Areas. KRN is a cooperative international partnership of individuals, diverse citizen groups, and agencies dedicated to the utilization, restoration, promotion and protection of water resources in the Kootenai-Kootenay River watershed. The goals of the KRN are to:

1. Involve individuals and their communities in sharing the value of the Kootenai/ay River watershed;
2. Improve communication among agencies and diverse citizen groups throughout the watershed;
3. Facilitate habitat enhancement and rehabilitation;
4. Fully use best available science practices to facilitate proactive water resources management; and
5. Pursue coordination of efforts regarding water resources models and measurement techniques.

The KRN in cooperation with MDEQ have solicited involvement throughout this process from numerous local conservation and advisory groups including the Friends of Grave Creek, the Lincoln County Conservation District, the Lincoln County Commissioners, Montana Fish Wildlife and Parks, National Resource Conservation Service, and the Kootenai National Forest (KNF). The KRN retained River Design Group, Inc. (RDG) and the USFS to assist in the development of the plan. Starting in August 2003 and during the development of this plan, the KRN has collaborated with MDEQ and the selected contractors to supplement existing data and information with additional field data collection, synthesis, and analysis. The KRN will continue to help coordinate stakeholder involvement with water quality improvements being made in the watershed.

1.3 Water Quality and Habitat Terminology

It is important to note that the term "water quality" encompasses the physical, chemical and biological health of a stream or waterbody. Many of the measures of fish habitat are linked to physical conditions within the stream and are therefore included within the definition of water quality. These fish habitat measures can include parameters such as levels of fine sediment in riffles, pool frequency or pool quality, amount of large woody debris in a stream channel, or stream width to depth values. In several locations throughout the document, and even within the name of the document, both water quality and habitat are used together. Although somewhat redundant, this terminology is used to help clarify and stress the many physical habitat parameters associated with water quality evaluations within this document. Additional terminology relating to Montana's Water Quality Standards and the TMDL development process will be defined in Section 3.0.

1.4 Document Organization

This plan is organized as follows:

- This section (Section 1.0) provides an introduction.
- Section 2.0 provides a summary of watershed characteristics.
- Section 3.0 provides additional detail on the 303(d) list, Montana Water Quality Standards and the TMDL development process.
- Section 4.0 provides a summary of water quality information, with focus on physical habitat data, for streams in the Grave Creek Watershed.
- Reference values and beneficial use support objectives, including TMDL targets, are developed in Section 5.0. Section 5.0 also includes an analysis where the water quality data from Grave Creek and tributary streams are compared to TMDL targets and an updated impairment determination is made for Grave Creek.
- Section 6.0 provides a source assessment with focus on sediment loading information.
- Section 7.0 identifies restoration objectives, including TMDLs and allocations to address Grave Creek sediment impairment.
- Section 8.0 identifies ongoing and proposed efforts to implement the restoration objectives and other water quality improvement and protection activities within the watershed.
- Section 9.0 provides a monitoring strategy to track implementation of this plan and related TMDLs, and address other monitoring priorities.
- Section 10.0 provides a summary of stakeholder and public involvement in the development of this plan.
- Section 11.0 includes the references.

SECTION 2.0
WATERSHED CHARACTERIZATION

2.1 Watershed and Subbasin Location

The Grave Creek Watershed is located in northwest Montana southwest of the town of Eureka, Montana. Grave Creek is a tributary to the Tobacco River. The Tobacco River is tributary to the Kootenai River and confluences with the Kootenai River at the Libby Reservoir (Lake Koocanusa) just west of Eureka and east of Libby, Montana. The Kootenai River Subbasin is an international watershed that encompasses parts of British Columbia (B.C.), Montana, and Idaho (Map 1). The headwaters of the Kootenai River originate in Kootenay National Park, B.C. The river flows south within the Rocky Mountain Trench into the Libby Reservoir. From the reservoir, the river turns west, passes through a gap between the Purcell and Cabinet Mountains, enters Idaho, and then loops north where it flows into Kootenay Lake, B.C. The waters leave the lake's West Arm and flow south to join the Columbia River at Castlegar, B.C. The Kootenai River is the second largest Columbia River tributary and is the third largest watershed in the Columbia Basin (36,000 km^2 or 8.96 million acres) (Knudson, 1994).

2.2 Land Ownership

The Grave Creek Watershed encompasses a total of 48,189 acres, of which the USFS administers 91 percent, or 44,367 acres (USFS, 2002). Private lands comprise approximately nine percent of the overall watershed area (Table 2-1) (Map 2). USFS-managed land includes the headwater streams and face tributaries feeding Grave Creek. The lower watershed is mainly privately owned, with the State of Montana owning a small 30-acre section.

Table 2-1: Landownership summary for the Grave Creek Watershed.

Landowner	Property Area (mi^2)	Percentage of Total Watershed Area
US Forest Service	69.3	91
Private	5.9	9
State of Montana	0.05	<1
Total	75.3	100

2.3 Cultural Characteristics

Much of the history of the Tobacco River Valley is recorded in personal journals and accounts of the early settlers. Descendents of many of the first families still live in the valley today and have recorded the history and development of the valley. Historical settlement of the valley is very similar to the patterns recorded for the interior Columbia River Basin.

The Kootenai name for Grave Creek was ‘Akonoho’ (Ayres, 1899). The origin of the name is described by Olga W. Johnson (1950) and Bryce Bohn (1998, unpublished). During the gold rush into the mines at Wild Horse, four travelers were camping along Akanoho Creek waiting for the level of the spring floodwaters to subside prior to attempting a crossing. One evening, a stranger leading a heavily loaded packhorse attempted to cross the channel to the dissuasion of the travelers. While attempting to cross, the horses and stranger lost their footing in the channel and were swept downstream. The travelers retrieved the body of the stranger and buried him along Grave Creek. From that point on, people referred to the swift flowing mountain-stream as Grave Creek (Bohn, 1998, unpublished report). Although the stream in the past has been referred to as *Graves* Creek, the remainder of this report will reference the focus stream as Grave Creek.

2.4 Population

As of the 2000 Montana census, the population of Lincoln County totaled 18,837 people (CEIC, 2002). A map of the 2000 Census block data displays population density in the Grave Creek Watershed (Map 3).

The nearest town to Grave Creek is Eureka, Montana with a population of 1,017 people. The largest town in the county, Libby (population 2,626), is located about 70 miles southwest of the Grave Creek Watershed. Eureka is located 8 miles from the Roosville Port of Entry at the U.S.-Canadian border. From 2000 Census track data sub-set to the Grave Creek Watershed, a population of approximately 360 people was calculated for the watershed. This number is likely a slight over-estimate due to inclusion of people outside of Grave Creek but within a Census track that is partially located in the watershed.

2.5 Geology

Mountains in the Kootenai River subbasin are composed of folded, faulted, and metamorphosed blocks of Precambrian sedimentary rocks of the Belt Series and minor basaltic intrusions (Ferreira et al., 1992). Primary rock types are metasedimentary argillites, siltites, and quartzites, which are hard and resistant to erosion. Where exposed, they form steep canyon walls and confined stream reaches. Porous rock and glaciation have profoundly influenced basin and channel morphology (Hauer et al., 1997).

The Grave Creek Watershed is located on the northwestern flank of the Whitefish Range, a large mountain range, which represents a portion of the Whitefish Thrust Fault. This fault pushed the mountain summits more than 3,000 feet above the valley bottom of the Rocky Mountain Trench. The landscape is correspondingly characterized by deep, u-shaped glacial valleys from the Pleistocene Epoch with steep valley walls and relatively narrow valley bottoms. Alpine glaciation carved numerous cirque basins at higher elevations, which further accentuate the steep terrain (USFS, 2002).

The bedrock geology of the watershed is varied in accordance with the results of seismic thrusting and layering (Harrison et al., 1992). In general, the outer (valley-facing) mountain chain (from Stahl Peak to the Krag-Krinklehorn massif) is derived from dolomite and limestone of the Helena Formation (Middle Proterozoic). These grayish calcareous outcrops are visible at the surface on rock outcrops, and extend as far east as the lower reaches of Stahl Creek and include the ridge between Kopsi and Williams Creeks. Some are visible in the vicinity of Cat Creek along the Grave Creek Road. East of these carbonaceous formations the bedrock is dominated by siliceous rock (argillites and quartzites) of the McNamara and Mt. Shields Formations. The chemical composition of these two different underlying bedrock types has a significant effect on vegetation patterns throughout the watershed.

2.6 Climate

The subbasin has a relatively moist climate, with annual precipitation even at low elevations generally exceeding 20 inches. Warm, wet air masses from the Pacific bring abundant rain and 40 to 300 inches of snowfall each year. In winter, Pacific air masses dominate and produce inland mountain climates that are not extremely cold, although subzero continental-polar air occasionally settles over the mountains of northern Idaho and vicinity.

The Continental Divide Range, with crest elevations of 10,000 ft to 11,500 ft along nearly 155 miles of ridgeline, is a major water source for the Kootenai River. The range receives 80 inches to 120 inches of precipitation annually (Bonde, 1987). Some of the high elevation country in the Purcell Range around Mt. Findlay receives 80 inches of precipitation a year; but most of the range, and most of the Selkirk and Cabinet mountains, receive only 40 inches to 60 inches annually (Daley et al., 1981). In the inhabited valley bottoms, annual precipitation varies from just under 20 inches at Rexford, Montana (USACOE, 1974) and Creston, British Columbia (Daley et al., 1981) to just over 40 inches at Fernie, British Columbia (Oliver, 1979).

The Rexford (Eureka) Ranger District of the Kootenai National Forest in Eureka is the closest weather station to Grave Creek. Average temperature and precipitation for the Eureka climate station is summarized in Table 2-2. The period of record for this climate station extends from 1960 through 2004. The climate summary information most closely resembles the climate of lower elevations in lower Grave Creek Watershed. Overall, higher elevations in the watershed have greater precipitation and snowfall and lower temperatures, more closely resembling the climate described above for the Kootenai River subbasin.

Table 2-2: Climate Summary Information for Eureka Ranger Station (http://www.wrcc.dri.edu/summary/climsmmt.html).													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	29.8	38.4	48.3	59.0	68.5	76.1	84.7	84.4	72.7	57.3	40.2	30.5	57.5
Average Min. Temperature (F)	15.5	20.6	26.2	32.7	40.1	46.4	49.6	48.4	40.6	32.4	25.8	18.1	33.0
Average Total Precipitation (in.)	1.18	0.77	0.81	0.95	1.77	2.11	1.30	1.07	1.11	0.94	1.19	1.19	14.39
Average Total Snow Fall (in.)	12.7	6.3	5.5	1.2	0.1	0.0	0.0	0.0	0.0	0.4	6.1	13.5	45.9
Average Snow Depth (in.)	4	2	1	0	0	0	0	0	0	0	1	2	1

Percent of possible observations for period of record.
Max. Temp.: 99.4% Min. Temp.: 99.3% Precipitation: 99.5% Snowfall: 86.4% Snow Depth: 78%

2.7 Topography

The Grave Creek drainage basin is located within the Northern Rocky Mountain physiographic province (EPA, 2000), which is characterized by north to northwest trending mountain ranges separated by straight valleys paralleling the adjacent ranges.

The topography of the Grave Creek Watershed is dominated by steep, heavily forested, confined headwater tributary valleys (Map 4). Consequently, nearly all of the tributaries to Grave Creek have high channel gradients. In contrast, the lower main stem of Grave Creek is characterized by a broad floodplain, meandering channel pattern, and low gradient.

2.8 Soils and Land Type Associations

The Kootenai National Forest has characterized soils by Land Type Associations (LTAs). LTAs are a composite classification of landform, vegetation, habitat type, geology and soils. Map 5 shows the LTAs for the Grave Creek Watershed. LTAs in the Grave Creek Watershed are listed in Table 2-3.

Table 2-3: Land Type Associations in the Grave Creek Watershed (USFS, 1995a).		
LTA	Soil	Landform
102	Andic Dystric Eutrochrepts	Lacustrine terraces
103	Andic Dystrochrepts	Alluvial terraces
105	Aquic Udifluvents	Poorly drained alluvial basins
106	Andic Dystrochrepts	Glacial outwash terraces

Table 2-3: Land Type Associations in the Grave Creek Watershed (USFS, 1995a).

LTA	Soil	Landform
108	Andic Dystric Eutrochrepts- Andic Dystrochrepts complex	Lacustrine terraces- Glacial outwash terraces complex
110	Eutrochrepts	Glacial outwash terraces
251	Andic Dystrochrepts-Rock outcrop complex	Breaklands
321	Typic Eutroboralfs	Drumlins
322	Eutric Glossoboralfs	Moraines
323	Typic Eutroboralfs	Moraines
324	Typic Eutrochrepts,	Moraines
351	Andic Dystrochrepts	Dissected glaciated mountain slopes
401	Rock outcrop-Andic Cryochrepts-Lithic Cryochrepts complex	Glacial trough walls
403	Rock outcrop-Lithic Cryochrepts-Andic Cryochrepts complex	Cirque headwalls and alpine ridges
404	Andic Cryochrepts	Moraines, steep
405	Lithic Cryochrepts- Andic Cryochrepts-Rock outcrop complex	Glaciated mountain ridges
406	Andic Cryochrepts	Glaciated mountain ridges
407	Andic Cryochrepts	Moraines
408	Andic Cryochrepts-Rock outcrop complex	Glaciated mountain slopes, very steep
510	Typic Calcixerolls	Mountain slopes

Soils in the Kootenai River subbasin, including soils in Grave Creek, formed from residual and colluvial materials eroded from Belt rocks or in materials deposited by glaciers, lakes, streams, and wind. Wind deposits include volcanic ash from Cascade Range volcanoes in Washington and Oregon. In many areas, soils formed in glacial till and are generally loamy and with moderate to high quantities of boulders, cobbles, and gravels. In general, soils are on steep slopes and well drained, with large amounts of broken rock, and are relatively productive. Rock outcrops are common.

In part because of the relatively short post-glacial history of the watershed, soils tend to be shallow and skeletal. In general, deeper soils are developed in valley bottoms where alluvial sediment and nutrients accumulate and higher biomass production and moisture results in greater rates of decomposition (USFS, 2002).

Soil types formed on moraines and consisting of friable glacial till within the Grave Creek Watershed are characterized by loamy-skeletal, mixed Andic Cryochrepts. The dominant soils have a surface layer of dark brown silt loam approximately 8 inches thick. The upper part of the subsoil is yellowish brown very stony silt loam approximately 8 inches thick. The lower part is light olive brown very stony silt loam about 25 inches thick. The substratum to a depth of 60 inches or more is dark grayish brown very stony sandy loam (USFS, 1995a).

The dominant soils that formed in glacial outwash deposits are loamy-skeletal, mixed, frigid Andic Dystrochrepts, characterized by gravelly silt loam in the upper surface layer, and gravelly very fine sandy loam in the lower 13 inches of the soil profile. The subsoil is strong brown very gravelly very fine sandy loam, and extends approximately 20 inches into the soils profile. The substratum to a depth of 60 inches or more is pale brown very fine sandy loam.

2.9 Hydrography and Hydrology

Libby Reservoir (Lake Koocanusa) and its tributaries receive runoff from 47 percent of the Kootenai River drainage basin. The reservoir has an annual average inflow of 10,615 cfs. Three Canadian rivers, the Kootenay, Elk, and Bull, supply 87 percent of the inflow (Chisholm et al., 1989). The Tobacco River, including Grave Creek, and numerous small tributaries, flows into the reservoir south of the International Border.

Tributaries to the Kootenai River and Lake Koocanusa, including Grave Creek, are characteristically high-gradient mountain-streams with bed material consisting of various mixtures of sand, gravel, rubble, boulders, and drifting amounts of clay and silt, predominantly of glaciolacustrine origin. Stream flow in unregulated tributaries generally peaks in May and June after the onset of snow melt, then declines to low flows from November through March. Flows occasionally peak during periodic rain-on-snow events typically in late fall or winter. Kootenai Falls, a 200-foot-high waterfall and a natural fish-migration barrier, is located eleven miles downstream of Libby, Montana.

As a primary tributary to the Tobacco River, the Grave Creek Watershed is approximately 74.2 square miles, with elevations ranging from 2,700 ft at the confluence with Fortine Creek to over 7,500 ft at the watershed divide (Map 6). Most of the watershed originates on the Kootenai National Forest with the headwaters of the drainage occurring in the roadless Ten Lakes Scenic Area. Mean annual precipitation was estimated on an area-weighted basis using the most recent precipitation data from the Kootenai National Forest. Annual precipitation ranges from over 63 inches at the highest elevations to approximately 23 inches at the confluence with Fortine Creek. Basin average annual precipitation is estimated to be 47.9 inches. A majority of the precipitation occurs as snow, which melts between April and June on most years, although mid-winter rain-on-snow events can produce floods of significant magnitude.

2.9.1 Surface Water

Flood Frequency Analysis

The United States Geological Survey (USGS) maintained a streamflow gaging station on Grave Creek from April 1, 1923 through June 30, 1924 (Figure 2-1). The limited period of records is not sufficient to conduct standard flood frequency analyses. The Montana Fish Wildlife and Parks (FWP) has also collected discrete flow data in lower Grave Creek, but this data is also insufficient for conducting a flood frequency analyses.

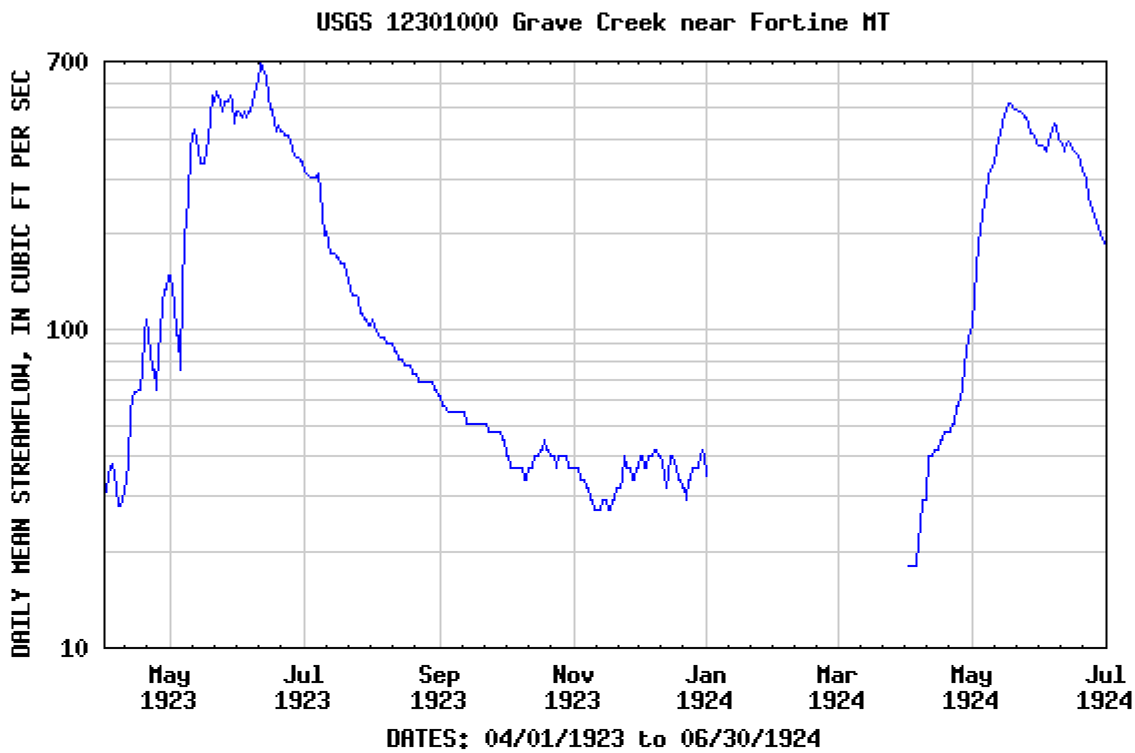


Figure 2-1: Grave Creek Hydrograph for April 1, 1923 through June 30, 1924 (Data Missing from January through April 1, 1924).

Recent studies conducted by Water Consulting, Inc. and River Design Group, Inc. established a flood series analysis for the watershed using several methods. The first method applied the United States Geological Survey regional equations developed for western Montana (Omang, 1992). The regional equations predict discharge as a function of area weighted mean annual precipitation and basin size. Grave Creek lies within the West Region. The average standard error of the prediction ranges from 45 to 52 percent. Table 2-4 presents the flood series based on the USGS regional equations.

Table 2-4: USGS Regional Equations Results for the Grave Creek Flood Series.

Return Interval and Equation	Predicted Discharge (cfs)
$Q_2 = 0.042\ A^{0.94}\ P^{1.49}$	768
$Q_{10} = 0.235\ A^{0.90}\ P^{1.25}$	1,368
$Q_{25} = 0.379\ A^{0.87}\ P^{1.19}$	1,605
$Q_{50} = 0.496\ A^{0.86}\ P^{1.17}$	1,862
$Q_{100} = 0.615\ A^{0.85}\ P^{1.15}$	2,047
$Q_{500} = 0.874\ A^{0.84}\ P^{1.14}$	2,568

The second flood series analysis method evaluated two adjacent stream gauging stations. Deep Creek, located to the south of Grave Creek, is a smaller tributary to Fortine Creek and reflects similar mean annual precipitation and hydro-physiographic characteristics to Grave Creek. Weighted mean annual precipitation for Deep Creek is 50 inches, with an approximate drainage area of 19 square miles. Fortine Creek, a second major tributary to the Tobacco River, is larger than Grave Creek with lower mean annual precipitation. Table 2-5 summarizes the analysis completed for both gages. The individual flood estimates were divided by the watershed area to determine the unit discharges in cubic feet per second per square mile (CSM).

Table 2-5: Unit area Discharge Results Based on Deep Creek, Fortine Creek, and USGS Regional Equation Flood Series Calculations.

Recurrence Interval (yrs)	Gaged CSM for Deep Creek USGS Gage $A=19mi^2$, P=50"	Gaged CSM for Fortine Creek USGS Gage $A=110mi^2$, P=28"	Predicted CSM for Grave Creek based on USGS Equations
Q_2	6.9	7.0	10.3
Q_{10}	10.7	12.1	18.4
Q_{25}	12.5	14.6	21.6
Q_{50}	13.8	16.6	25.1
Q_{100}	15.1	18.5	27.6
Q_{500}	17.9	23.3	34.6

The gauged CSM flood series values for Deep Creek and Fortine Creek were much lower than the estimated flood CSM values for Grave Creek. Fortine Creek is a larger watershed yet the estimated unit discharge was significantly lower than Grave Creek. A larger proportion of the Fortine Creek watershed area is situated in zones of lower mean annual precipitation, resulting in lower unit discharges, on average. While a detailed investigation on weighted basin area was not completed, a larger proportion of the Grave Creek Watershed is likely distributed in zones of higher mean annual precipitation, resulting in greater unit discharges than Deep Creek and Fortine Creek, on average. For these reasons and due to the lack of long-term streamflow gauging data for Grave Creek, the results of the USGS regression equations (Omang, 1992) were selected to predict flood flows for the Grave Creek Watershed.

A third flood series analysis method was used to estimate the bankfull discharge in the lower watershed upstream of the Highway 93 North Bridge. Channel cross-sections were surveyed and several discharge measurements conducted over a range of flow conditions to calibrate Manning's coefficient for hydraulic modeling. Longitudinal profiles, channel cross-sections, and Wolman pebble counts were completed to characterize the hydraulic geometry of a stable riffle section upstream of Highway 93. Relative roughness for bankfull flow was computed by comparing the mean depth of the channel at bankfull to the measured D_{84} of the riffle. Values were compared to resistance factors developed by Limerinos (1970) and Leopold, Wolman and Miller (1964) to determine a friction factor and corresponding bed roughness. Modeling results using the USGS regional equations predicted a bankfull ($Q_{1.6}$ to $Q_{1.8}$) discharge ranging from 640 cfs to 680 cfs.

Select bankfull and flood discharges for the Grave Creek Watershed are summarized in Table 2-6.

Table 2-6: Selected Bankfull and Flood Discharges for Grave Creek.	
Return Period (years)	Discharge (cfs)
$Q_{Bankfull}$	640 - 680
Q_2	768
Q_{10}	1,368
Q_{25}	1,605
Q_{50}	1,862
Q_{100}	2,047

Irrigation Withdrawals

Several points of diversion are located along lower Grave Creek. Appropriated water rights for Grave Creek total approximately 60,000 acre-feet of water annually (http://nris.state.mt.us/apps/dnrc2002/waterrightmain.asp). Glen Lake Irrigation District (GLID) holds the water right for the primary diversion. GLID has several senior water right claims that total 205 CFS (approximately 55,600 acre-feet), or almost 93% of the appropriated water in Grave Creek. The remaining appropriated water is diverted for a variety of uses, primarily for flood and sprinkler irrigation.

The location of the GLID diversion and ditch are noted in Map 7.

2.9.2 Groundwater

A large portion of the Grave Creek drainage is underlain by differentially compacted glacial till deposited as lateral, terminal, and recessional moraines. Precambrian belt series rock formations characterize the subsurface geology. These rock formations can absorb and release only small amounts of water per unit area, but their total outcrop area is large, and therefore the total contribution to streams is sufficient to help sustain base flows (Coffin et al., 1971). Outwash deposits and alluvium create glacio-fluvial landforms in the lower reaches of Grave Creek from Vukonich Bridge downstream to the confluence with Fortine Creek. These deposits are capable of absorbing and releasing relatively large volumes of water per unit area. Groundwater exchanges in the lower reaches create gaining, losing, flow-through and parallel-flow reaches. Groundwater and surface water interaction also creates hyporheic zones, areas in which groundwater and stream water mix at the channel bed scale. In other watersheds, areas of groundwater upwelling have been identified as critical bull trout spawning areas (Baxter and Hauer, 2000).

2.10 Vegetation Cover

Vegetation of the Grave Creek Watershed was studied in detail in the summer of 1999 by the USFS. The diverse geology, topographic relief, and varied durations of snow persistence have been demonstrated to be decisive ecological gradients for forest vegetation (USFS, 2002). The plant association approach has been applied to delineate and map vegetation types. The major forest vegetation or aggregations of forest associations are listed in Table 2-7. A map of the 1992 National Landcover Dataset displays generalized landcover classification for Grave Creek (Map 8).

Table 2-7: Plant Associations of the Grave Creek Watershed and Major Forest Type Associations (from USFS 2002).

Forest Type (Association)	Major trees	Elevation (ft)	Acres	Comments	Major Natural Disturbance
(1) Warm-Dry			**6041**		
Douglas fir-Ponderosa Pine/Oregon Grape	Douglas-fir, Western Larch	2900-3200		Main forest type on moister sites in the dry valley bottoms	Fire, insect & disease
Douglas fir-Ponderosa Pine/Oregon Grape	Douglas-fir, Ponderosa Pine	2900-3200	2113	On dry knolls; open savanna before fire suppression	Fire, insect & disease
Larch-Paper Birch Maple	Paper Birch, Western Larch, Lodgepole Pine, White Spruce	3300-3500	555	Hardwood forest type along lower Grave Creek (FS)	Fire
Aspen sites	Quaking Aspen	2900-3100	512	Hardwood stands in valley bottom, private land	Fire
Agricultural land (hay meadows, pasture)	n/a	2900-3100	884	Private land, most converted meadows and aspen groves	n/a
(2) Warm-Mod. Dry			**6085**		
Douglas fir-Ponderosa Pine/Ninebark	Douglas-fire, Western Larch	3400-3800	4590	Found in lower Grave Creek	Fire, insect & disease
Larch – Douglas fir	Western Larch, Douglas-fir	3400-3800	1495	Localized around lower Grave Creek	Windthrow, Insect & Disease, Fire
(3) Warm-Moist			**1052**		
Western Red Cedar/Oakfern	Western Red Cedar, Douglas-fir, Subalpine fir, Western White Pine, Engelmann sp.	3600-4400	1052	Restricted to Stahl and Clarence Creeks, old growth	Windthrow, Insect & Disease, Fire
(4) Cool to Cold-Moist & Subalpine			**33451**		
Subalpine fir-Larch/Dwarf Billberry	Subalpine fir, Engelmann	4000-5000	717	More common in	Fire, insect & Disease

Table 2-7: Plant Associations of the Grave Creek Watershed and Major Forest Type Associations (from USFS 2002).

Forest Type (Association)	Major trees	Elevation (ft)	Acres	Comments	Major Natural Disturbance
Subassociation	Spruce			Salish Mtns.	
Subalpine fir/Beargrass	Subalpine fir, Engelmann Spruce	4000-6600	8555	Common association of upper elevation dry ground	Insect & Disease, Windthrow, Fire
Subalpine fire – Spruce/Menziesia	Subalpine fir, Engelmann Spruce	3800-6800	18658	Most abundant type, covering 39% of total area	Insect & Disease, Windthrow, Fire
Subalpine fir – Whitebark Pine/Big Huckleberry	Subalpine fir, Engelmann Spruce, Whitebark Pine	6600-7500	5316	Harsh sites on dry subalpine ridges' whitebark affected by dieback	Insect & Disease, Snow crush, Fire
Subalpine fir – Whitebark Pine/Grouse Whortleberry	Subalpine fir	6400-7000	205	In areas of late-melting winter snows in cirques	Snow crush, Insect & Disease
Rock, talus, avalanche chutes, all elevations		2900-7500	1972	Non-forested sites, especially at high elevations	Process

Vegetation communities in the Grave Creek Watershed have experienced several changes related to natural and human-caused disturbances. In particular, vegetation changes have occurred in response to human activities associated with a variety of land uses, including agriculture, grazing and timber harvest.

Agricultural and grazing in the lower private lands of the watershed have affected the riparian community that was historically comprised of a cottonwood (*Populus trichocarpa*) overstory and a diverse shrub understory. The existing lower watershed riparian community is functioning below its historical potential, mainly due to past and current land disturbance in addition to the colonization of invasive species on stream banks and the adjacent floodplain.

Timber harvest in the middle and upper watershed converted mature forests (climax-like species composition, low stems/acre and high basal area density) to mixed forest communities characterized by pole-size to large alpine fir and spruce at low densities. Vast quantities of menziesia and alder inhibit tree regeneration in the large gaps left by past clearcut harvests (USFS, 2002).

Land uses are discussed in more detail in the following land use section.

2.11 Land Use

Pre-European Settlement

The Grave Creek Watershed has a long history of use by the Kootenai Indians. The lower reaches of Grave Creek were a favorite camping spot for the Kootenai when traveling along the old Kootenai Trail. The meadows provided lush vegetation that was otherwise unavailable in the heavily timbered upper reaches of the basin.

The vast trail networks established in the Tobacco River Valley were also used by the Kootenais for centuries. A major trail network provided travel from the western flank of the Whitefish Mountain Range onto the eastern plains. Thomas Blakiston, the first European visitor to travel up Grave Creek, followed the Grave Creek Trail up to Bald Mountain and Timothy Meadow, down Yak-in-a-kak Creek to the North Fork of the Flathead River, and through Boundary pass to Waterton Lakes. Today the trail is paralleled by a USFS road along much of its original route (Bohn, 1998, unpublished report).

Homesteading, Agriculture and Grazing

Development and early homesteading in the Tobacco River Valley began in the late 1890s. By 1897, most of the prime creek bottoms and meadows had been claimed (Johnson, 1950). Historically, the lower Grave Creek valley from the mouth of the canyon downstream to Highway 93 consisted of a multiple channel system developed within a broad, well-vegetated spruce wetland (General Land Office map dated March 16, 1896). The channels meandered across the valley bottom and likely supported diverse wetland habitats. However, high water tables and frequent inundation of the spruce wetland likely hindered agricultural production. As a result, many of the lower gradient meadows and riparian areas in the lower valley bottom were cleared of riparian vegetation. The early settlers filled the multiple channels and diverted the water into the southern-most channel (Johnson, 1950). These modifications to accommodate hay pastures likely contributed to the degradation of stream channel stability and aquatic habitats. Once cleared, grazing by livestock likely prevented the re-establishment of the native riparian community. Many of the meadows cleared following the harsh winter of 1892-1893 are still devoid of a stable native riparian community.

Agricultural pressure on the stream corridor has continued during the twentieth century. WCI, RDG, and BioQuest International Consulting Ltd have documented the effects on channel stability, fish habitat, and riparian conditions. Throughout the 1900s, periodic flood events, timber harvest and road construction, grazing, riparian vegetation losses, and channel alterations along the downstream private reaches to accommodate agricultural and residential developments have altered channel form and function. Perhaps the most damaging of these influencers was the periodic bulldozing of the channel that occurred below Forest Service lands following large flood events in an attempt to stabilize or clean the channel of sediment and debris. In-channel log drives also negatively influenced channel condition, when additional channel modifications were undertaken to facilitate the log drives. These underlying conditions and land use practices have had significant implications on stream channel stability, the quantity and quality of available fish habitat, and the structure and composition of the riparian community.

Timber Harvest and Road Building

Historically, timber harvest in the watershed was concurrent with homesteading in the late 1800s. Homesteading typically resulted in removal of trees along lower Grave Creek. The early harvesting culminated in the mid-1920s when the majority of the accessible timber had been harvested (Bohn, 1998, unpublished report). Timber harvest continued on a relatively small scale until the widespread spruce bark beetle infestation of the 1950s.

The management of the spruce bark beetle epidemic changed the character of the entire Grave Creek basin. In the 1950s and 1960s, large-scale logging was initiated in response to the spruce bark beetle infestation that affected northwestern Montana and Idaho. A timber salvage program was implemented to remove decaying trees and portions of the forest expected to succumb to the beetle infestation (USFS, 2002). Large (dominant trees 15 inch to 21 inch DBH) and very large (dominant trees >21 inch DBH) Engelmann spruce (*Picea engelmannii*) and alpine fir (*Abies lasiocarpa*) were removed from the headwaters of most of the primary tributaries in the watershed (Figure 2-2).

A majority of the spruce logging in the watershed occurred in the upper main stem reaches and tributaries (Williams and Blue Sky, in particular) of the watershed. Review of historical aerial photographs show management activities in riparian areas, numerous stream crossings (again, most notable in Williams and Blue Sky drainages), and large clearcuts with minimal riparian buffer strips maintained between the hillslopes and channel network.

An analysis of recorded Forest Service timber harvest activity throughout the watershed is presented in Appendix A and shown on Map 9. Approximately 6,400 acres were harvested during the first spruce salvage operation (USFS, 1974) with an additional 2,600 acres in the 1960s and 1980s for an approximate total of 10,000 acres of harvest. Forest Service database records (TSMRS) indicate approximately 5,800 of the 10,000 acres involved intermediate and regeneration harvest activity, with other types of harvest activity occurring in the remaining acreage. Regeneration harvest leads to very little retained vegetation immediately after harvest since most trees are removed. Intermediate harvest selects only individual trees. Both harvest types involve roads and other land disturbing activities that can have result in significant sediment loading where BMPs are not utilized. All together, approximately 10 miles^2 (13%) of the watershed have been harvested at least once. Of this, a little over 5 miles^2 (7%) was harvested in stands that are in or adjacent to the riparian corridor, although actual harvest activity may not have occurred in the portion of the stand that is within the riparian buffer as discussed in Appendix A. Nevertheless, harvest did occur in riparian areas as noted later in the assessment of mass wasting events in Section 6.0 and as shown by Photos 1 and 2.

To access merchantable timber, approximately 100 miles of road were constructed in the 1950s in the Williams, Jiggs, Kopsi, Blue Sky, Lewis, Foundation, Stahl, and Clarence drainages. Based on the most current GIS data available, approximately 170 miles of road exist in the Grave Creek Watershed today. Over 100 miles (62%) are located in stands that are in or adjacent to riparian corridors; 35 miles of road (21%) are located within 300 feet of streams. Many of these roads have been closed and have revegetated such that sediment production and mass wasting impacts are less of a concern from historical conditions. An analysis of road building throughout the watershed is detailed in Appendix B and Map 10, with additional sediment loading assessment presented later in Section 6.0 and Appendix I. This analysis does not include a network of jammer roads and skid trails, although revegetation of these timber harvest features has mitigated any sediment or water routing impacts.

A majority of the spruce harvest was located within the rain-on-snow zone of the watershed, characterized by heavy snowpack, thin soils, and high peak flow contributions during the snowmelt season. Jammer or skid road construction on steep, sensitive soils within the rain-on-snow zone (4,500 ft to 5,500 ft) coupled with the removal of large diameter trees would have increased water yield, peak flows, and sediment production in the watershed. Fifty-two miles of road (31%) exist in the rain-on-snow zone. Just over 3 miles^2 (4%) of the watershed was harvested at least once within the rain-on-snow zone. An analysis of timber harvest and road building activity in the rain-on-snow zone of the watershed is presented in Appendix C and within Map 11.

The above timber harvest and road building information is based primarily on the analyses in Appendices A, B, and C. Future detailed analysis may result in additional refinement to some of the details, but would not have an impact on the conclusions within this document given the way that the data is used in later sections for water quality planning purposes.

Mining

Discovery of gold in the upper Rocky Mountains attracted many prospectors to the Tobacco Valley. While no major mineral strikes were made in the Tobacco Valley, several prospectors did make small finds that provided enough encouragement for a claim to be filed near the location of the Sons of Rest cabin in the upper reaches of Grave Creek (Johnson, 1950).

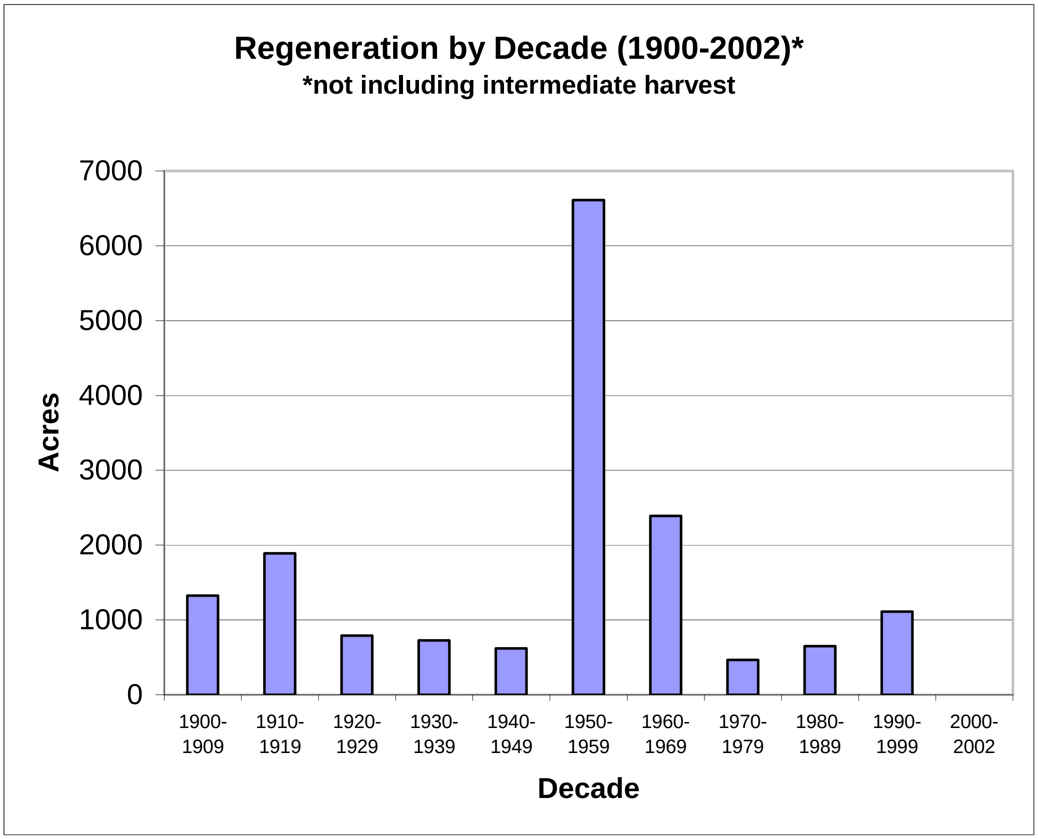


Figure 2-2: Acres of Regenerating Disturbance by Decade Over the 20th Century. The peak in the 1950s and 1960s is from spruce beetle logging; the higher figure from the 1990s is almost entirely attributable to the 1988 fire in Blue Sky drainage (1,040 acres burned). (Only US Forest Service ownership calculated, based on stand database query of year origin per decade) (USFS, 2002).

2.12 Stream Geomorphology

The channel morphology of Grave Creek transitions from steep confined valley types to broad, alluvial landforms in the lower segments upstream of the confluence with Fortine Creek. Channel morphology of the primary tributaries, Williams, Blue Sky, Kopsi, Lewis, Foundation, Clarence, Stahl, and South Fork Stahl Creeks, is similar to main stem Grave Creek although the unconfined alluvial form is unique to the lower main stem. Channel stability and sensitivity to disturbance vary by the stream channel type.

2.12.1 Tributary Streams

The upper headwaters of Grave Creek's tributary streams are characterized by colluvial valleys associated with glacially scoured lands and highly dissected fluvial slopes. These landforms and resulting stream channel types are classified as A and G types according to Rosgen (1996) and Channel Alluvial Valley according to Montgomery and Buffington (1993). Channel types are deeply entrenched, confined and associated with structurally controlled first and second order drainages.

Glacial activity throughout the Pleistocene blanketed the headwaters and major drainages with differentially compacted till. The till was deposited as lateral moraines on relatively steeply dipping Precambrain metasedimentary bedrock. Zones of lower elevation in the tributaries were subject to extensive outwash material resulting in deep deposits of till and fluvial sediments in the transitional reaches of the watersheds. These semi-confined and unconfined landforms exhibit lower gradient, meandering alluvial channel types (Rosgen B stream types in semi-confined landforms and Rosgen C stream types in unconfined landforms) dominated by coarse gravel and cobble particle sizes.

2.12.2 Main Stem Grave Creek

Upper main stem Grave Creek from Blue Sky to Foundation Creek consists of riffle-pool features in semi-confined, alluvial landforms (Rosgen C stream types). Some inclusions of transitional step-pool / riffle-pool channel types are found where landforms are narrower and more confining.

The middle reaches of Grave Creek from Williams to Blue Sky Creek are characterized primarily by step-pool morphologies (Rosgen B stream types) in semi-confined and unconfined, alluvial valleys. Some inclusions of transitional step-pool / riffle-pool channel types are found where landforms are less confining.

The lowest reaches of Grave Creek are markedly different than the upper, forested segments. From Williams Creek to the canyon reach, lower Grave Creek consists of riffle-pool features in semi-confined valley with inclusions of riffle-pool features where the valley is less confining. From Highway 93 to the canyon reach, lower Grave Creek exhibits riffle-pool morphology within an unconfined, fluvial valley. The potential channel type is described as a C according to the Rosgen classification. The canyon reach is confined with bedrock structural control. Rosgen stream type in the canyon reach is F.

2.12.3 Stream Stability and Sensitivy

The headwaters of the tributary drainages and uppermost reaches of Grave Creek main stem have not deviated significantly from their stable form due to stable bed forming features of these "cascade" channel types generally classified as Rosgen A and G types. The primary and natural sources of sediment and debris to these reaches are colluvial draws and avalanche chutes. These sources periodically provide large volumes of trees and other organic material to the system, oftentimes causing extensive debris jams to form, channel avulsions, and bank cutting. These natural events are integral to maintaining high levels of coarse woody debris to forested streams in the Pacific Northwest.

Landforms of the lower reaches of the tributary watersheds and middle reaches of Grave Creek main stem are relatively unstable. Glacial moraines bound both sides of the channel in these reaches, limiting floodplain development. These features are composed of a mixture of particle sizes. When disturbed through road construction or logging, these landforms may respond with accelerated soil creep and slope failure, and can become significant sources of sediment. The channel types found on these landforms are inherently stable and maintain a high sediment transport capacity; however, increases in sediment loads can result in excess surface or substrate fines, pool filling, a reduction in channel roughness, and the potential for bank erosion (Whittaker, J. F., 1987).

Historically, these reaches produced minimal in-channel sediment due to channel stability provided by dense, healthy riparian vegetation and structural controls of the valley and landforms. Historical riparian harvesting in the form of complete tree removal or removal of the larger trees, reduced bank stability and the potential for larger woody debris recruitment in places (Photos 1, 2, and 3). This provided an increased potential for bank erosion, mass wasting, and reduced LWD in the channel. Mature trees and significant recovery is likely and has been observed where riparian harvest occurred in the 1950s or 1960s, whereas more recent riparian logging (Photo 2) would still involve areas of reduced bank strength, reduced LWD recruitment, and a higher potential for mass wasting.

According to the historical Government Land Office notes, the lower Grave Creek valley existed as a broad, spruce wetland defined by multiple channels. This historical condition is better defined as a stable, low sediment supply, multiple channel system developed within a wetland environment, versus a “braided” condition which implies general instability and dynamicity resulting from excess bedload and total sediment transport impairment. These original multiple channels covered a wide floodplain area representing a condition that is no longer considered the stream’s potential based on permanent human settlement in the valley (refer to Section E.2.3.2.1).

The existing potential Rosgen stream type in the unconfined, alluvial valley of lower Grave Creek is a C stream type. Residential encroachment, conversion of riparian vegetation to agricultural cover types, and a multitude of direct and indirect modifications to channel morphology have converted large reaches of the channel into a braided, multiple threaded system characterized by accelerated bank erosion and high sediment supply (Rosgen D and C→D stream type). The braided ‘D’ channel regimes tend to be located downstream of the Flanagan Ranch to approximately .25 miles upstream of the Highway 93 bridge, and from the Highway 93 bridge downstream to approximately .25 miles upstream of the confluence of Grave Creek and Fortine Creek.

2.13 Fisheries and Other Aquatic Life

Grave Creek supports a largely native assemblage of fish comprised of ten species within four families (Table 2-8). Native salmonids include bull trout, westslope cutthroat trout, and mountain whitefish. Introduced salmonids include brook trout, rainbow trout, and kokanee salmon. The large-scale sucker is the lone representative of the catostomid family. The torrent sculpin is presumably the only member of the sculpin family occurring in the focus area. The redside shiner and northern pikeminnow represent the minnow family (cyprinidae). Classified as a bull trout core area (Montana Bull Trout Scientific Group, 1996b), Grave Creek is the major bull trout spawning tributary to Lake Koocanusa (USFS, 2000). Threats to resident and migratory life forms of bull trout in the drainage include habitat degradation, introduced fish species, rural residential development, forestry, water diversions, and agricultural land uses (Montana Bull Trout Scientific Group, 1996b). These threats can also impact other native species, particularly westslope cutthroat trout.

Fish distribution data provided by Montana Fish, Wildlife and parks is displayed in Map 12. Appendix D provides additional fisheries details in addition to some limited results from macroinvertebrate sampling.

Table 2-8: Native and Introduced Fish Species Sampled Inhabiting Grave Creek.

Fish Species
Native Species
Bull trout (*Salvelinus confluentus*)
Westslope cutthroat trout (*Oncorhynchus clarki lewisi*)
Large-scale sucker (*Catostomus macrocheilus*)
Northern pikeminnow (*Ptychocheilus oregonensis*)
Mountain whitefish (*Prosopium williamsoni*)
Torrent sculpin (*Cottus rhothecus*)
Redside shiner (*Richardsonius balteatus*)
Introduced Species
Rainbow trout (*Oncorhynchus mykiss*)
Brook trout (*Salvelinus fontinalis*)
Kokanee salmon (*Oncorhynchus nerka*)

SECTION 3.0
REGULATORY FRAMEWORK AND TMDL DEVELOPMENT

This section and Appendix E present details about Grave Creek impairment determinations recorded on the State of Montana 303(d) list and documented within MDEQ files. This is followed by a discussion of applicable Montana Water Quality Standards and reference conditions, and a general description of how the standards and reference conditions are used in this plan to make updated water quality impairment determinations. The approach used within this plan for identifying solutions to impairments, including development of TMDLs and allocations, is also described.

3.1 Grave Creek 303(d) Impairment Status

3.1.1 Recent 303(d) Listing Information

The Montana 303(d) list, published every other year, identifies the main stem of Grave Creek from Foundation Creek downstream to the confluence of Grave Creek and Fortine Creek as impaired. Table 3-1 provides a summary of the impairment information from both the 1996 and 2004 303(d) lists. The Montana 2004 303(d) list (MDEQ, 2004) is the most current EPA-approved list. Table 3-1 includes information from the 1996 303(d) list to ensure accountability for all previously identified causes of impairment. The impairment is “partial support” of aquatic life, cold-water fish and recreation (from dewatering). Note that the 2004 list incorporates and expands upon all impairment information within the 1996 list. As discussed further in Section E.1.1, causes of impairment can be grouped into three major categories of sediment, habitat alterations and dewatering.

Table 3-1: List of Beneficial Use Impairments for Grave Creek (1996 and 2004).

Listed Stream and Number	List	Probable Causes	Probable Sources	Beneficial Uses Not Fully Supported (Partial Support)
Grave Creek (MT76D004-6)	1996	Flow Alteration Other Habitat Alterations Siltation	Agriculture Silviculture	Aquatic Life Cold water Fish
	2004	Bank Erosion Dewatering Fish Habitat Degradation Flow Alteration Other Habitat Alterations Siltation	Agriculture Grazing-related Sources Silviculture Logging Road Construction/ Maintenance Dam Construction Flow Regulation/ Modification Hydromodification	Aquatic Life Cold water Fish Recreation

3.1.2 Grave Creek Impairment Justifications

The information within the MDEQ SCD/BUD files for Grave Creek (MDEQ, 2004c) was sufficient for making the impairment determinations identified on the 303(d) list. Below is a summary of information used for making the impairment determinations.

3.1.2.1 Sediment and Habitat Alterations

Sediment and habitat alteration impacts linked to human activities within the watershed are described in several reports within the MDEQ SCD/BUD files for Grave Creek (MDEQ, 2004c). Most information is found within a watershed analysis report (Bohn, 1998) where impacts to Grave Creek and the watershed are identified and discussed. Sources include stream channel realignment, timber harvest (clearcuts, roads, riparian cutting, peak flow modifications), large woody debris removal projects, urban and agricultural development along the riparian corridor, and grazing. Most of the timber harvest sources are linked to historical harvest activities. Section 3.1.2.1 provides additional details from the Bohn report, including results from aerial photo interpretation where land use activities, including timber harvest, are linked to stream widening and loss of sinuosity. Other reports discussing similar sediment and habitat alteration impacts, as well as fish passage problems that have been addressed along lower Grave Creek, are also discussed in Appendix E.

3.1.2.2 Dewatering

Flow losses due to irrigation diversions is of concern identified within the MDEQ SCD/BUD files. Section E.1.2.2 discusses low flow concerns and reference material used for making this impairment determination.

3.1.3 Water Quality Restoration Planning and TMDL Development Requirements

Table 3-2 summarizes the impairment cause categories, impairment linkages, 303(d) list linkages, and potential TMDL development requirements based on the listing information and rationale provided. It is important to note that Table 3-2 is derived from the 303(d) list and updated MDEQ files, and was used for further assessment planning and data evaluation performed in Sections 4.0 and 5.0. As part of water quality restoration planning and TMDL development, this additional assessment data and analysis is used to update impairment determinations.

Table 3-2: Impairment Cause Summary and Restoration Planning for Grave Creek.			
Impairment Cause Category	Impairment Linkage	303(d) List Linkages	Potential TMDL Development Requirement
Siltation	Excess Fine Sediment	Siltation, Bank Erosion	Yes (contingent upon water quality impairment status update)
Other Habitat Alterations (pollutant conditions)	Excess coarse or total sediment	Other Habitat Alterations; Fish Habitat Degradation; Bank Erosion	Yes (contingent upon water quality impairment status update)
Other Habitat Alterations (non-pollutant conditions)	Loss of Fish Passage Capability; Loss of Large Woody Debris; possibly others	Other Habitat Alterations; Fish Habitat Degradation	No (water quality restoration planning still applies contingent upon water quality impairment status update)
Flow Alteration	Reduced Flow	Dewatering; Flow Alterations	No (water quality restoration planning still applies contingent upon water quality impairment status update)

3.2 Applicable Water Quality Standards

Water quality standards include: the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a waterbody. The ultimate goal of this water quality restoration plan, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. The water quality standards form the basis for impairment determinations and development of numeric values used for TMDL targets and other use support objectives. This section and Section E.2 provide a summary of the applicable water quality standards for sediment and other conditions limiting cold-water fish as identified in Tables 3-1 and 3-2.

3.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. Section E.2.1 provides additional detail on waterbody classification and beneficial uses under Montana Law. Note that Grave Creek and all waters within the Grave Creek Watershed are classified as B-1 (17.30.607). Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply (17.30.623[1]).

3.2.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy. Section E.2.2 provides details on these standards, with narrative standards being applicable to the Grave Creek impairment causes. These narrative standards include the beneficial use support standard (17.30.623[1]) for a B-1 Stream, and the standards in Table E-3 that can be applied to many of the excess sediment concentrations in Grave Creek Watershed streams.

The relevant narrative criteria in Table E-3 do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels of sediment or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a waterbody's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental or injurious to beneficial uses (see definitions in Table E-3). As discussed in Section E.2.2, reasonable land, soil, and water conservation practices generally include BMPs, but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses.

3.2.3 Reference Conditions

3.2.3.1 Definition of Reference Conditions

Section E.2.3.1 provides a complete description of reference conditions as provided within Appendix E of the State of Montana 303(d) list (MDEQ, 2004). MDEQ uses the reference condition to determine if narrative water quality standards are being achieved. The term “reference condition” is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a waterbody's greatest potential for water quality given existing and historic land use activities. Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference conditions should reflect minimum impacts from human activities. It attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil and water conservation practices.

The following methods, defined in more detail in Section E.3.1 further defines primary and secondary approaches for determining reference conditions, with primary approaches being preferred over secondary approaches. Often more than one approach is used for the same waterbody.

Primary approaches include:

- Comparisons to minimally impaired waterbodies that are in a nearby watershed or in the same region.
- Comparing historical data from the waterbody of concern to existing conditions.
- Comparisons to unimpaired segments of the same stream.

Secondary approaches include:

- Reviewing literature.
- Seeking expert opinion.
- Applying quantitative modeling.

3.2.3.2 Development of Reference Conditions for the Grave Creek Watershed

3.2.3.2.1 Stream Potential Given Historic Land Uses

As discussed in Appendix E, there is the potential for improvements to water quality as streams within the Grave Creek Watershed continue to recover from historical practices. This recovery represents the greatest potential. In lower Grave Creek, land uses may preclude recovery to the historic condition of a multiple thread channel across much of the lower drainage bottom as described in Section 2.11. Nevertheless, there is evidence that the stream's greatest potential within the constraints of a single thread channel and existing and future land uses is one where fish habitat and overall water quality conditions can be significantly improved.

3.2.3.2.2 Use of Statistics for Developing Reference Values or Ranges

Section E.2.3.2.2 provides discussion on the application of statistics to help define reference values or reference ranges to compare against results from the Grave Creek Watershed. A commonly used approach in this document is the use of non-normal or non-parametric statistics where the range from the 25^{th} to the 75^{th} percentiles is defined as the expected reference range or the median value is defined as the expected reference value (reference Figure E-1). Another approach is the use of the normal or parametric statistics where one standard deviation around the mean is used to define the expected reference range or the mean (average) is defined as the expected reference value. The use of the statistical ranges from regional reference streams is a primary reference approach. Both of the other two primary approaches defined in Section 3.2.3.1 are also applied since there is historical air photo data to help define reference conditions for lower Grave Creek and since there is a reach along lower Grave Creek that is considered minimally impacted. Some reference development in the watershed also uses secondary approaches due to data limitations. Reference development is further addressed in Section 5.1.

3.3 Application of Water Quality Standards and Reference Conditions

The water quality standards and reference condition approach is used to develop an updated water quality impairment status. This includes the below steps which are defined in greater detail in Section E.3 and presented by the Figure E-3 flow chart.

1) Present water quality data for the Grave Creek Watershed (Section 4.0).
2) Develop water quality reference values for the Grave Creek Watershed using the guidance presented above (Section 5.1).
3) Use the reference values to define beneficial use support conditions relative to the defined impairments in Tables 3-1 and 3-2, including TMDL targets that must be met to satisfy water quality standards (Section 5.2).
4) Compare the existing water quality data from waterbodies in the Grave Creek Watershed to targets and use support objectives (Section 5.3 departure analysis). This comparison provides the basis for the updated water quality impairment status in Section 5.4.

3.4 Restoration Objectives and TMDL Development

Once water quality impairment determinations are updated, solutions to any remaining or additional problems are developed within the context of restoration objectives and TMDLs. In the Grave Creek Watershed, this includes the steps below that are defined in greater detail in Section E.4 and presented by the Figure E-4 flow chart of this process.

1. Perform a detailed source assessment, including sediment loading analysis (Section 6.0).
2. Develop restoration objectives that define the actions that, if implemented, would lead to conditions where all TMDL targets and use support objectives are satisfied (Section 7.0).
3. Identify implementation and monitoring (Sections 8.0 and 9.0).

As discussed in several sections of this plan and within Appendix E, adaptive management is an important component of this water quality restoration and TMDL development process.

3.5 TMDL Implementation and State Law

State Law (75-5-703(8)) directs the MDEQ to “support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL”. This is an important directive that is reflected in the overall TMDL and water quality plan development and implementation strategy within this plan, particularly as it applies to existing nonpoint sources of pollutants/pollution on private lands. It is important to note that water quality protection measures are not considered voluntary where such measures area already a requirement under existing Federal, State or Local regulations. Also, water quality permitting activities must be consistent with this water quality plan and TMDL. Implementation of this plan is further discussed in Section 8.0.

Montana State Law (75-5-703(7)) also directs the DEQ to perform monitoring to "determine whether compliance with water quality standards has been attained for a particular water body or whether the water body is no longer threatened." State Law (75-5-703(9)) further requires that "if the monitoring program provided under subsection (7) demonstrates that the TMDL is not achieving compliance with applicable water quality standards within 5 years after approval of a TMDL, the department shall conduct a formal evaluation of progress in restoring water quality and the status of reasonable land, soil, and water conservation practice implementation to determine if:

a. the implementation of a new or improved phase of voluntary reasonable land, soil, and water conservation practice is necessary;
b. water quality is improving but a specified time is needed for compliance with water quality standards; or
c. revisions to the TMDL are necessary to achieve applicable water quality standards."

Section 9.0 of this document defines some of the recommended monitoring program goals to help satisfy the above TMDL requirements. Consistent with "b." above, there is a potential situation where all reasonable land, soil, and water conservation practices have been applied, thus satisfying the allocations within the TMDL, but the stream is still not in compliance with water quality standards because more time is needed for recovery since excess pollutant loading could still be working through the system.

SECTION 4.0
STREAM CONDITION DATA SUMMARIES

This section summarizes existing channel, floodplain, fish habitat and upland conditions. Appendix G includes additional discussion and details about the stream condition assessment and results. Also included in Appendix G is a general discussion on human activities and potential linkages between these activities and existing conditions. The stream condition assessment is focused on nonpoint sources of pollution, links with riparian condition and stream morphology, and the relation of riparian and stream morphology conditions to land use practices in the Grave Creek Watershed. Biological assessment results, including fisheries and macroinvertebrate information, are presented in Appendix D.

Tables 4-1 and 4-2 present data for pool frequency (Table 4-1) and large woody debris concentration (Table 4-2) by stream and stream reach type. McNeil Core results for Grave Creek main stem near Clarence Creek are included in Table 4-3. Tables 4-4, 4-5, 4-6 and 4-7 present additional habitat and channel morphology data by stream and stream reach type. These tables include data for composite particle size distribution and percent surface fines (Table 4-4); percent surface fines in pool tail outs (Table 4-5); width, width-to-depth ratio and sinuosity (Table 4-6), and pool depth along with Pfankuch ratings (Table 4-7).

Pool frequency, large woody debris concentration, and percent surface fines in pool tail outs were determined from USFS R1/R4 data collected by the Kootenai National Forest in 2001. McNeil core data is collected and analyzed by Montana Fish, Wildlife and Parks. The Kootenai National Forest conducted Wolman pebble counts in 2003 to determine composite particle sized distribution and percent fines for all reaches in and above the lower Grave Creek canyon. WCI collected riffle material data for lower Grave Creek below the canyon. Bankfull channel width and width-to-depth ratio are based on Rosgen Level II assessment data also collected by the Kootenai National Forest in 2003 in all reaches within and above the canyon reach. Width and width-to-depth data for lower Grave Creek below the canyon was collected by WCI. Sinuosity was determined from aerial photo measurements of stream length and valley length.

Table 4-8 contains meander length ratio (meander length / bankfull width) for lower Grave Creek below the canyon. Meander length ratio was determined from aerial photograph measurements of meander length and field survey measurements of bankfull width (WCI, 2000).

Most data summarized in these tables are discussed in further detail as part of the departure analysis and water quality impairment status discussion in Sections 5.3 and 5.4.

Pool Frequency

Table 4-1: Pool Frequency (Number of Pools per Unit Length) by Stream and Stream Type (from USFS R1R4 2001, Unpublished Data).

Stream	Type	Pool Frequency (pools/mi)
Williams Lake	B	24.0
Williams	A	40.0
Williams	B	38.0
Stahl	A	106.3
Stahl	B	82.0
Lewis	C	26.2
Lewis	B	35.7
Clarence	C	8.6
Clarence	B	28.6
Foundation	B	32.0
Blue Sky	B	23.7
Upper Grave	C	26.0
Upper Grave	B	23.8
Middle Grave	C	11.7
Middle Grave	B	61.6
Lower Grave	C	9.1
Lower Grave	B	18.5
Lower Grave	F	8.8

Large Woody Debris

Table 4-2: Large Woody Debris Concentration (Amount of Large Woody Debris per Unit Length) Statistics by Stream and Stream Type (from USFS R1R4 2001, Unpublished Data).

Stream	Type	Statistic				
		Minimum	25th Percentile	Median	75th Percentile	Maximum
Williams Lake	B	0	0	158	419	1789
Williams	A	0	0	55	187	894
Williams	B	0	29	238	593	12697
Stahl	A	0	230	377	596	1558
Stahl	B	0	131	274	488	1238
Lewis	C	0	129	270	481	596
Lewis	B	0	157	304	393	1932
Clarence	C	0	128	167	329	619
Clarence	B	0	0	571	993	4526
Foundation	B	0	0	70	196	847
Blue Sky	B	0	0	36	320	732
Upper Grave	C	0	108	189	307	1319
Upper Grave	B	0	0	61	174	894
Middle Grave	C	0	70	105	256	467

Table 4-2: Large Woody Debris Concentration (Amount of Large Woody Debris per Unit Length) Statistics by Stream and Stream Type (from USFS R1R4 2001, Unpublished Data).						
Stream	Type	Statistic				
		Minimum	25th Percentile	Median	75th Percentile	Maximum
Middle Grave	B	0	0	56	233	5366
Lower Grave	C	0	48	101	171	607
Lower Grave	B	0	22	81	159	305
Lower Grave	F	0	62	106	158	555

Percent Substrate Fines

Table 4-3: Median Percentage of Streambed Material Smaller Than 6.35 mm in McNeil Core Samples Collected from Bull Trout Spawning Areas in Tributary Streams to the Kootenai River Basin, 1994 – 2002. (MFWP, 2003).									
	1994	1995	1996	1997	1998	1999	2000	2001	2002*
Grave Creek					22.0		25.3	20.4	

* Data not yet analyzed.

Sediment Particle Size and Composite Percent Surface Fines

Table 4-4: Sediment Particle Size and Composite Percent Surface Fines (Pebble Count Results for Fines < 2 mm and < 6.4 mm (USFS, 2003, Except*).							
Stream	Reach	Stream Type	D16	D50	D84	Percent Surface Fines in Riffle	
						% < 2 mm	% < 6.4 mm
Lower Grave Creek below Canyon*	1	D4	18	50	146	≤11	≤12
Canyon	2	F4b	11	60	180	3	7
Lower Grave Creek above Canyon	3	F2b				5	11
Middle Grave Creek	4	B4	11	51	94	10	15
Middle Grave Creek	5	B3	7	90	250	0	6
Middle Grave Creek	6	B4c	8	58	170	6	13
Middle Grave Creek	7	B3	16	88	256	5	13
Middle Grave Creek	8	C4	7	47	115	5	15
Upper Grave Creek	9	B4	6	40	185	5	15
Upper Grave Creek	10	C4	9	35	80	6	13
Upper Grave Creek	11	B4	4.5	42	175	12	18
Clarence	1	B4a	30	64	150	2	3
Clarence	2	C4b	11	38	100	8	10
Clarence	3	B4a	15	56	120	1	5
Clarence	4	B3a	60	150	500	1	2
Clarence	5	B4a	18	50	128	4	5
Clarence	6	B4a	24	62	512	3	3
Stahl	1	B4a	10	40	120	8	9

Table 4-4: Sediment Particle Size and Composite Percent Surface Fines (Pebble Count Results for Fines < 2 mm and < 6.4 mm (USFS, 2003, Except*).							
						Percent Surface Fines in Riffle	
Stream	Reach	Stream Type	D16	D50	D84	% < 2 mm	% < 6.4 mm
Stahl	2	A3	24	100	415	1	4
Stahl	3	A3a+	11	100	200	6	7
Stahl	4	A4a+	3	35	85	8	17
Stahl	5	B3a	11	80	220	1	7
Stahl	6	B4a	8	50	160	5	14
SF Stahl	1	B4a	8	50	175	9	15
Lewis	1	B4	11	30	88	7	10
Lewis	2	C4b	14	45	98	2	6
Lewis	3	B4a	4.5	21	55	5	19
Lewis	4	B4	11	40	96	3	8
Lewis	5	B3a	21	75	185	2	3
Foundation	1	B4a	14	47	100	6	9
Foundation	2	B4a	12	30	88	4	9
Foundation	3	B3a	10	28	120	4	10
Foundation	4	A3	21	40	160	2	6
Blue Sky	1	B4a	11	48	115	1	6
Blue Sky	2	B4a	6	32	100	2	16
Blue Sky	3	B4a	4	38	120	12	20
Kopsi	1	B4a	11	50	175	--	--
Kopsi	2	B4a	17	53	175	--	--
Williams	1	B3a	26	80	200	6	7
Williams	2	A3a+	17	70	270	3	6
Williams	3	B3a	23	65	150	6	7
Williams	4	B3	27	102	200	1	4
Williams	5	A3a	18	80	310	1	7
Wms Lake trib	1	B3a	21	78	290		

***Collected by WCI, 2000.

Percent surface fines <6.4 mm in pool tails/glides

Table 4-5: Percent Surface Fines <6.4 mm in Pool Tails/Glides. Measured by Using 49-Point Grid Toss Method. (USFS, 2001).						
Stream	Stream Type	Statistic				
		Minimum	25th Percentile	Median	75th Percentile	Maximum
Williams Lake	B	0.0	10.0	10.0	23.8	65.0
Williams	A	0.0	0.0	5.0	5.0	20.0
Williams	B	0.0	5.0	5.0	10.0	70.0
Stahl	A	0.0	0.0	5.0	5.0	40.0
Stahl	B	0.0	10.0	10.0	15.0	50.0
Lewis	C	5.0	7.5	10.0	12.5	25.0
Lewis	B	0.0	1.3	5.0	8.8	70.0
Clarence	C	0.0	1.3	5.0	5.0	10.0

Table 4-5: Percent Surface Fines <6.4 mm in Pool Tails/Glides. Measured by Using 49-Point Grid Toss Method. (USFS, 2001).						
Stream	Stream Type	Statistic				
		Minimum	25th Percentile	Median	75th Percentile	Maximum
Clarence	B	0.0	0.0	5.0	5.0	20.0
Foundation	B	0.0	0.0	0.0	0.0	5.0
Blue Sky	B	0.0	0.0	0.0	5.0	35.0
Upper Grave	C	0.0	10.0	10.0	15.0	80.0
Upper Grave	B	0.0	0.0	0.0	5.0	15.0
Middle Grave	C	0.0	1.3	5.0	8.8	10.0
Middle Grave	B	0.0	0.0	5.0	5.0	25.0
Lower Grave	C	0.0	5.0	10.0	20.0	80.0
Lower Grave	B	0.0	1.3	7.5	15.0	25.0
Lower Grave	F	0.0	5.0	5.0	10.0	40.0

Bankfull Width, Width-to-Depth Ratio and Sinuosity

Table 4-6: Bankfull Width, Width to Depth Ratio (Ratio of Bankfull Width to Bankfull Depth at Riffle Cross Sections), and Sinuosity (USFS, 2003).					
Stream	Reach	Stream Type	Bankfull Width (feet)	Width-to-Depth Ratio	Sinuosity
Lower Grave Creek below Canyon*	1	D4	116	93.5	1.08
Canyon	2	F4b	42.3	19	1.03
Lower Grave Creek above Canyon	3	F2b	52.3	15	1.13
Middle Grave Creek	4	B4	79.5	26	1.09
Middle Grave Creek	5	B3	49.2	29	1.09
Middle Grave Creek	6	B4c	50.2	13	1.12
Middle Grave Creek	7	B3	50.8	18	1.10
Middle Grave Creek	8	C4	37.7	21	1.10
Upper Grave Creek	9	B4	26.2	13	1.10
Upper Grave Creek	10	C4	34.4	20	1.12
Upper Grave Creek	11	B4	29.5	17	1.36
Clarence	1	B4a	17.0	5	1.23
Clarence	2	C4b	16.4	6	1.14
Clarence	3	B4a	13.7	11	1.06
Clarence	4	B3a	16.8	14	1.16
Clarence	5	B4a	16.6	12	1.33
Clarence	6	B4a	6.7	9	1.13
Stahl	1	B4a	32.9	17	1.27
Stahl	2	A3	19.9	11	1.10
Stahl	3	A3a+	17.0	10	1.08
Stahl	4	A4a+	17.0	8	1.08
Stahl	5	B3a	16.4	13	1.05
Stahl	6	B4a	12.2	13	1.07
SF Stahl	1	B4a	11.9	18	1.12

Table 4-6: Bankfull Width, Width to Depth Ratio (Ratio of Bankfull Width to Bankfull Depth at Riffle Cross Sections), and Sinuosity (USFS, 2003).					
Stream	Reach	Stream Type	Bankfull Width (feet)	Width-to-Depth Ratio	Sinuosity
Lewis	1	B4	11.9	12	1.04
Lewis	2	C4b	13.1	10	1.17
Lewis	3	B4a	16.1	17	1.10
Lewis	4	B4	6.9	5	1.07
Lewis	5	B3a	12.3	9	1.07
Foundation	1	B4a	18.4	23	1.05
Foundation	2	B4a	12.6	19	1.11
Foundation	3	B3a	6.7	11	1.16
Foundation	4	A3	6.3	16	1.14
Blue Sky	1	B4a	17.0	10	1.14
Blue Sky	2	B4a	23.3	13	1.20
Blue Sky	3	B4a	18.8	11	1.50
Kopsi	1	B4a	14.9	11	1.19
Kopsi	2	B4a	14.4	12	1.09
Williams	1	B3a	28.1	15	1.20
Williams	2	A3a+	38.7	35	1.10
Williams	3	B3a	22.6	18	1.35
Williams	4	B3	17.3	20	1.40
Williams	5	A3a	15.7	17	1.15
Wms Lake trib	1	B3a	20.0	20	1.20

***** Collected by WCI, 2000.

Pool Depth and Pfankuch Ratings

Table 4-7: Pool Depth and Pfankuch Rating Results.				
Stream	Type	Average Maximum Pool Depth (ft)	Average Residual Pool Maximum Depth (ft)	Pfankuch Scores
Lower Grave	C	3.8	2.7	Not scored
Lower Grave	B	3.7	2.1	Not scored
Lower Grave	F	5.1	3.5	1 Good
Middle Grave	C	2.9	1.2	1 Good
Middle Grave	B	3.0	1.5	**1 Poor;** **2 Fair**; 1 Good
Upper Grave	C	2.2	1.4	**1 Fair**
Upper Grave	B	1.6	0.8	**2 Fair**
Williams	B	2.1	1.3	**3 Fair**
Clarence	C	2.8	2.0	1 Good
Clarence	B	2.0	1.5	**2 Fair**; 3 Good

Table 4-7: Pool Depth and Pfankuch Rating Results.				
Stream	Type	Average Maximum Pool Depth (ft)	Average Residual Pool Maximum Depth (ft)	Pfankuch Scores
Stahl	B	2.2	1.2	**1 Fair** 2 Good
Blue Sky	B	2.4	1.5	3 Good
Lewis	C	1.8	1.2	1 Good
Lewis	B	2.0	1.5	**2 Fair**; 1 Good
Foundation	B	1.6	1.0	**3 Fair**

Meander Length Ratio

Table 4-8: Meander Length Ratio (Meander Length / Bankfull Width) as Determined From Aerial Photograph Measurements of Meander Length and Field Survey Measurements of Bankfull Width (WCI, 2000).			
Stream	Reach	Stream Type	Meander Length Ratio
Lower Grave Creek below Canyon	1	D4	6.7 (5.2 - 8.2)

Other Stream Conditions

Additional stream condition discussions and data are presented in Appendix G. This data and relate discussion address additional physical habitat assessments, temperature measures on lower Grave Creek, fish passage concerns, and dewatering concerns.

SECTION 5.0
REFERENCE CONDITIONS AND WATER QUALITY IMPAIRMENT STATUS UPDATES FOR THE GRAVE CREEK PLANNING AREA

This section provides updated impairment determinations for the Grave Creek Planning Area. The first step (Section 5.1 and Appendix H) involves development of water quality reference values using the guidance presented in Section 3.0 and Appendix E. These reference values will focus on the parameters that provide the best indicator of beneficial use support, with focus on sediment and habitat alteration parameters.

The next step (Section 5.2) is to use the reference values to define beneficial use support conditions linked to meeting water quality standards for impairment causes. Where there is a probable link to excess sediment (pollutant) loading impacts, beneficial use support conditions are presented as “targets” consistent with TMDL development terminology. Where there is a probable link to excess pollution type impacts, the beneficial use support conditions are presented as “use support objectives.”

Finally, the existing Grave Creek Watershed data presented in Section 4.0 is compared to targets and use support objectives. This comparison, referred to as a departure analysis, is used to assist with the final water quality impairment determinations. Section 5.3 presents this comparison and Section 5.4 provides the updated water quality impairment status for the Grave Creek Planning Area.

5.1 Reference Value Development

Appendix H provides detailed reference parameter development information for the parameters listed below.

- Pool Frequency (number of pools per unit length)
- Large Woody Debris (amount of large woody debris per unit length)
- Macroinvertebrate Metrics
- Percent Substrate Fines (McNeil Core results for percent < 6.38 mm in glide areas (pool tails))
- Percent Surface Fines (pebble count results for fines < 2 mm and < 6.4 mm in riffles and grid toss results for percent fines < 6.4 mm in glide areas)
- Width to Depth Ratio (ratio of bankfull width to bankfull depth at riffle cross sections)
- Sinuosity
- Meander Length Ratio

These parameters cover a broad range of direct habitat measures and measures of channel conditions, as well as a direct measure of aquatic life (macroinvertebrate metrics). The resulting reference information developed in Appendix H will be used for updated and new impairment determinations.

As discussed in Appendix H, the goal is to apply a primary approach for reference development (Section 3.2.3.1). Focus is on the use of regional reference data supplemented by some internal Grave Creek Watershed data and secondary reference development approaches.

5.2 TMDL Target Targets and Other Beneficial Use Support Objectives

This section presents beneficial use support objectives for the Grave Creek Watershed. These beneficial use support objectives are numeric or measurable values that represent desired conditions and achievement of water quality standards, both numeric and narrative, for a waterbody. Since narrative standards apply to the impairments (Section 3.0), the beneficial use support objectives are based on reference conditions and reference parameters as defined in Section 5.1 and Appendix H. Sediment, habitat and flow impairments are the focus of the beneficial use support objectives. The beneficial use objectives are also referred to as the water quality endpoints by which the ultimate success of implementation of this plan will depend upon.

There are two types of beneficial use support objectives:

1. TMDL Targets: Beneficial use support objectives are presented as “TMDL targets” where a pollutant is involved. TMDL targets are developed within this section to address excess pollutant conditions linked to both fine and coarse sediment based on the types of loading and impacts noted in the stream.

2. Use Support Objectives: Beneficial use support objectives are presented as “use support objectives” when a pollutant is not linked directly to the negative beneficial use impacts. These use support objectives address “pollution” conditions that otherwise are not addressed adequately via the TMDL target development. Use support objectives address specific habitat concerns such as fish passage and low LWD levels as well as flow alterations from dewatering.

The above approach helps to ensure that all impairments identified on the 303(d) list are addressed within the Grave Creek Water Quality and Habitat Restoration Plan.

5.2.1 TMDL Targets

A range of targets is developed to address potential sediment impairment conditions using several indicator parameters. Per EPA sediment guidance (EPA, 1999) it is stated that “in many watersheds more than one indicator and associated numeric target might be appropriate to account for process complexity and the potential lack of certainty regarding the effectiveness of an individual indicator.”

Targets fall within three categories in this document as described below. All targets are developed for sediment, with consideration of both fine and coarse or total sediment impairment indicators.

1. Type I Targets: Type I targets must be satisfied under most conditions to ensure full support of the beneficial use. Not meeting a Type I target means a potential impairment determination, as long as the application of this target is supported by supplemental indicators that can be linked to sources of pollutant loading at a minimum. Indicator parameters used for developing Type I targets include pool frequency, percent fines < 2mm in riffles (pebble count), percent subsurface fines (McNeil core), and macroinvertebrate metrics.
2. Type II Targets: Type II targets can be used to assist with the impairment determination similar to Type I targets. There is more flexibility with the application of these targets. The Type II targets can be used as substitutes for Type I targets under some conditions, such as where Type I target data is lacking for a given stream segment and it is determined that meeting or not meeting Type II targets provides sufficient information for making impairment status updates. Where sufficient Type I target data is available, a Type II Target may be used more as a supplemental indicator as described below. Indicator parameters used for developing Type II targets include width to depth ratio, grid toss fines, and pebble count percent fines.
3. Supplemental Indicators: Supplemental indicators provide supporting and/or collaborative information when used in combination with the above targets. Supplemental indicators can also help refine targets through time as part of the adaptive management approach and can help determine whether or not meeting one or more targets is a result of natural versus human causes. Supplemental indicators alone cannot be used to make an impairment determination. Supplemental indicators do not require development of a reference or numeric value, although development of a reference value or a value that indicates relatively high levels of human impact is often desirable. Supplemental indicators include values for large woody debris, sinuosity, meander length ratio, bull trout redd levels, and residual pool depth. Several additional supplemental indicators include sediment loading information and sources, visual indicators of in-channel sediment or stream stability, and other fish data.

Supplemental indicators are used in this document in concert with the targets to help determine the updated impairment status. At the time this document is approved, only the TMDL targets will become the established water quality goals for this waterbody to assess future compliance with water quality standards where sediment is involved. In the future, if one or more targets are not met, updated impairment determinations may incorporate the supplemental indicators established in this document and/or other appropriate technical and science-based information to assess why the targets are not met or whether the targets need to be modified.

Each target includes a rationale and applicability considerations. Because of the adaptive management considerations discussed below, all targets developed in this document are subject to potential modification and further interpretations through time, with the MDEQ taking a lead or needing to approve any modifications. The sections following the natural variability and adaptive management discussion provide target development and application details. Table 5-1 provides a summary of the targets and supplemental indicators.

5.2.1.1 Natural Variability and Adaptive Management

Natural Variability

The targets established in this section all apply under normal or median type conditions of natural background loading and natural disturbance. It is recognized that under some natural conditions such as a large fire or flood events, it may be impossible to satisfy some of the targets until the stream and/or the watershed recovers from the natural event. The goal, under these conditions, will be to ensure that management activities within the watershed or individual tributaries are undertaken in such a way that the achievement of targets is not significantly delayed compared to natural recovery. Another goal will be that human activities do not significantly increase the extent of negative water quality or habitat impacts from natural events during the recovery period. Human activities within the Grave Creek Watershed that are lacking application of reasonable land, soil and water conservation practices, or have historically occurred without the application of these practices, cannot be defined as a natural disturbance or as naturally occurring.

It is recognized that natural disturbance pulses can be a positive influence toward the creation and maintenance of habitat features such as pools or LWD. An example is the LWD pulse from a recent snowslide on upper Grave Creek (Photo 18). In fact, some significant flood or other types of natural disturbances may be necessary to eventually meet target conditions. For example, flood flows may be necessary to help move excess bedload size material through the system under conditions where width to depth and other stream morphology conditions can effectively transport excess material. In some systems, flood flows interact with LWD to create pool and other desirable habitat features.

Table 5-1: Summary of TMDL Targets and Supplemental Indicators.

Parameter	Target Type	Value	How Applied	How Measured
Pool Frequency	Type I	Refer to Table 5-2	By stream width, stream order, Rosgen stream types	R1/R4 Method or Equivalent
Surface Fines < 2 mm in Riffles	Type I	< 20%	All reaches	Wolman Pebble Count
Substrate Fines < 6.35 mm	Type I	≤ 28%	All spawning reaches; applied in pool tail areas	McNeil Core Sampling
Macroinvertebrate Populations	Type I	Acceptable metrics per MDEQ protocol	All reaches (focus on riffles)	Standard MDEQ protocols
Width to Depth	Type II	≤ 27 ≤ 25	Lower Grave C reaches Other Grave Watershed B & C reaches	Standard Bankfull Cross Section Measures
Percent Fines < 6.35 mm in Pool Tails	Type II	≤ 10%	All reaches	Grid Toss or Equivalent
Percent Surface Fines < 6.35 mm	Type II	≤ 15%	All reaches	Wolman Pebble Count
Large Woody Debris	Supplemental Indicator	Refer to Table 5-5	By stream width, stream order, Rosgen stream types	R1/R4 Method or Equivalent
Sinuosity	Supplemental Indicator	1.2 – 1.6	Lower Grave C reaches	Standard aerial assessment
Meander Length Ratio	Supplemental Indicator	13.8 – 19.2	Lower Grave C reaches	Standard aerial assessment
Bull Trout Redds	Supplemental Indicator	> 156 – 173 range	Spawning reaches	Standard count methods
Residual Pool Depth	Supplemental Indicator	> 3 feet on average	All reaches	R1/R4 or equivalent method
Sediment loading, visual indicators, Pfankuch Scores, other fish data.	Supplemental Indicators	No set values	All reaches	Variable

Adaptive Management

Adaptive management is applied toward the water quality goals defined within this section. For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts that human activities and natural conditions have on water quality and stream habitat conditions, and continued assessment of how aquatic life and cold-water fish, particularly bull trout and cutthroat trout, respond to changes in water quality and stream habitat conditions. Adaptive management addresses important considerations such as feasibility and uncertainty in establishment of targets. For example, despite implementation of all restoration activities (Sections 7.0 and 8.0), the attainment of targets may not be feasible due to natural disturbance such as forest fires, flood events, or landslides. Similarly, it is possible that the natural potential of some streams will preclude achievement of some targets. For instance, natural geologic and other conditions may contribute sediment at levels that cause a deviation from numeric targets associated with sediment. Conversely, some targets may be underestimates of the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluations. Supplemental indicators are used to help with these determinations. In light of all this, it is important to recognize that the adaptive management approach provides the flexibility to refine targets as necessary to ensure protection of the resource or to adapt to new information concerning target achievability.

As part of this adaptive management approach, increased land use activities should be tracked along with increased monitoring of target parameters before and after land use activities should always be considered. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to a complete measure of target parameters below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity.

5.2.1.2 Type I TMDL Targets

Type I Targets: Type I targets must be satisfied under most conditions to ensure full support of the beneficial use. Not meeting a Type I target means a likely impairment determination, as long as the application of this target is supported by supplemental indicators that can be linked to sources of pollutant loading at a minimum. Indicator parameters used for developing Type I targets include pool frequency, percent fines <2mm in riffles (pebble count), and percent subsurface fines (McNeil core).

5.2.1.2.1 Pool Frequency Targets

Pool frequency targets are presented in Table 5-2.

Table 5-2: Pool Frequency Targets.	
Stream Order & Type (Bankfull Width)	Target Value (pools/mile)
B & C streams 10' - 20' (generally 2nd or 3rd order streams)	73 This value can be modified down to 56 when streams approach 20' width
B & C streams 20' - 35' (generally 3rd or 4th order streams)	47 This value can be modified down to 35 when streams approach 35' width
B & C streams 35' - 50' (generally 4th order sections of middle or upper Grave Creek)	29 This value can be modified down to 26 when streams approach 50' width
Lower Grave Creek B & F reaches (generally > 40")	29 This value can be modified down to 26 when streams are in the 40 to 50' width range
Lower Grave Creek C reaches (generally >40')	12 – 24 (restoration projects should optimize opportunities to create pools where appropriate)

Rationale

The targets for pool frequency are directly from the low end of the reference results developed in Section 5.1. This target is directly linked to the habitat alterations and to excess sediment loading conditions associated with bed load and larger size material contributing to pool filling and/or interfering with pool formation. Loss of pools from excess sediment supply results in a direct reduction in fish habitat quantity and quality.

This target is also linked to dewatering cause of impairment in lower Grave Creek. The lack of pools makes dewatering even more detrimental to fish. Decreased pool frequency is the result of aggradation and pool filling which displaces in-stream water from the once deep pools that can provide refuge for fish, especially at low flow conditions. When streams aggrade and pools fill, in-stream water spreads across wide and shallow riffles which provide little habitat, and which under low flow conditions may dry up completely, providing no habitat.

Target Applicability Considerations

Not meeting the low end of the target range in the applicable reaches suggests a potential sediment impairment to cold-water fish. As discussed in Section 5.2, the application of the pool frequency reference values can overlap stream size ranges where data presented in Section 4.0 is based on combined reaches. For example, the summary data in Table 4-1 includes values from some stream reaches in a given stream segment with widths less than 20 feet combined with other reaches in the same segment with widths greater than 20 feet. This is addressed by allowing the lower value modifications consistent with the Forest Service interim RMOs (USFS, 2000).

Another consideration is the statistical distribution of several reaches from a given stream segment. Since the target values are developed from a statistical distribution of reference streams, it follows that a stream segment that has a similar distribution may be satisfying the target range even if some individual reach values do not meet the target.

As additional reference data become available, pool frequency target values/ranges may be refined. Furthermore, pool frequency targets may be supplemented and/or replaced by additional pool reference values or additional analysis based on measures such as residual pool depth or residual pool volume. Development of new pool targets could require a similar reference analysis as developed in Section 5.1, and could end up requiring significant sampling of reference streams to assist with this additional reference development. At this time, residual pool volume is identified as a supplemental indicator until further reference development is available.

5.2.1.2.2 Percent Surface Fines < 2 mm in Riffles

The target for percent surface fines < 2 mm (pebble count method) in riffles is < 20%.

Rationale

Research by macroinvertebrate specialists (Relya, et al., 2004) indicates that surface fines (< 2 mm) need to be elevated to levels between 20 – 40%, based on pebble count data, to result in a decrease in macroinvertebrate richness. Development of this target is one of the important criteria for evaluating whether or not excess sediment loading indicates a “siltation” or excess fine sediment type of impairment cause.

Target Applicability

Not meeting this target suggests a fine sediment impairment to aquatic life and possibly cold water fish. Where the target value is exceeded in a representative riffle, the stream is potentially impaired unless there is appropriate evidence, including macroinvertebrate results from the impacted riffle area to otherwise suggest that the high level of fines is not causing impairment to aquatic life. Where there are multiple representative spatial samples in a reach, meeting the target value with 75% or more of the pebble count results may be acceptable as long as there are acceptable macroinvertebrate results from at least one or more areas with elevated fine sediment. Part of the reason for allowing this flexibility is the inherent variability in pebble count results, particularly at the low range of sediment sizes. Another reason is due to the fact that the macroinvertebrate samples are a more direct measure of beneficial use based on developed reference approaches.

5.2.1.2.3 Percent Substrate Fines in Spawning Gravels

The target for percent substrate fines (< 6.35 mm) is less than 28% based on the McNeil Core method described by Weaver and Fraley (1991).

Rationale

Development of this target is one of the important criteria for evaluating whether or not excess fine sediment loading indicates a “siltation” type of impairment cause. Elevated levels of fine sediment in pool tail areas where fish spawning can occur will reduce fry emergence, therefore impairing cold-water fish. The discussion of percent subsurface fines reference data in Section H.1.4.2 supports the use of a percent substrate fines target value of less than 28%.

McNeil Core values that fall below 15%, which is the low end of the reference range, could be an indicator of another type of problem such as a degrading stream reach. If values this low occur, further investigation may be warranted.

Target Applicability Considerations

This target can be applied based on yearly average results from a given stream reach or spawning segment. Where sampling is routinely performed, the target can instead be applied to an average value from three subsequent years of sampling.

This target (< 28% substrate fines) should only be applied in areas where bull trout or cutthroat trout spawning occurs or has the potential to occur under full support conditions. Not meeting this target alone represents a potential impairment from excess fine sediment if the upper end of the value is exceeded. If the lower end is exceeded, the stream could be impaired due to habitat alterations and additional study should be done to ensure proper pool values in the impacted range and to ensure that spawning locations are not being lost.

Core sampling tends to focus on potential impacts to bull trout spawning success. Equivalent core sampling targets or Type II targets that can provide a surrogate for core substrate fines also apply to cutthroat trout spawning areas.

5.2.1.2.4 Macroinvertebrate Metrics

The target value for macroinvertebrate metrics associated with sediment impairment indicators is a full support determination based on standard MDEQ protocols.

Rationale

This standard water quality target is consistently applied to waterbodies in Montana, and provides a direct indication of beneficial use support for aquatic life.

Target Applicability Considerations:

Not meeting this target represents a potential impairment to aquatic life. Representative macroinvertebrate data have yet to be collected in most of the watersheds (Section D.5). When data are available, this target should be applied to reaches of upper and/or middle Grave Creek as well as all significant tributaries evaluated. Data collection should ideally include riffle samples from two to four typical cross sections along each stream segment being evaluated. Sampling should also be performed in areas where target conditions indicate a possible impairment (such as high percent fines in riffle areas).

5.2.1.3 Type II TMDL Targets

Type II targets can be used to assist with the impairment determination similar to Type I targets. There is more flexibility with the application of these targets. The Type II targets can be used as substitutes for Type I targets under some conditions, such as where Type I target data is lacking for a given stream segment and it is determined that meeting or not meeting Type II targets provides sufficient information for making impairment status updates. Where sufficient Type I target data is available, a Type II Target may be used more as a supplemental indicator. Indicator parameters used for developing Type II targets include width to depth ratio, grid toss fines, pebble count percent fines, and macroinvertebrate metrics.

5.2.1.3.1 Bankfull Width to Bankfull Depth Ratio

Width to depth ratio targets for the Grave Creek Watershed are presented in Table 5-3.

Table 5-3: Width to Depth Ratio Targets.

Stream	Reference Range and Target
Lower Grave Creek	Reference Range: 13 – 27 TMDL Target ≤ 27
Other Grave Creek Watershed B & C Reaches	Reference Range: 10 – 25; TMDL Target: ≤ 25 **and** no more than a 20% increase in reaches that currently fall within this range

Rationale

This target is directly linked to potential habitat alterations and is linked to excess sediment loading conditions. An excessive width-to-depth (w/d) ratio can be the result of accelerated bank erosion and can decrease a stream’s sediment transport capacity resulting in aggradation and pool filling. Excessive w/d can also lead to increased temperatures that can have negative impacts on aquatic life in Grave Creek or downstream waters. The values in Table 5-3 are the reference values developed in Section 5.1.

This target is also linked to dewatering concerns in lower Grave Creek. Decreasing the width-to-depth ratio will concentrate flow into a narrower, deeper channel thereby increasing the stage of flow at any discharge. Therefore, it will probably take less flow to meet a wetted perimeter type goal in a narrower, deeper channel than in the existing over-widened channel.

Target Applicability Considerations

Not meeting this target implies potential impairment to cold-water fish. Although presented as a Type II target where compliance with other Type I Targets can be take precedence, the importance of this target as an indicator of potential beneficial use support problems should not be underestimated, particularly in the lower impacted C reaches of Grave Creek below the GLID. Excessive w/d values are a major indicator of sediment transport problems that can and likely are contributing to aggradation and pool filling. Furthermore, continued high w/d ratios may eventually need to be evaluated from the perspective of a potential temperature impacts in lower Grave Creek. In addition, cursory review of stream conditions and temperature data indicate that elevated temperatures may be a concern in the Tobacco River. Therefore, efforts to keep water in Grave Creek from unnaturally warming up are desirable for Tobacco River aquatic life.

Achievement of this target in lower Grave Creek is possible in reaches that undergo active channel restoration, especially since a w/d ratio closer to 20 will be a typical design goal. Other reaches with either marginal w/d departure from the target, or where the w/d may depart significantly from target but active channel restoration is not pursued would be left to natural recovery. The natural recovery will likely lead to a decrease in width-to depth over time, although the time frame for natural recovery in some reaches could be several decades.

Falling below the low end of the reference range is also an indication of a potential problem that should be investigated to ensure that channel degradation is not occurring. This degradation could lead to entrenchment, a loss of pools and/or a loss of other favorable aquatic life or fish habitat.

5.2.1.3.2 Percent Surface Fines (Pebble Count and Grid Toss)

Table 5-4 presents Type II target values for pebble count percent surface fines and in percent surface fines in pool tail-outs from the grid toss.

Table 5-4: Percent Surface Fines Targets.	
Parameter	Target Value
% Fines < 6.35 mm in Pool Tails-Outs (Grid Toss)	≤ 10%
% Fines < 6.35 mm (Composite Pebble Count)	≤ 15%

Rationale

Development of these target values is one of the important criteria to help evaluate whether or not excess sediment loading indicates a “siltation” type of impairment cause. The target values are based on the reference indicators developed in Section 5.1 and internal information that suggests values above the targets are cause for concern. Unpublished data from TMDL development in the Yaak suggests a relationship between pebble count percent fines values and McNeil Core percent fines results. The upper end (15%) of the reference range for pebble count percent fines < 6.35 mm is applied because values between 13 to 15% in middle Grave Creek are associated with acceptable McNeil Core substrate results. The unpublished Yaak data also suggests acceptable McNeil Core results for values as high as 15% and higher.

Target Applicability

Not meeting one or more of the above targets can be used to suggest a potential impairment determination, depending on the availability of other Type I targets for evaluating percent fines. The targets help with impairment or use support determinations in areas where McNeil Core data is lacking to evaluate substrate fines in fish spawning areas. The grid toss target can also apply in areas where pebble count data are lacking. For a beneficial use determination linked to macroinvertebrate health, the macroinvertebrate metrics and 20% percent fines < 2 mm Type I targets (Sections 5.2.1.2.2 and 5.2.1.2.4) take precedent over the pebble count or grid toss targets presented in Table 5-4.

Where large sets of data are available, the median value can be used for comparison to the target value with caution. Individual reach areas where the target is not met may still require additional investigation to ensure that important spawning habitat or large reaches do not have significant beneficial use impacts.

5.2.1.4 Supplemental Indicators

Supplemental indicators provide supporting and/or collaborative information when used in combination with the above Type I and Type II targets. Supplemental indicators can also help determine whether not meeting one or more targets is a result of natural versus human causes. Supplemental indicators alone cannot be used to make an impairment determination. Supplemental indicators do not require development of a reference or numeric value, although development of a reference value or a value that indicates relatively high levels of human impact is often desirable. Supplemental indicators include values for large woody debris, sinuosity, meander length ratio, and bull trout redd levels. Several additional indicators are also discussed.

5.2.1.4.1 Large Woody Debris (LWD) Frequency

LWD frequency supplemental indicator values are presented in Table 5-5.

Table 5-5: Summary of LWD Reference Values for Grave Creek Watershed.		
Stream Order & Type (Bankfull Width)	LWD / Mile Indicator Range	LWD and/or Aggregates per Mile Indicator Range
B & C streams 10' - 20' (generally 2nd and 3rd order)	163 - 371	228 - 519
B & C streams 20' - 35' (generally 3rd and 4th order streams)	112 - 443	157 - 620
B and C streams 36' - 50', (generally 4th or 5th order streams)	104 - 210	146 - 294
Lower Grave Creek C & B reaches > 40'	104 - 210	146 - 294

The above indicator values are based on the reference ranges developed in Section H.2. A lack of woody debris (values less than the low end of the indicator range in Table 5-5) can be linked to potential sediment impairment since LWD helps establish streambed stability, dissipates energy, and directly influences sediment storage (Rosgen, 1996). LWD can also play a role in pool formation, although this role may not be as significant in the Grave Creek Watershed as noted in other watersheds. Nevertheless, the Grave Creek EAWS (USFS, 2002) notes that for Grave Creek below Blue Sky greater pool depths are linked to large woody debris.

Statistical distributions of the individual stream or watershed data can be used to help evaluate overall LWD conditions relative to reference. Future monitoring of the streams of interest and any reference streams should include identification of any linkages between LWD and pool formation.

5.2.1.4.2 Sinuosity

The sinuosity supplemental indicator applied to the lower Grave Creek below GLID is a range of 1.2 to 1.6.

Rationale

This indicator is linked to habitat alterations and is linked to excess sediment loading conditions. Reduced sinuosity causes increased sheer stress contributing to accelerated bank erosion, increased width-to-depth ratio and reduced sediment transport capacity. As a result, there is an excess sediment supply, aggradation and pool filling. The sinuosity range is based on the reference development in Section 5.1.

This indicator is also linked to the dewatering concern. Increasing sinuosity will result in greater length of flow and an increased opportunity for bank storage during high flow, and slow release of water from bank storage later in the summer season when low flow conditions are of greatest concern.

This indicator only applies to the reaches of lower Grave Creek below the GLID. It is intended for C reaches or those reaches where the potential is a C stream type. Not meeting the low end of the range implies continued sediment problems. Exceeding the high end should not be a problem.

5.2.1.4.3 Meander Length Ratio

The supplemental indicator for meander length ratio (MLR) is a range of 13.8 – 19.2.

This dimensionless ratio is defined as the meander wavelength/bankfull width. Reduced MLR can be the result of increased width to depth ratio from accelerated bank erosion and is an indication of reduced sediment transport capacity, excess sediment supply, aggradation and pool filling. Reference reach data for lower Grave Creek presented in Section G suggest an optimal design range of 13.8 – 19.2 (Table 4-8), which is used as the supplemental indicator range and is only applied to the C reaches of lower Grave Creek.

5.2.1.4.4 Bull Trout Redd Counts

Existing values for bull trout redd counts and subsequent trends in bull trout redd counts is used as a supplemental indicator.

This indicator is directly linked to the beneficial use of cold-water fish. Grave Creek and tributaries to Grave Creek provide important spawning habitat for bull trout. A significant decline in spawning indicates a potential beneficial use support problem that could be linked to excessive fine and/or coarse/bedload sediment problems, although it is recognized that there are a large number of other factors that could also influence redd count values. Recent redd count values for assessed reaches of Grave Creek have ranged from 156 to 173 in 2002 and 2003 respectively.

5.2.1.4.5 Residual Pool Depth or Pool Quality

Pool quality in Grave Creek was identified as functioning at risk based on 1992 and 1993 Forest Service surveys that identified that most pools were generally shallow, less than three feet deep (USFS, 2000). This three-foot depth is therefore used as a supplemental indicator value based on professional judgment within the referred-to document, with the goal being to have pool depths greater than three feet. This three-foot value is compared to both the average maximum pool depth and the average maximum residual pool depths. Residual pool depth would be preferable as a Type I or Type II target indicator parameter, and should be applied in that manner once further reference development can be accomplished or if there is greater confidence in the application of the three-foot value.

5.2.1.4.6 Additional Supplemental Indicators

Several additional supplemental indicators include sediment loading information and sources, visual indicators of in-channel sediment or stream stability, and other fish data.

Data and results within Appendices A, B, C, D, G, I, and J provide data that can and will be used to supplement use support determinations. This includes a goal of Pfankuch scores of at least “good” consistent with supplemental indicator development in other forested watersheds, including the Flathead Headwaters (EPA, 2005).

5.2.2 Use Support Objectives

Beneficial use support objectives are presented as “use support objectives” when a pollutant is not linked directly to the negative beneficial use impairment. These use support objectives address “pollution” conditions that otherwise are not addressed adequately via the TMDL target development. Use support objectives address specific habitat concerns such as fish passage and low LWD levels as well as flow alterations from dewatering. Table 5-6 provides a summary of these use support objectives.

5.2.2.1 Large Woody Debris Use Support Objective Values

The same values used for LWD as supplemental indicators (Table 5-5) also apply as use support objectives to assist with habitat alteration impairment determinations.

Rationale

Woody debris is an important component for fisheries and aquatic life habitat. A significant lack of LWD in comparison to a reference condition can provide a basis for an impairment determination due to loss of aquatic habitat. The 1993 Forest Survey, as discussed in the Section 7 Consultation (USFS, 2000), identified that cover associated with pools varies from 5-75 percent, and that instream cover is provided by logs, rocks, undercut banks, and overhanging vegetation and root wads.

Applicability Considerations

Not meeting the LWD use support objective, along with other indications of habitat problems, can justify an “other habitat alterations” impairment cause. Impairment determinations linked to LWD should generally be limited to smaller stream sizes, primarily those less than 35 feet bankfull width. It can be applied to larger C reaches where LWD retention is more likely. Statistical distributions of the individual stream or watershed data can be used to help evaluate overall LWD conditions relative to reference. Future monitoring of the streams of interest and any reference streams should include identification of any linkages between LWD and increased refugia for fish.

Table 5-6: Summary of Use Support Objectives.			
Parameter	Value/Condition	How Applied	How Measured
LWD Frequency	Refer to Table 5-5	By stream width, stream order, Rosgen stream types	R1/R4 Method or Equivalent
Fish Passage	No human caused fish passage barriers that lead to undesirable fishery or aquatic life conditions	All reaches	Standard fish barrier approaches; expert biological opinions
Minimum Flow	Wetted Perimeter or Similar Value based on 7Q10 flow; updated based on channel morphology improvements	Lower Grave Creek	Flow sampling

5.2.2.2 Fish Passage

Human caused fish passage barriers that lead to undesirable fishery or aquatic life conditions can justify an impairment linked to habitat alteration.

Rationale and Applicability Considerations

Where fish passage is desirable, the presence of any significant human caused fish passage barrier can provide the basis for an impaired waterbody determination. This is because the fish passage problem can prevent a waterbody from fully supporting the cold-water fish beneficial use. In some cases, it may be desirable to keep a culvert or other type of barrier in place to prevent undesirable species from moving into areas they currently do not inhabit. Input from fisheries professionals will be used to determine where fish passage barriers are a significant concern.

5.2.2.3 Minimum In-stream Flow in Lower Grave Creek

The minimum summer flows in lower Grave Creek should remain above a wetted perimeter or similar value during normal flow years.

Rationale and Applicability Considerations

Fish and aquatic life need water to survive at a level that provides basic beneficial use support conditions for various life stages. A lack of flow also limits recreational use of the stream. The low flows also negatively impact habitat connectivity and temperature. Previous studies have suggested a minimum flow of 70 cfs (Appendix E). This flow recommendation should be evaluated to see if it is still appropriate. Also, new calculations should be performed based on improved channel morphology to see how improved channel morphology decreases wetted perimeter requirements. Meeting the sediment TMDL targets in lower Grave Creek is expected to significantly reduce the amount of water needed to meet the desired in-stream flow.

Not meeting minimum flows needed for basic aquatic life support and to allow for fish passage is adequate justification for a continued flow alterations impairment determination to aquatic life and cold-water fish. Application of this use support objective and the restoration objectives defined in Section 7.2 must be in recognition of the fact that there are legal water rights associated with the diversions where water is removed from lower Grave Creek.

5.3 Departure Analyses and Discussion

Targets, supplemental indicators, and beneficial use support objectives were developed in Sections 5.1 and 5.2. The section presents stream summary data from Section 4.0 and compares the summary data to the Section 5.2 targets, supplemental indicators and use support objective values. These comparisons are done for Grave Creek as well as the tributary streams to Grave Creek.

5.3.1 Pool Frequency

Table 5-7 provides existing pool frequency data for stream segments and compares these values to the target values from Section 5.2.1.2. All comparisons are made to the low end of the reference/target range since levels above the low end are considered desirable and an indication of full support whereas levels below the low end of the range indicate impairment. Target ranges have been modified to be consistent with interim Forest Service RMOs based on typical bankfull widths from Appendix G. Target comparisons are only made for B, C and F stream reaches. The departure values in Table 5-7 show that pool frequency values are well below target values for most stream segments within the Grave Creek Watershed. Stahl Creek is the only stream that consistently meets the target value for pool frequency for all reach types evaluated. Middle Grave B reaches also meet pool frequency target values.

Table 5-7: Grave Creek Watershed Pool Frequency (Pools / Mile) and Comparison to Target Values.

Stream	Type	Statistic	Typical Bankfull Widths measured (feet)	Existing	Target	Departure	
						Value	Percent
Lower Grave	C	Average	> 50	9	12	**-3**	**-25%**
Lower Grave	B	Average	> 50	19	26	**-7**	**-27%**
Lower Grave	F	Average	40 – 50	9	26	**-17**	**-65%**
Middle Grave	C	Average	38	12	29	**-17**	**-59%**
Middle Grave	B	Average	> 40	62	26	+36	+138%
Upper Grave	C	Average	34	26	35	**-9**	**-25%**
Upper Grave	B	Average	30	24	42	**-18**	**-43%**
Williams Lake	B	Average	Estimated at 20	24	56	**-32**	**-57%**
Williams	B	Average	17 - 28	38	47	**-9**	**-19%**
Clarence	C	Average	16	9	73	**-64**	**-88%**
Clarence	B	Average	14 - 17	29	73	**-44**	**-60%**

Table 5-7: Grave Creek Watershed Pool Frequency (Pools / Mile) and Comparison to Target Values.

Stream	Type	Statistic	Typical Bankfull Widths measured (feet)	Existing	Target	Departure	
						Value	Percent
Stahl	B	Average	12 - 33	82	35 – 73	+9 to +47	+12% to +134%
Blue Sky	B	Average	17 - 23	24	47 – 56	**-23 to -32**	**-49% to –57%**
Lewis	C	Average	13	26	73	**-47**	**-64%**
Lewis	B	Average	12 – 16	36	73	**-37**	**-51%**
Foundation	B	Average	7 - 18	32	73	**-41**	**-56%**

5.3.2 Macroinvertebrate Data

Macroinvertebrate sampling is limited to one reach in lower Grave Creek where restoration work has been done. The results compared favorably to MDEQ metrics used to help with beneficial use support determinations.

5.3.3 Percent Surface Fines in Riffles (Pebble Count)

Table 5-8 presents composite pebble count results for < 2 mm and Table 5-9 presents composite pebble count results for < 6.35 mm. Both tables include target values and a comparison to target values. All comparisons are done to the high end of the reference/target range since levels below the high end are considered desirable and an indication of full support whereas levels above the high end of the range indicate impairment. Application of the target values to A reaches is only as a supplemental indicator.

Table 5-8 data show that all stream reaches assessed meet the Type I target of no more than 20% fines < 2 mm. Unfortunately, the target condition is based on percent surface fines via pebble counts in riffles, whereas the Grave Creek data represents composite pebble counts that includes both riffles and pools based on the percentage of each. Given the fact that all results are significantly below 20%, it is assumed that the riffle portion of the pebble counts are likely below 20% also since riffle data would contribute a higher percentage toward the composite pebble count given the relatively low pool percentage/frequencies.

Table 5-8: Percent Surface Fines < 2 mm and Comparison to Target Values (Pebble Count).					
Stream	Reach	Stream Type	% Fines < 2 mm	Type I Target (%)	Target Comparison
Lower Grave Creek below Canyon	1	D4	11	20	Meets Target
Canyon	2	F4b	3	20	Meets Target
Lower Grave Creek above Canyon	3	F2b	5	20	Meets Target
Middle Grave Creek	4	B4	10	20	Meets Target
Middle Grave Creek	5	B3	0	20	Meets Target
Middle Grave Creek	6	B4c	6	20	Meets Target
Middle Grave Creek	7	B3	5	20	Meets Target
Middle Grave Creek	8	C4	5	20	Meets Target
Upper Grave Creek	9	B4	5	20	Meets Target
Upper Grave Creek	10	C4	6	20	Meets Target
Upper Grave Creek	11	B4	12	20	Meets Target
Williams	1	B3a	6	20	Meets Target
Williams	2	A3a+	3	20	Meets Target
Williams	3	B3a	6	20	Meets Target
Williams	4	B3	1	20	Meets Target
Williams	5	A3a	1	20	Meets Target
Clarence	1	B4a	2	20	Meets Target
Clarence	2	C4b	8	20	Meets Target
Clarence	3	B4a	1	20	Meets Target
Clarence	4	B3a	1	20	Meets Target
Clarence	5	B4a	4	20	Meets Target
Clarence	6	B4a	3	20	Meets Target
Stahl	1	B4a	8	20	Meets Target
Stahl	2	A3	1	20	Meets Target
Stahl	3	A3a+	6	20	Meets Target
Stahl	4	A4a+	8	20	Meets Target
Stahl	5	B3a	1	20	Meets Target
Stahl	6	B4a	5	20	Meets Target
SF Stahl	1	B4a	9	20	Meets Target
Blue Sky	1	B4a	1	20	Meets Target
Blue Sky	2	B4a	2	20	Meets Target
Blue Sky	3	B4a	12	20	Meets Target

Table 5-8: Percent Surface Fines < 2 mm and Comparison to Target Values (Pebble Count).					
Stream	Reach	Stream Type	% Fines < 2 mm	Type I Target (%)	Target Comparison
Lewis	1	B4	7	20	Meets Target
Lewis	2	C4b	2	20	Meets Target
Lewis	3	B4a	5	20	Meets Target
Lewis	4	B4	3	20	Meets Target
Lewis	5	B3a	2	20	Meets Target
Foundation	1	B4a	6	20	Meets Target
Foundation	2	B4a	4	20	Meets Target
Foundation	3	B3a	4	20	Meets Target
Foundation	4	A3	2	20	Meets Target

The Table 5-9 data show that most reaches are at or below the Type II target of 15% surface fines < 6.35 mm. B or C reaches that exceed this value include upper Grave Creek (B4 reach), Blue Sky (2 B4 reaches), and Lewis (B4a reach).

Table 5-9: Percent Surface Fines < 6.35 mm and Comparison to Target Value (Pebble Count).					
Stream	Reach	Stream Type	% Fines < 6.4 mm	Type II Target (%)	Target Comparison
Lower Grave Creek below Canyon	1	D4	13	15	Meets Target
Canyon	2	F4b	7	15	Meets Target
Lower Grave Creek above Canyon	3	F2b	11	15	Meets Target
Middle Grave Creek	4	B4	15	15	Meets Target
Middle Grave Creek	5	B3	6	15	Meets Target
Middle Grave Creek	6	B4c	13	15	Meets Target
Middle Grave Creek	7	B3	13	15	Meets Target
Middle Grave Creek	8	C4	15	15	Meets Target
Upper Grave Creek	9	B4	15	15	Meets Target
Upper Grave Creek	10	C4	13	15	Meets Target
Upper Grave Creek	11	B4	18	15	**20% Above Target**
Williams	1	B3a	7	15	Meets Target
Williams	2	A3a+	6	15	Meets Target
Williams	3	B3a	7	15	Meets Target
Williams	4	B3	4	15	Meets Target
Williams	5	A3a	7	15	Meets Target
Clarence	1	B4a	3	15	Meets Target
Clarence	2	C4b	10	15	Meets Target
Clarence	3	B4a	5	15	Meets Target
Clarence	4	B3a	2	15	Meets Target
Clarence	5	B4a	5	15	Meets Target
Clarence	6	B4a	3	15	Meets Target

Table 5-9: Percent Surface Fines < 6.35 mm and Comparison to Target Value (Pebble Count).					
Stream	Reach	Stream Type	% Fines < 6.4 mm	Type II Target (%)	Target Comparison
Stahl	1	B4a	9	15	Meets Target
Stahl	2	A3	4	15	Meets Target
Stahl	3	A3a+	7	15	Meets Target
Stahl	4	A4a+	17	15	**13% Above Target**
Stahl	5	B3a	7	15	Meets Target
Stahl	6	B4a	14	15	Meets Target
SF Stahl	1	B4a	15	15	Meets Target
Blue Sky	1	B4a	6	15	Meets Target
Blue Sky	2	B4a	16	15	**7% Above Target**
Blue Sky	3	B4a	20	15	**33% Above Target**
Lewis	1	B4	10	15	Meets Target
Lewis	2	C4b	6	15	Meets Target
Lewis	3	B4a	19	15	**21% Above Target**
Lewis	4	B4	8	15	Meets Target
Lewis	5	B3a	3	15	Meets Target
Foundation	1	B4a	9	15	Meets Target
Foundation	2	B4a	9	15	Meets Target
Foundation	3	B3a	10	15	Meets Target
Foundation	4	A3	6	15	Meets Target

5.3.4 Percent Fines in Pool Tails (Grid Toss)

Table 5-10 presents the median grid toss values for streams in the Grave Creek Watershed. All grid toss results meet the target of less than or equal to 10% fines < 6.35 mm. It is worth noting that several reach types just meet this target value.

Table 5-10: Grave Creek Percent Surface Fines < 6.35 mm in Pool Tails (Grid Toss Method).					
Stream	Type	Statistic	Grid-Toss (% < 6.35 mm)	Type II Target	Target Comparison
Lower Grave	C	Median	10.0	≤ 10.0	At Target Level
Lower Grave	B	Median	7.5	≤ 10.0	Meets Target
Lower Grave	F	Median	5.0	≤ 10.0	Meets Target
Middle Grave	C	Median	5.0	≤ 10.0	Meets Target
Middle Grave	B	Median	5.0	≤ 10.0	Meets Target
Upper Grave	C	Median	10.0	≤ 10.0	At Target Level
Upper Grave	B	Median	0.0	≤ 10.0	Meets Target
Williams Lake	B	Median	10.0	≤ 10.0	At Target Level
Williams	A	Median	5.0	≤ 10.0	Meets Target
Williams	B	Median	5.0	≤ 10.0	Meets Target
Clarence	C	Median	5.0	≤ 10.0	Meets Target

Table 5-10: Grave Creek Percent Surface Fines < 6.35 mm in Pool Tails (Grid Toss Method).					
Stream	Type	Statistic	Grid-Toss (% < 6.35 mm)	Type II Target	Target Comparison
Clarence	B	Median	5.0	≤ 10.0	Meets Target
Stahl	A	Median	5.0	≤ 10.0	Meets Target
Stahl	B	Median	10.0	≤ 10.0	At Target Level
Blue Sky	B	Median	0.0	≤ 10.0	Meets Target
Lewis	C	Median	10.0	≤ 10.0	At Target Level
Lewis	B	Median	5.0	≤ 10.0	Meets Target
Foundation	B	Median	0.0	≤ 10.0	Meets Target

5.3.5 Percent Substrate Fines (McNeil Core Sampling)

McNeil Core values data from middle Grave Creek reach(es) near Clarence Creek show acceptable McNeil Core substrate fine sediment results. The percent > 6.35 mm values all range from 20.4% to 25.3%. This is in comparison to the target value of 28%, with values below 28% considered an indication of acceptable levels of fine sediment.

5.3.6 Width to Depth

Table 5-11 presents width to depth values and comparisons to the type I target values developed in Section 5.2.1.3.1. In lower Grave Creek, the target is applied to the D4 reach because it is considered to have a C4 potential. The target is also applied to the F reaches of lower Grave Creek as a supplemental indicator. The target values do not apply to the A reaches. Literature (Rosgen, 1996) values for an A stream type suggest that the width to depth would normally fall below 12. Where width to depth information is not consistent with this value, it is noted in the table and such information can be used within the context of a supplemental indicator.

There are three locations where the stream w/d is greater than the target range for B or C stream types or stream reaches with a potential of being a C as is the situation in lower Grave Creek. Note that several B reaches are below the low end of the reference range with low w/d ratios, indicating naturally low values for these narrower streams, a possible stream misclassification, and/or localized degradation. Channel stability ratings presented in Appendix G are inconclusive regarding possible degradation or instability in these reaches.

Table 5-11: Bankfull Width, Width to Depth Ratio (Ratio of Bankfull Width to Bankfull Depth at Riffle Cross Sections) and Target Comparisons.

Stream	Reach	Stream Type	Bankfull Width (feet)	Width-to-Depth Ratio	Width to Depth Type II Target	Target Comparison
Lower Grave Creek below Canyon	1	D4 (C4 potential)	116	93.5	≤ 27	**Well Above Target**
Canyon	2	F4b	42.3	19	≤ 27	Acceptable
Lower Grave Creek above Canyon	3	F2b	52.3	15	≤ 27	Acceptable
Middle Grave Creek	4	B4	79.5	26	≤ 25	**4% Above Target**
Middle Grave Creek	5	B3	49.2	29	≤ 25	**16% Above Target**
Middle Grave Creek	6	B4c	50.2	13	≤ 25	Acceptable
Middle Grave Creek	7	B3	50.8	18	≤ 25	Acceptable
Middle Grave Creek	8	C4	37.7	21	≤ 25	Acceptable
Upper Grave Creek	9	B4	26.2	13	≤ 25	Acceptable
Upper Grave Creek	10	C4	34.4	20	≤ 25	Acceptable
Upper Grave Creek	11	B4	29.5	17	≤ 25	Acceptable
Williams	1	B3a	28.1	15	≤ 25	Acceptable
Williams	2	A3a+	38.7	35	< 10 (Indicator Value)	**250% Above Indicator Value**
Williams	3	B3a	22.6	18	≤ 25	Acceptable
Williams	4	B3	17.3	20	≤ 25	Acceptable
Williams	5	A3a	15.7	17	< 10 (Indicator Value)	**70% Above Indicator Value**
Wms Lake trib	1	B3a	20.0	20	≤ 25	Acceptable
Clarence	1	B4a	17.0	5	≤ 25	**50% Below Reference Value of 10**
Clarence	2	C4b	16.4	6	≤ 25	**40% Below Reference Value of 10**
Clarence	3	B4a	13.7	11	≤ 25	Acceptable
Clarence	4	B3a	16.8	14	≤ 25	Acceptable
Clarence	5	B4a	16.6	12	≤ 25	Acceptable
Clarence	6	B4a	6.7	9	≤ 25	**10% Below Reference Value of 10**
Stahl	1	B4a	32.9	17	≤ 25	Acceptable

Table 5-11: Bankfull Width, Width to Depth Ratio (Ratio of Bankfull Width to Bankfull Depth at Riffle Cross Sections) and Target Comparisons.

Stream	Reach	Stream Type	Bankfull Width (feet)	Width-to-Depth Ratio	Width to Depth Type II Target	Target Comparison
Stahl	2	A3	19.9	11	< 10 (Indicator Value)	Acceptable
Stahl	3	A3a+	17.0	10	< 10 (Indicator Value)	Acceptable
Stahl	4	A4a+	17.0	8	< 10 (Indicator Value)	Acceptable
Stahl	5	B3a	16.4	13	≤ 25	Acceptable
Stahl	6	B4a	12.2	13	≤ 25	Acceptable
SF Stahl	1	B4a	11.9	18	≤ 25	Acceptable
Lewis	1	B4	11.9	12	≤ 25	Acceptable
Lewis	2	C4b	13.1	10	≤ 25	Acceptable
Lewis	3	B4a	16.1	17	≤ 25	Acceptable
Lewis	4	B4	6.9	5	≤ 25	**50% Below Reference value of 10**
Lewis	5	B3a	12.3	9	≤ 25	**10% Below Reference value of 10**
Blue Sky	1	B4a	17.0	10	≤ 25	Acceptable
Blue Sky	2	B4a	23.3	13	≤ 25	Acceptable
Blue Sky	3	B4a	18.8	11	≤ 25	Acceptable
Kopsi	1	B4a	14.9	11	≤ 25	Acceptable
Kopsi	2	B4a	14.4	12	≤ 25	Acceptable
Foundation	1	B4a	18.4	23	≤ 25	Acceptable, toward the high end
Foundation	2	B4a	12.6	19	≤ 25	Acceptable
Foundation	3	B3a	6.7	11	≤ 25	Acceptable
Foundation	4	A3	6.3	16	< 10 (Indicator Value)	**60% Above Indicator Value**

5.3.7 Lower Grave Creek Sinuosity and Meander Length Ratio

Sinuosity and meander length ratio (MLR) ranges were developed as supplemental indicators for lower Grave Creek in Sections 5.2.1.4.2 and 5.2.1.4.3. Table 5-12 provides a comparison summary of the values in lower Grave Creek to these supplemental indicator values. Width to depth ratio results from Table 5-11 are also incorporated. All values represent significant departures. Even though the sinuosity departure does not appear high, the fact that sinuosity cannot go below 1.0 suggests a much more significant departure than computed.

Table 5-12: Main Stem Grave Creek Existing Departure from Targets and Supplemental Indicator Ranges for Bankfull Channel Dimensions and Planform Geometry Parameters.

Stream	Type	Measure	Existing (average)	Target/Indicator Range	Departure	
					Values	Percent
Lower Grave	C	W/D	93.5	13 - 27	**- 66.5**	**- 71**
		Sinuosity	1.08	1.2 – 1.6	**-0.12**	**-10**
		Meander Length Ratio	6.7 (5.2 - 8.2)	13.8 -19.2	**-8.6 to -11.0**	**-59 (-62 to -57)**

5.3.8 Large Woody Debris (LWD) Frequency

Table 5-13 presents the LWD frequency results from stream reach types, the applicable supplemental indicator values which are also use as use support objective values, and a comparison between the two. The comparisons are to the low end of the indicator/use objective range (indicator range) since values below this range would be considered undesirable. Although the indicator range was developed primarily for B and C Rosgen reaches, it can also be applied to A and F reaches as an additional supplemental indicator. The results show an overall trend of low LWD values throughout the Grave Creek Watershed. Many stream reaches are significantly below the low end of the indicator range, whereas both Stahl and Lewis Creek had all assessed reach medians within the indicator range, and the B reaches of Williams and Clarence Creeks also fell within the indicator range, but generally below the reference median used to develop this range (Appendix H).

Table 5-13: Grave Creek Watershed Large Woody Debris Values (Singles + Aggregates + Rootwads / Mile) and Comparison to Values Used as Supplemental Indicators and Use Support Objectives.

Stream	Type	Statistic	Existing	Indicator/Use Support Range	Departure from Low End of Target Range	
					Value	Percent
Lower Grave	C	Median	101	146 - 294	**- 45**	**- 31%**
Lower Grave	B	Median	81	146 - 294	**- 65**	**- 44%**
Lower Grave	F	Median	106	146 - 294	**- 40**	**- 27%**
Middle Grave	C	Median	105	146 - 294	**- 41**	**- 28%**
Middle Grave	B	Median	56	146 - 294	**- 90**	**- 62%**
Upper Grave	C	Median	189	157 - 620	+ 32	+ 21%
Upper Grave	B	Median	61	157 - 620	**- 96**	**- 61%**
Williams	A	Median	55	157 - 620	**- 102**	**- 65%**
Williams	B	Median	238	157 - 620	+ 81	+ 52%

Table 5-13: Grave Creek Watershed Large Woody Debris Values (Singles + Aggregates + Rootwads / Mile) and Comparison to Values Used as Supplemental Indicators and Use Support Objectives.						
					Departure from Low End of Target Range	
Stream	Type	Statistic	Existing	Indicator/Use Support Range	Value	Percent
Williams Lake	B	Median	158	228 – 519	**- 70**	**- 31%**
Clarence	C	Median	167	228 – 519	**- 61**	**- 27%**
Clarence	B	Median	571	228 – 519	+ 343	+ 150%
Stahl	A	Median	377	228 – 519	+ 149	+ 65%
Stahl	B	Median	274	228 – 519	+ 46	+ 20%
Blue Sky	B	Median	36	157 - 620	**- 121**	**- 77%**
Lewis	C	Median	270	228 – 519	+ 42	+ 18%
Lewis	B	Median	304	228 – 519	+ 76	+ 33%
Foundation	B	Median	70	228 – 519	**- 158**	**- 69%**

5.3.9 Pool Depth and Pfankuch Ratings

The average maximum residual pool depths and average maximum pool depths are presented in Table 5-14. Most values are below the three-foot indicator, although lower pool depths would normally be anticipated in narrower B and C reaches within tributaries. Higher values are noted in lower Grave Creek where deeper pools should exist due to the larger stream size.

Also included in Table 5-14 are the Pfankuch ratings. Values would ideally tend toward a "good" rating, whereas many stream reaches are rated as "fair". One reach of middle Grave Creek is rated as "poor," possibly in the area where there has been excess stream widening indicators.

Table 5-14: Pool Depth and Pfankuch Rating Results.				
Stream	Type	Average Maximum Pool Depth (ft)	Average Residual Pool Maximum Depth (ft)	Pfankuch Scores
Lower Grave	C	3.8	2.7	Not scored
Lower Grave	B	3.7	2.1	Not scored
Lower Grave	F	5.1	3.5	1 Good
Middle Grave	C	2.9	1.2	1 Good
Middle Grave	B	3.0	1.5	**1 Poor;** **2 Fair**; 1 Good
Upper Grave	C	2.2	1.4	**1 Fair**
Upper Grave	B	1.6	0.8	**2 Fair**
Williams	B	2.1	1.3	**3 Fair**
Clarence	C	2.8	2.0	1 Good
Clarence	B	2.0	1.5	**2 Fair**; 3 Good

Table 5-14: Pool Depth and Pfankuch Rating Results.				
Stream	Type	Average Maximum Pool Depth (ft)	Average Residual Pool Maximum Depth (ft)	Pfankuch Scores
Stahl	B	2.2	1.2	**1 Fair** 2 Good
Blue Sky	B	2.4	1.5	3 Good
Lewis	C	1.8	1.2	1 Good
Lewis	B	2.0	1.5	**2 Fair**; 1 Good
Foundation	B	1.6	1.0	**3 Fair**

5.4 Water Quality Impairment Status Update for the Grave Creek Watershed

This section provides a water quality impairment status update for the Grave Creek Watershed. This update is based primarily on the application of Montana Water Quality Standards and the application of the targets, supplemental indicators and other use support objectives presented in Section 5.2 and the departure analysis in Section 5.3. Focus is on Grave Creek and the impairment causes identified on the most recent 303(d) list. As discussed in Section E.1.1, these causes can be summarized as “siltation” (fine sediment), “(other) habitat alterations”, and “flow alterations”. Also discussed in Section E.1.1 is the potential linkage between habitat alterations causes and problems from excess or total sediment load within a stream.

To assist with this effort, historical and existing land use indicators must be a consideration. Based on the narrative standards (Section E.2.2), impairment determinations must have linkage to existing and/or historical land use practices as a contributing factor to the departure from reference condition. Therefore historical and existing land use and linkages to sediment loading and habitat impacts, as well as natural conditions were all considered as part of the process of this impairment status update.

Grave Creek is currently identified as one segment on the 303(d) list and within the MDEQ SCD/BUD files (MDEQ, 2004c). Any impairment updates within this document apply to all of Grave Creek from the headwaters at Foundation Creek to the mouth at Fortine Creek, although there is specific discussion for Grave Creek below the GLID and above the GLID due to the differing impairment indicators and land uses.

5.4.1 Grave Creek Impairment Status Update

Below is a discussion on the application of the targets, supplemental indicators and other use support objectives to Grave Creek. Section 5.4.1.1 focuses on the status of the sediment targets and supplemental indicators. This section also incorporates discussion on linkages between the sediment targets/indicators and habitat alteration impairment indicators. Section 5.4.1.2 focuses on the status of other use support objectives linked to pollution impairments. Section 5.4.1.3 uses the information from Sections 5.4.1.1 and 5.4.1.2 for making updated impairment determinations.

5.4.1.1 Sediment Targets and Supplemental Indicator Summary Evaluation for Grave Creek

Table 5-15 and the remainder of this section provide a discussion on the status of each sediment target and supplemental indicator for all of Grave Creek. Note that the targets and supplemental indicators for sediment also provide key indicators of potentially unique habitat alteration problems. Also note that each target or supplemental indicator can be specifically linked to fine, coarse and/or total sediment impairment or use support conditions.

Pool Frequency Type I Target (Reference Table 5-7)

Six of seven of the Grave Creek reaches evaluated do not meet the pool frequency targets. The middle Grave Creek B reach is the only location where the pool target is satisfied. Other reaches are anywhere from 25% to 65% below the target value. These results imply an impairment condition from either excess sediment and/or habitat alterations.

Macroinvertebrate Type I Target

The only macroinvertebrate data is for lower Grave Creek. The results generally show acceptable conditions in a portion of lower Grave Creek before and after active restoration work, with concern about collection capabilities for one riffle. The data is limited in spatial coverage. There is no data in the upper reaches above GLID nor is there data in the sections of lower Grave Creek below GLID where excess fine and/or coarse sediment loading from banks or other upstream sources could negatively impact macroinvertebrate health.

Percent Surface Fines < 2 mm in Riffles Type I Target (Reference Table 5-8)

All composite pebble count results from all reaches of Grave Creek are consistently less than 12%. These values suggest that the riffle component of the pebble counts would also be consistently less than the 20% target. These results indicate that percent surface fines in riffles would not impact aquatic life. There is a lack of data for some of the lower Grave Creek reaches below GLID.

Percent Surface Fines in Spawning Gravels Type I Target

McNeil Core data is limited to primary bull trout spawning locations along middle Grave Creek. Results from recent years are all below the target value, implying that excess fine sediment in spawning substrate is not a problem for aquatic life, at least in reaches of Grave Creek referred to as middle Grave Creek in this document. Substrate fines

(McNeil Core) data is not available for upper or lower reaches of Grave Creek where other salmonid spawning may occur.

Table 5-15: Grave Creek Sediment Targets and Supplemental Indicators Status.

Parameter & Target Type	Status	Impairment or Use Support Indications
Pool Frequency **Type I Target**	6 of 7 reaches do not meet target; particularly in lower and upper Grave reaches where values are well below the target.	Results suggest impairment from excess sediment (coarse and/or total sediment); and/or impairment from habitat alterations.
Macroinvertebrate Results **Type I Target**	Limited spatial results suggest good support.	Good aquatic life support indication, but only applicable to limited area of lower Grave Creek.
Pebble Count Surface Fines < 2 mm in Riffles **Type I Target**	All assessed reaches meet the target.	Results suggest a lack of a fine sediment impairment to aquatic life in most reaches. Data lacking in portions of lower Grave Creek.
McNeil Core Substrate Fines < 6.35 mm **Type I Target**	Target met in middle Grave Creek; important area for bull trout spawning.	Results suggest a lack of fine sediment impairment to cold-water fish in middle Grave Creek. Data lacking in lower and upper Grave Creek.
Pebble Count Surface Fines < 6.35 mm **Type II Target**	10 of 11 reaches meet the target, one upper Grave Creek value 20% above the target.	Results suggest a lack of fine sediment impairment to cold-water fish in most or all reaches of Grave Creek; possible concern in upper Grave Creek.
Grid Toss Surface Fines < 6.35 mm in Pool Tail Outs **Type II Target**	All reaches meet the target value.	Results suggest a lack of fine sediment impairment to cold-water fish and aquatic life for most or all of Grave Creek.
Width to Depth **Type II Target**	This target is not satisfied in lower Grave Creek and in portions of middle Grave Creek; portions of middle Grave and all measured locations in upper Grave satisfy this target.	Good indicator of sediment (coarse, fine, and/or total) impairment and/or habitat alteration impairment for lower Grave and portions of middle Grave. Results in upper Grave and portions of middle Grave suggest a lack of sediment or habitat impairment.
Sinuosity and Meander Length Ratio **Supplemental Indicators** for Lower Grave Creek only	Values are below the reference range.	Results suggest potential sediment and/or habitat alteration impairment; applied to lower Grave Creek only.

Table 5-15: Grave Creek Sediment Targets and Supplemental Indicators Status.		
Parameter & Target Type	Status	Impairment or Use Support Indications
Large Woody Debris **Supplemental Indicator**	Values below or just above reference ranges throughout Grave Creek.	Low LWD and potential influence on pool formation and overall habitat complexity suggest potential habitat alterations impairment.
Bull Trout Redds and Juvenile Fish Data **Supplemental Indicator**	Redd counts increasing; as are juvenile counts; bull trout juvenile values much higher than cutthroat trout values.	Results suggest fair to good bull trout fishery; the actual potential is unknown and may be a function of available habitat and reservoir effects (Lake Koocanusa).
Pool Depth **Supplemental Indicator**	Values tend to be low based on at least two assessments.	Results suggest potential pool filling from excess sediment (coarse and/or fine) loading and/or a habitat alteration linked to low LWD values.
Pfankuch Ratings **Supplemental Indicator**	Lower Grave F – 1 Good Middle and upper Grave – 1 Poor, 5 Fair, and 2 Good.	Results suggest potential for habitat alteration or sediment impairment, although some of the lower ratings may be linked to natural conditions.
Fine and Coarse Sediment Loading **Supplemental Indicator**	Both fine and coarse sediment loading sources existing throughout the watershed.	Results provide linkage to human induced sediment loading to the stream system.
Land Use **Supplemental Indicators**	Historically higher; currently very low in upper watershed; still high along lower Grave Creek.	Results suggest potential for recovery in upper watershed, and suggest potential impairment in lower portions of watershed.
Visual Indicators and Professional Judgments **(Supplemental Indicator)**	Consistent indications of major sediment and/or habitat problems in lower Grave Creek; consistent indications of lesser sediment and habitat concerns (in recent years) in middle to upper Grave Creek reaches.	Results suggest impairment for habitat and/or sediment in lower Grave Creek, less certain for middle and upper Grave Creek although impacts still noted as well as ongoing recovery of the system noted.

Percent Surface Fines Type II Target ($\leq$ 15% for < 6.35 mm; Reference Table 5-9)

These values are used as a surrogate to help evaluate potential problems with excess substrate fines in spawning gravels where McNeil Core data is lacking. Ten of eleven reaches have values less than or equal to the 15% target value. In general, the results imply no problem with excess fine sediment in spawning gravels over most of Grave Creek. The exception is the upper Grave Creek B4 reach which has a value of 18%, possibly indicating impacts to trout spawning substrate. Also, a large portion of lower Grave Creek below GLID is lacking pebble count data, although this reach may not be important for native salmonid spawning.

Percent Surface Fines in Pool Tailouts Type II Target (≤ 10% for < 6.35 mm; Reference Table 5-10)

The median grid toss results satisfy the Type II target for all assessed reaches of Grave Creek. This implies that excess fine sediment is not a problem for aquatic life use support.

Width to Depth Ratio Type II Target (Reference Table 5-11)

The width to depth ratio results indicates that sections of lower Grave Creek below GLID are well above the upper end of this target. These results are consistent with width increases over time based on air photo analysis results. The results are also consistent with observations on stream stability and over-widened conditions. Sections of middle Grave Creek are also above this target, consistent with similar observations in these reaches (Bohn, 1998). These results, which are linked to land uses, indicate a potential habitat alteration condition as well as a condition consistent with potential sediment (coarse and/or fine) load accumulation linked to reduced sediment transport capabilities.

Other reaches of middle and upper Grave Creek satisfy the target value and suggest stable conditions.

Sinuosity Supplemental Indicator (1.2 – 1.6 Range; Reference Table 5-12)

Sinuosity for lower Grave Creek is well below the supplemental indicator range. This is likely associated with the channelization activities and other human impacts. This low sinuosity indicates a potential habitat alteration condition as well as a condition consistent with potential sediment (coarse and/or fine) load accumulation linked to reduced sediment transport capabilities. Sinuosity was not evaluated for Grave Creek above the GLID and is not considered an applicable measurement given the structural controls imposed on channel morphology by the valley walls.

Meander Length Ratio (MLR) Supplemental Indicator (13.8 – 19.2 Range; Reference Table 5-12)

The MLR for lower Grave Creek is below this supplemental indicator range indicating an over-widened and straightened stream with sediment transport problems. MLR was not evaluated for Grave Creek above the GLID and was not considered an applicable measurement.

Large Woody Debris Supplemental Indicator (Desirable Values are Dependent on Stream Width; Reference Table 5-13)

There is greater uncertainty in the application of this LWD indicator in lower and middle portions of Grave Creek than in the narrower upper Grave Creek or narrower middle Grave Creek reaches. The median LWD value for lower Grave Creek is well below the low end of the reference range. This lack of LWD can have a negative role in sediment storage and pool formation, and is an indicator of negative impacts from land use activities in the watershed.

The B reaches of upper Grave Creek and both the B and C reaches of middle Grave Creek fall below the low end of the reference range suggesting potential problems with habitat and potential linkages to sediment storage and transport. The upper Grave Creek C reaches are just above the low end of the reference range. Recent LWD inputs from a snow slide (Photo 18) have increased LWD values in upper Grave Creek and possibly lower reaches. This LWD input will likely be captured in future assessments and should be specifically tracked regarding LWD retention, pool formation and habitat contributions (refer to Section 9.0).

Bull Trout Redd Counts and Other Fish Data (Reference Appendix D)

Most or all bull trout spawning occurs above the GLID. Over the past several years, bull trout redd counts have increased to values as high as 173 in the mainstem of Grave Creek (Table D-3). This is a potential indicator of fishery response to habitat improvements, most notably removal of the fish barrier at the GLID. Other factors such as more restrictive bull trout fishing regulations may also play a significant role.

Appendix D also provides juvenile fish population estimates for bull trout and westslope cutthroat trout. The bull trout spawning and bull trout juvenile data appear to be positive indicators of beneficial use support, although it is nearly impossible to know what the full recovery potential is for the Grave Creek fishery where further habitat related improvements are possible. Note that the juvenile cutthroat density values in Grave Creek are much lower than the bull trout values (Figure D-2), although both fisheries may be improving over time based on the data.

Pool Depth (Reference Table 5-14)

As indicated in the Section 7 Consultation documentation (USFS, 2000), pools are considered generally shallow. The more recent assessment results presented in Appendix G and Section 5.3 support this conclusion, particularly in upper sections of Grave Creek. As more data on appropriate reference values becomes available, pool depth, preferably residual pool depth can be utilized as a Type I or Type II Target. At this time the data suggests a potential excess sediment and/or habitat alteration problem.

Pfankuch Ratings (Reference Table 5-14)

Lower Grave Creek was not given Pfankuch ratings except in an F reach that was rated "Good." The middle and upper reaches had 1 "Poor" rating, 5 "Fair" ratings, and 2 "Good" ratings. These ratings suggest the potential for habitat alteration or sediment problems.

Fine Sediment Loading (Reference Section 6.0 and Appendices I and J)

Existing fine sediment loading from roads has been modeled. This loading value, presented in Appendix I, is neither particularly high nor low when compared to similar watersheds with low to medium road densities as seen in the Grave Creek Watershed (MDEQ, 2004d). Yet, there are opportunities for BMP improvements that should be pursued.

The human caused mass wasting in the watershed above GLID contributes fine sediment at a modeled rate similar to the modeled natural hillslope rate (See Table 6-1). Lower Grave Creek bank erosion rates, much of which would include fine sediment loading, are very high. Most of this is considered preventable loading given the channelization, riparian impacts and other existing and historical land use stressors along lower Grave Creek.

Fine sediment loading in the middle and upper watershed areas during historical timber harvest, including sediment loading from initiation of the human caused mass wasting sites, would have been very high, as discussed in several documents (Bohn, 1998; USFS, 2000; USFS, 2002). Much of this fine sediment may have worked through the system over the years, particularly in the portions of the watershed above the GLID. Some slides in the watershed continue to enlarge and threaten to contribute large amounts of coarse and fine sediment to the stream system (Bohn, 1998).

The fine sediment loading linked to human activities lacking BMPs or reasonable land, soil and water conservation practices is sufficient to suggest a potential fine sediment impairment. This is particularly true in the lower Grave Creek below GLID due to the high bank erosion values. Furthermore, channel alterations in portions of lower Grave Creek can contribute to unnatural accumulations of sediment, further supporting a potential fine sediment problem.

Coarse Sediment Loading (Reference Section 6.0 and Appendices I and J)

Most of the fine sediment loading sources above, except the modeled road surface erosion loading, also includes coarse sediment loading. For example, the base of most mass wasting sites are similar in composition to erodible banks which are composed of glacial deposits that can contribute large quantities of unsorted material, predominately gravel and cobbles, to the channel (USFS, 2002). Also, eroding banks in lower Grave Creek would include a coarse sediment fraction. Historically, there would have been high coarse sediment loads linked to human activities, similar to the historically high fine sediment loads. Unfortunately, coarse sediment loads do not work through the system as quickly as finer sediment and there is a much greater likelihood of excess coarse sediment remaining in the system from past activities. Therefore, the coarse sediment loading or existing load in Grave Creek linked to human activities lacking BMPs or reasonable land, soil and water conservation practices is sufficient to suggest a potential coarse sediment impairment.

Other Land Use Indicators (Reference Section 2.0 and Appendix A, B and C)

Recent (< 15 years) forest activities in the watershed above the GLID do not represent a high level of activity, although even a relatively low level of activity lacking BMPs can have relatively high impact. Current ECA and water yield or peak flow values linked to human activities are not very high. Road density is also not very high, although there appear to be further opportunities for BMP improvements. Road encroachment is noted in some drainages and specifically at one major site along upper Grave Creek (Photo 6). Some roads and past harvest have been in the rain on snow zones and within riparian areas, including recent riparian harvest activities (Photos 1, 2 and 3). The impacts from these forest activities are fairly well identified via the discussions on sediment loading and reduced LWD recruitment.

Additional land use indicators include visual evidence of the removal of woody debris from the stream (Photo 11), the failures of several structures, and other human related encroachment such as gabion additions (Photo 17). The extent of habitat or other type impacts from these activities is uncertain, although it is possible they still have some impact on the lack of pools or reduced fish habitat in the system. Also, it is noted in one report (USFS, 2002) that many gabions and log drop structures are non functional and some are even causing erosion.

Further downstream along lower Grave Creek, there is visual evidence of impacts from channelization in the form of braided “D” type channel regimes downstream of the Flanagan Ranch to approximately 0.25 miles upstream of the Highway 93 Bridge. Also, the results from the bank erosion assessment (Appendix J) attributed significant bank erosion to human induced activities, including agricultural and development activities along stream banks.

Visual Indicators and Professional Judgments of Excess Sediment Loading and/or Sediment/Habitat Type Impacts

Lower sections of Grave Creek appear overly wide with excess total or bedload sediment accumulations. This is supported by several reports including the Section 7 Consultation (USFS, 2000), the Bohn report (Bohn, 1998) and the Grave Creek Watershed Ecosystem Analysis (USFS, 2002). The braided appearance provides visual evidence of poor habitat in major reaches of lower Grave Creek. Sections of middle and upper Grave Creek also show evidence of possible increased coarse sediment or potential indication of aggrading type conditions (Photos 12, 13, and 15). Nevertheless, one portion of the Section 7 documentation suggests “although certain indicators of habitat quality have been compromised, overall habitat conditions are considered fair to good for the Grave Creek Watershed" (USFS, 2000). Another document (USFS, 2002) suggests that the channel condition trends are stable for many of the tributaries, with a trend of increasing stability in Grave Creek. Furthermore, it is suggested in the Bohn 1998 report that "the departure from 'reference' in many critical reaches was not excessive, suggesting that alteration in land management techniques and restoration of the physical habitats have a high likelihood of success.

5.4.1.2 Evaluation of Other Use Support Objectives Status for Grave Creek

Table 5-16 presents the status of "use support objectives" where a pollutant is not linked directly to a potential beneficial use impairment in Grave Creek. These use support objectives address "pollution" conditions of habitat alterations linked to a lack of LWD or fish passage, as well as flow alterations from dewatering.

Table 5-16: Other Use Support Objectives Status for Grave Creek.

Parameter	Status	Impairment or Use Support Indications
LWD Frequency	Values below or just above reference ranges throughout Grave Creek	Low LWD and potential influence on pool formation and overall habitat complexity suggest potential habitat alterations impairment
Fish Passage	No major physical fish passage barriers noted; potential fish passage linked to low flows are addressed under minimum flow (see below)	No habitat alteration impairment causes from physical fish passage barriers
Minimum Flow	Grave Creek has documented low flow conditions linked to water diversions and over-widened channel conditions	Results indicate continued beneficial use impairment from flow alterations/dewatering

5.4.1.3 Impairment Determinations for Grave Creek

According to Montana State Law, an "impaired waterbody" means a waterbody or stream segment for which sufficient credible data shows that the waterbody or stream segment is failing to achieve compliance with applicable water quality standards (75-5-

103). Table E.4 presents water quality standards that are applicable to sediment (17.30.632(2)(f) and 17.30.637(1), which address both coarse or fine material based on the "sediment" definition (17.30.602 (28)) also presented in Table E-4. Per 17.30.632(2)(f) no person may cause increases above naturally occurring concentrations of sediment which will or are likely to render the waters harmful, detrimental, or injurious to recreation, fish, or other wildlife. Also per 17.30.637(1)(d) state surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create concentrations or combinations of material that are harmful to human, animal, plant or aquatic life.

Based on the above standards and associated definitions, a waterbody is failing to achieve compliance with one or more of the applicable sediment standards when:

1. A Type I target is not met, and
2. Excess sediment concentration(s) associated with not meeting this target are linked to increased sediment loading from existing or historical practices lacking reasonable land, soil and conservation practices.

This is because the Type I targets, when not satisfied, are based on conditions representing harm to cold water fish and/or aquatic life. As discussed in Section 5.2, Type II targets can also be used to make an impairment determination or further support an impairment determination, especially where Type I target data is lacking. Also, supplemental indicators are used to help evaluate linkages between elevated sediment concentrations and human sources and/or impacts to cold-water fish or aquatic life, and to help determine whether the stream's natural capability and eventual applicability of all targets via adaptive management.

Where excess sediment concentrations are not a factor in the impairment determination as defined by the above water quality standards, a "habitat alteration" impairment determination can be made based on 17.30.623(1) as defined for a B-1 classification in Table E-3. This determination should be consistent with a weight-of-evidence approach utilized by MDEQ for making most impairment determinations as defined in Appendix A to the 2004 Montana Water Quality Integrated Report (MDEQ, 2004). This type of impairment would tend to be under the "pollution" category not requiring TMDL development.

Coarse or Total Sediment Impairment

The conditions in lower Grave Creek suggest an impaired stream with indications of excess sediment loading associated with an overly wide stream with high bank erosion rates, reduced transport capabilities, and elevated sediment loading upstream. This conclusion is supported by the fact that both the Type I pool target and the Type II width to depth target are not satisfied. Furthermore, several supplemental indicator results support this determination and provide sufficient linkage to sediment sources. It appears that the sediment impairment is mostly linked to larger, bedload size material, although any bed material load size, including fine sediment, may be contributing to pool filling and other undesirable conditions. Future 303(d) lists will include new cause options, some of which are associated with sediment. One of these new options is "sedimentation/siltation", which may end up being the preferred impairment cause for Grave Creek in the upcoming 2006 303(d) list. A total sediment TMDL that addresses both fine and coarse sediment loading will be developed to address this condition.

Further upstream, the low pool values, in conjunction with loading sources and several other supplemental indicator results (Table 5-15) suggest potential impairment all along Grave Creek. The low pool values are likely due to a combination of the following conditions:

1. Excess sediment loading contributing to pool filling, riffle extension and reduction in habitat complexity;
2. Human induced geomorphic conditions limiting sediment transport and adding to sediment loading;
3. Reductions in pool -forming LWD (from harvest or physical removals); and/or
4. The natural conditions within Grave Creek.

It is noted that conditions in Stahl Creek and middle Grave Creek (Table 5-7) suggest pool values within the target range can be achieved, and the departure analysis show pool frequency values well below reference/target values. Sections 2.0 and 6.0 identify and quantify human activities that contribute to elevated sediment loading and reduced LWD recruitment as well as physical removal of LWD. There are no major human induced geomorphic limitations noted in most reaches of middle and upper Grave Creek, and there is some professional opinion that upper and middle reaches of Grave Creek are naturally limited in pools and LWD.

If the lack of pools is predominately from excess sediment loading and/or a loss of sediment transport capabilities due to human induced geomorphic conditions, then a sediment TMDL could be developed to address the problem. If the lack of pools is due to low LWD values from harvest and physical removals, then the impairment is likely due to habitat alterations that are probably outside the scope of a sediment TMDL.

If the low pool values are predominately due to natural conditions, then there is no impairment in middle and upper Grave Creek reaches linked to these low pool values. A number of years of assessment results under conditions where forestry BMPs and all reasonable land, soil and water conservation practices are in place and LWD values have had the opportunity to recover would be necessary to show that the upper reaches of Grave Creek are functioning at their potential. This data would be consistent with adaptive management and would serve as an additional supplemental indicator as defined below in Section 5.4.3. Because this information is currently lacking, the appropriate approach to ensure protection of the resource is to continue to treat the whole length of Grave Creek as one waterbody segment at this time and address impairment causes and solutions at the watershed scale. This is consistent with the most recent 2004 303(d) listing information for Grave Creek and requires no modifications to the 303(d) list other than potential modifications associated with the use of new listing cause options in 2006.

Fortunately, the development of a total sediment TMDL for the lower portion of Grave Creek will also address sediment loading throughout the watershed in such a way that provides protection from excess sediment loading to the middle and upper reaches of Grave Creek. Additional restoration goals to allow recovery of LWD, possibly in conjunction with a continued habitat alterations impairment cause, will provide further protection.

Fine Sediment Impairment

Where data is available, pebble count, grid toss and macroinvertebrate results suggest that fine sediment alone is not a cause for impairment. There are fine sediment related data gaps in key areas where stream morphology is impacted in lower Grave Creek. It is unknown how improved morphology will impact fine sediment storage once other targets, such as width to depth ratio, are satisfied in lower Grave Creek. Satisfying the width to depth ratio target would likely result in reduced bank erosion and reduced fine sediment loading, thus reducing the potential for fine sediment impacts.

Further upstream, the majority of the Type I and Type II targets linked solely to excess fine sediment are satisfied, although there are no macroinvertebrate data. Supplemental indicator results identify fine sediment sources, although the loading values alone only suggest the possibility of impairment.

The Table 5-15 data suggests that Grave Creek is probably not impaired due to fine sediment alone. Additional data to further support any such conclusion would be desirable, including macroinvertebrate data and additional percent fines data in upper Grave Creek. Nevertheless, the development of a total sediment TMDL for all of Grave Creek will specifically address both fine and coarse sediment loading and therefore address any potential siltation/fine sediment impairment conditions. This total sediment TMDL, specifically any allocations linked to fine sediment sources, will account for the fact that the majority of indicators along Grave Creek, particularly above GLID, suggest that excess fine sediment alone may not be a problem.

Other Habitat Alterations Impairment Determination

As noted above, the lack of pools and other indicators addressed via the total sediment TMDL may end up under a “habitat alterations” and/or future “sedimentation/siltation” type of cause impairment. Table 5-16 also notes that a lack of LWD alone could justify a “habitat alterations” type impairment due to a loss of important cold-water fish refugia. At this time, there is a lack of data specifically identifying whether or not the low LWD values are impacting aquatic life enough to justify impairment. Furthermore, recent LWD additions to the system will have increased values in upper Grave Creek, and there is greater uncertainty in the application of LWD reference values further downstream in middle and lower Grave Creek reaches. Therefore, low LWD values will not be identified as a separate "habitat alterations" cause of impairment, although actions to facilitate LWD recovery will be identified as a restoration objective in Section 7.0 since improved LWD may also help meet pool targets and improve pool quality. Fish passage concerns formally linked to the GLID no longer appears to be a cause for impairment as discussed throughout the document.

Flow Alterations/Dewatering Use Support Objective

Although data is somewhat limited, all indicators point to a continuation of the dewatering conditions described in the MDEQ SCD/BUD files for lower Grave Creek. These dewatering conditions are made significantly worse due to the overly widened channel. Therefore, Grave Creek will still be identified as impaired for flow alterations/dewatering, and restoration objectives will be developed to address this concern.

5.4.2 Tributaries Impairment Status Discussion

5.4.2.1 Comparisons to Targets, Supplemental Indicators and Other Use Support Objectives

Table 5-17 provides a summary on the application of the targets and supplemental indicators to several of the tributaries to Grave Creek. These tributaries include Williams, Stahl, Clarence, Blue Sky, Lewis, and Foundation Creeks. Below is further discussion on the impairment indications for sediment and habitat.

Coarse or Total Sediment Impairment Indications in Grave Creek Tributaries

The conditions in several tributaries (Williams, Clarence, Blue Sky, Foundation) are similar to those in portions of upper and middle Grave Creek where pool targets are not met and other indicators such as LWD, loading sources, pool depth, and visual observations suggest potential impairment linked to coarse sediment and/or habitat alterations. Conditions in Stahl Creek do not imply impairment. The relatively high natural background load and lower human loading and overall lower land use indicators in Lewis Creek suggests the possibility that pool filling is linked to natural conditions. It is interesting to note that the Lewis Creek pool values are similar to several other tributaries with lower natural background and higher human related coarse and fine sediment loading. It is also interesting that the Grave Creek Watershed EAWS (USFS, 2002) notes negative impacts from log drop structures and pool filling from excessive bedload in Lewis Creek. The document does not identify the bedload source but goes on to say "the channel condition has improved in the last 20 years. However, portions of the channel are still widening and aggrading." This language implies a potential impact from historical logging and channel work.

LWD levels in the tributaries do not correlate well with pool frequency results based on Tables 5-7 and 5-13, suggesting uncertain conditions regarding LWD and pool formation. Gathering data to further evaluate this linkage and possible LWD impacts on habitat quality would be desirable since other documents (USFS, 2000; USFS, 2002) suggest or identify a linkage between pool quality and LWD in the Grave Creek Watershed and the linkages between LWD and pool formation are well established in many areas.

Fine Sediment Impairment Indications in Grave Creek Tributaries

The majority of the Type I and Type II targets linked solely to excess fine sediment are satisfied in most tributaries, although there are no macroinvertebrate or substrate fines data. Blue Sky Creek results suggest the highest likelihood of a concern linked to potentially high substrate fines, although the 1998 Kopsi fire could be a factor. Supplemental indicator results identify fine sediment sources in all tributaries, although the loading values alone only suggest the possibility of impairment.

Other Habitat Alterations Impairment Determination

The low LWD values may imply a lack of refugia for fish in some tributaries. Fish passage concerns at this time are limited to a culvert on Foundation Creek that is a barrier to upstream fish migration and represents a possible unique habitat alterations impairment. This condition will be specifically addressed in the restoration objectives portion of the document (Section 7.0).

5.4.2.2 Tributaries Impairment Status

No tributaries have been previously identified as either impaired or fully supporting of any beneficial uses. At this time, no impairment or use support decisions are made for any of the tributaries to Grave Creek pending future assessment and SCD/BUD work. This assessment work can incorporate suggestions within this document, specifically those in Section 9.0, and will likely be consistent with normal MDEQ stream assessment data gathering requirements that would likely include macroinvertebrate sampling as well as other efforts to fill data gaps for complete use support determinations.

It is important to note that the development of a total sediment TMDL for Grave Creek will include sediment load allocations for sources throughout the watershed. These sediment load allocations will be developed in Section 7.0 as part of the restoration objectives, and will provide a level of protection from excess sediment loading to the tributaries by specifically addressing both fine and coarse sediment loading sources. Because the focus of these allocations is on protection of Grave Creek, future development within a given tributary may require additional load allocations specific to the tributary drainage where work is proposed in order to ensure protection of the resource. The need for additional TMDL load allocations should be based on the anticipated or potential sediment loading in comparison to the existing loading described Section 6.0.

5.4.3 Adaptive Management Linkages

As more data is collected in the Grave Creek Watershed, it will be possible to obtain a better understanding on the natural condition of Grave Creek and the tributaries, the role of LWD and its linkage to pool formation, the role of residual coarse sediment on pool formation, and a better understanding of fine sediment impacts or lack thereof. This improved understanding is part of the adaptive management process defined in Section 5.2 and developed further in the monitoring recommendations in Section 9.0.

This adaptive management may be used for future impairment status updates by MDEQ or in consultation with MDEQ. As discussed in Section 5.2.1, if one or more targets are not met in the future, updated impairment determinations may incorporate the supplemental indicators established in this document and/or other appropriate technical and science-based information to assess why the targets are not met or whether the targets need to be modified. It is expected that trend data over time will be a future supplemental indicator and an important component of adaptive management. At a minimum, this trend information should focus on pool frequency, pool quality, LWD values, and linkages between LWD and pools. This information is particularly important for the upper Grave Creek Watershed, including tributaries to Grave Creek. If there is no increasing trend in pool frequency and pool depth values throughout upper Grave Creek and within tributary drainages, then it may be appropriate to conclude that these streams have reached their capability and pool related target and indicator parameters are naturally low in the Grave Creek Watershed. Given the potential slow recovery time linked to coarse sediment loading and/or reductions in LWD, any conclusions based on trend data would likely require data covering at least a 10 to 20 year period from when the data was collected for this document. The amount of time necessary will be a function of data collection frequency and the frequency and extent of natural events such as floods or fires that can confound trend conclusions. Also, any human activities not consistent with the allocations in the upper watershed can result in the need to "reset the clock" depending on the extent and locations of sediment loading.

Table 5-17: Grave Creek Tributaries Sediment Targets and Supplemental Indicators Status.

Parameter & Target Type	Status	Impairment or Use Support Indications
Pool Frequency **Type I Target** (reference Table 5-7)	Williams, Clarence, Blue Sky, Lewis and Foundation all do not meet applicable target; Stahl Creek satisfies the target	Results suggest impairment from excess sediment (coarse and/or total sediment); and/or impairment from habitat alterations in most tributaries
Macroinvertebrate Results **Type I Target**	No data	No data
Pebble Count Surface Fines < 2 mm in Riffles **Type I Target** (reference Table 5-8)	All assessed reaches meet the target	Results suggest a lack of a fine sediment impairment to aquatic life in tributaries.
McNeil Core Substrate Fines < 6.35 mm **Type I Target**	No data	No data
Pebble Count Surface Fines < 6.35 mm **Type II Target** (reference Table 5-9)	Applied to B & C reaches only; all reaches in Williams, Clarence, Stahl, and Foundation satisfy the target; 4 out of 5 reaches in Lewis satisfy the target; 1 of 3 reaches in Blue Sky satisfy the target	Results suggest a lack of fine sediment impairment to cold-water fish in most tributaries; higher values in Lewis and Blue Sky may have links to natural background conditions
Grid Toss Surface Fines < 6.35 mm in Pool Tail Outs **Type II Target** (reference Table 5-10)	All reaches meet the target value.	Results suggest a lack of fine sediment impairment to cold-water fish and aquatic life for Grave Creek tributaries
Width to Depth **Type II Target** (reference Table 5-11)	Applied to B & C reaches: the upper end of this target range is not exceeded in any tributaries; as a supplemental indicator some A reaches appear overly wide and some reaches are unusually narrow	Results generally suggest a lack of sediment or habitat impairment, but not necessarily for all reaches

Table 5-17: Grave Creek Tributaries Sediment Targets and Supplemental Indicators Status.

Parameter & Target Type	Status	Impairment or Use Support Indications
Large Woody Debris **Supplemental Indicator** (reference Table 5-13)	Applied to A, B, C reaches; Williams B, Clarence B, Stahl B, Lewis B and Lewis C reaches all meet reference value; Williams A, Clarence C, Blue Sky B, and Foundation B reaches do not meet reference values	Many reaches have low LWD levels which can have a negative influence on pool formation and overall habitat complexity, thus suggesting some potential habitat alterations impairment conditions
Bull Trout Redds and Juvenile Fish Data **Supplemental Indicator** (reference Table D-3)	Only bull trout redd data reported in Clarence and Blue Sky, both streams seem to have increasing trend	The results suggest some level of use support via maintenance of bull trout spawning habitat in these two tributaries; the actual potential is unknown and may be a function of available habitat and reservoir effects (Lake Koocanusa)
Pool Depth **Supplemental Indicator** (reference Table 5-14)	Values appear to be relatively low in all tributaries	Results suggest potential pool filling from excess sediment (coarse and/or fine) loading and/or a habitat alteration linked to low LWD values
Pfankuch Ratings **Supplemental Indicator** (reference Table 5-14)	All tributary reaches: 11 Fair ratings; 11 Good ratings	Results suggest potential for habitat alteration or sediment impairment, although some of the lower ratings may be linked to natural conditions
Fine and Coarse Sediment Loading **Supplemental Indicator** (reference Section 6.0)	Both fine and coarse sediment loading sources exist throughout the tributary watersheds; natural loading in Lewis Creek high relative to human loading	Results provide linkage to human induced sediment loading to the stream system, a criteria that must be met for any impairment determinations

Table 5-17: Grave Creek Tributaries Sediment Targets and Supplemental Indicators Status.

Parameter & Target Type	Status	Impairment or Use Support Indications
Land Use **Supplemental Indicators**	Historically higher; no longer high in most tributaries	Results suggest potential for recovery in upper watershed
Visual Indicators and Professional Judgments **(Supplemental Indicator)**	Consistent indications of some sediment and habitat concerns (in recent years) based on reference documents (Bohn, 1998; USFS, 2000; USFS, 2002)	Results suggest potential impairment for habitat and/or sediment in some tributaries; some uncertainty and varying professional opinions similar to the situation for middle and upper Grave Creek

SECTION 6.0
SEDIMENT LOADING SOURCE ASSESSMENT SUMMARY

This section summarizes the findings of the sediment source assessment and loading analysis. Several sediment-modeling approaches were used to evaluate the sediment sources identified within the watershed. Detailed evaluations of sediment loading by load category, sub-watershed, stream reach, and associated land use are presented in Appendices I & J. Two general sediment particles sizes are of concern. Fine sediment includes clay, silt, sand, and small gravel while large gravel, cobble, and boulders are considered coarse sediment. When analyzing impacts to beneficial use support, fine sediment is typically discussed from the perspective of particle sizes less than 6.35 mm in diameter. Appendix H provides the primary discussion on sediment size impacts.

In-stream sediment sources, those sources identified as contributing sediment to the stream network, including bank erosion and mass wasting, are described in detail in Appendix J. Bank erosion was evaluated using a modified Bank Erodibility Hazard Index (BEHI) approach. Surface erosion from mass wasting sites was evaluated using the WEPP model and treating the slope failure sites similar to road fill slopes. Erosion of sediment from the toe slopes of mass failures is activated by in-stream and/or out of bank flows. This erosion mechanism was also evaluated with a modified BEHI approach. The bank erosion and mass wasting sources would consist of a combination of fine and coarse sediment sizes.

Upland sediment sources were also identified from air photo interpretation. Sediment loads from these sources were not calculated due to the unlikely probability of sediment delivery to the channel from distant sources given the time between the initiation of any human caused events and apparent revegetation between the sources and the stream channel network.

Road surface erosion based on assumed existing road conditions was modeled by the USFS using the WEPP:Road model. Appendix I explains the road sediment modeling method and results. A natural background load associated with surface erosion from hillslopes was calculated using a basic model. The sediment from road surface erosion and natural background loading linked to erosion from hillslopes would be primarily in the fine sediment size category. Other sediment loading from sources such as culvert failures were not calculated due to the infrequent occurrence and minimal contribution to the stream network relative to other delivery sources.

Note that comparison of sediment loads calculated for the various sources and load categories should be made with caution as methodologies used to estimate the loads have varying degrees of accuracy and are based on different model inputs in some cases. For example, bulk density varied among the different models used. Bank erosion and mass wasting site toe slope erosion calculations (both using modified BEHI method) used saturated soil bulk density of 1.5-1.6 g/cc. WEPP: Road for mass failure surface erosion and for road surface erosion uses a dry bulk density of 1.4 g/cc for fillslopes and 1.8 g/cc for road surfaces. The natural background erosion rate of 30 tons / $mile^2$ is based on 1.5 g/cc bulk density.

The sediment load determinations focused on existing sediment loading to the stream network. This effort did not attempt to quantify historic sediment loading from the periods of highest timber harvest activity within the upper watershed with the exception of estimates of initial mass wasting loads.

6.1 Summary of Total Annual Modeled Sediment Load for the Grave Creek Watershed

Total modeled sediment loading in the Grave Creek watershed is attributed primarily to human caused sources of accelerated bank erosion in the lower Grave Creek stream segment (Table 6-1). Bank erosion in lower Grave Creek accounts for the majority (9,433 tons) of the modeled total annual sediment load, most of which is linked to human causes, perhaps mostly due to past channelization. Sediment from mass wasting sites, primarily located in the assessed tributaries and in upper and middle Grave Creek main stem, accounts for an additional 2,299 tons of the total annual modeled sediment load, 67% of which is attributed to human causes. A significantly smaller annual sediment load (203 tons) is attributed to road surface erosion. The modeled natural background loading from hillslope erosion is 2,250 tons per year.

As shown in Table 6-1, the total annual modeled sediment load to the whole Grave Creek watershed is about 13,713 tons, of which 81% is linked to human causes. Additional loading from steep first order streams, as discussed in Section 6.2.1, would add to the natural background loading such that the human caused yearly loading would be of a lower percentage. On the other hand, coarse sediment loading from initiation of mass wasting events (Section 6.2.2.2) and past bank erosion areas linked to timber harvest would add a significant sediment load. Much of this coarse material may remain in the system, potentially impacting aquatic habitat given the potentially slow movement of bedload and coarser size material through a stream system, particularly in comparison to the transport of finer and/or suspended sediment loads (Leopold, 1994; Watson et al., 1998; Dunne et al., 1980). Increased hillslope erosion and road erosion loading from historical harvest activities would have also been very high, although much of this load was probably finer sediment and may have flushed through the system.

Section 6.2 provides additional discussion for the specific modeling approaches and results for the loading results captured in Table 6-1, and Section 6.3 discusses loading results by tributary watershed and for Grave Creek.

Table 6-1: Summary of Total Modeled Sediment Load (Tons/Year) for the Grave Creek Watershed by Load Category.

Stream	Load Category							
	Bank Erosion[1] (Lower Grave Creek Only)	Mass Wasting Sites[1]		Roads	Natural Background Erosion (area * 30 t/mi^2)	Summary		
		Human	Natural			Human	Natural	Total
Lower Main Stem Grave Creek In-Stream Sources	9433					9393	40	9433
Upper and Middle Main Stem Grave Creek In-Stream Sources		331	107			331	107	438
Grave Creek Watershed Loading not Captured within Tributary Watersheds				105	840	105	840	945
Williams Creek Watershed		404	31	15	285	419	316	735
Clarence Creek Watershed		223	5	24	180	247	184	431
Stahl & S. Fork Stahl Creek Watershed		345	5	27	360	372	365	737
Lewis Creek Watershed		54	555	12	150	66	705	771
Blue Sky Creek Watershed		149	44	18	375	167	419	586
Foundation Creek Watershed		41	5	3	60	44	65	109
Total Loading to Grave Creek above GLID		1547	752	154	1830[2]	1701	2582	4283
Total Loading to Grave Creek Watershed	9433	1547	752	203	2250	11,143	2570	13713

1: Eroding banks in upper and middle watershed and tributaries captured under mass wasting sites modeling approach; no mass wasting sites identified along lower Grave Creek.
2: 840 tons per acre value for loading not captured in tributary watersheds is split in half for upper and lower watershed totals.

6.2 Sediment Loading by Source Type

6.2.1 Natural Background Sediment Load

An estimate of natural background sediment from hillslope erosion was determined by multiplying area in square miles by a value representing an average rate of forest hillslope erosion. The value used is 30 tons per mile (Washington Forest Practices Board, 1997).

Not all mechanisms of natural sediment loading were accounted for in this assessment. Natural background sediment load from hillslope erosion was accounted for as described above. It is recognized that additional mechanisms of natural sediment loading exist within the watershed. For example, while natural mass wasting sites were identified in Blue Sky and Lewis Creeks, it is likely that additional natural mass wasting sites exist in the watershed, and contribute to the natural sediment load. The in-stream sources analysis below provides a quantification of this natural load.

Another example of natural sediment loading unaccounted for is from the steep A3 and A4 stream types. These reaches were surveyed for morphological classification but not surveyed for the sediment loading assessment. Rosgen (1996) characterizes first-order, A3 and A4 stream types as highly susceptible to bank erosion susceptibility, high sediment supply sources, and having high bedload transports rates. Natural sediment sources such as debris torrents, avalanches, and mass wasting are common in these stream types. (Appendix G Table G-2). Naturally these stream types in the headwaters of Grave Creek tributaries supply a large sediment load of both coarse and fine material to the channel network.

6.2.2 Sediment Loading from In-stream Sources

In-stream sources include sites associated with bank erosion or with historic mass wasting. Refer to Appendix J for details on in-stream sediment source modeling. Table 6-2 summarizes in-stream sediment source loading attributed to mass wasting sites. Throughout the Grave Creek watershed above the GLID, in-stream sediment sources were modeled as mass wasting sites although a few locations are more representative of typical bank erosion, whereas in lower Grave Creek the in-stream sediment sources were all modeled as bank erosion.

6.2.2.1 Bank Erosion

Bank erosion was identified almost exclusively in lower Grave Creek (Photos 12 and 19) and accounts for most of the total annual sediment load at 9,433 tons (Table 6-1). Bank erosion was the sole sediment-loading category associated with the in-stream sediment sources identified in lower Grave Creek. The sediment load associated with bank erosion is 9,433 tons. Riparian modifications, roads and channel alteration are the primary causes of accelerated bank erosion in lower Grave Creek main stem. Only 1% of the bank erosion was attributed completely to natural causes.

6.2.2.2 Historical Mass Wasting Sites

Historical mass wasting sites are the second type of in-stream sediment source (Photos 8, 9 and 10). Two mechanisms of sediment erosion from mass wasting sites were modeled. The first mechanism is erosion from the surface of the mass failure. This mechanism was modeled with WEPP: Road, treating surface erosion from mass failures similar to road fill slope erosion. The second mechanism involves activation of the toe slope of mass failures by stream flow.

Aside from bank erosion in lower Grave Creek, massing wasting sites in Lewis Creek are the next greatest in-stream sediment sources with 609 tons contributed annually (Table 6-2). Natural causes accounted for 555 of the 609 tons of the mass-wasting load contributed to Lewis Creek.

Williams Creek has the next highest in-stream sediment source load (404 tons), all of which is attributed to human activities. In-stream sediment source loads from mass wasting sites in middle and upper Main stem contribute 331 tons associated with human causes and 107 tons from natural causes. In-stream sediment source loads from mass wasting sites in the other tributaries range from 42 tons per year in Foundation Creek to 242 tons per year in Stahl Creek. All of this additional loading, except for 44 tons of the load in Blue Sky is attributed to human activities.

It is recognized that even though natural mass wasting loads were not identified in the lower portions of the other tributary drainages, such sites could exist in the middle and upper tributary reaches. The sediment sources identified by air photo interpretation (Map 15) provide an idea of the frequency of similar mass wasting sites where the middle and upper tributary reaches were not inventoried. Based on this map, it appears that Williams would have an extrapolated natural mass wasting load of about 31 tons similar to the extrapolated load for Blue Sky. Map 15 shows few sediment sites in the upper watersheds for Stahl, Clarence and Foundation at about 15% of the number seen in Williams or Blue Sky. This is consistent with the less steep and shorter steep slope lengths found in Stahl and Clarence compared to Williams, Blue Sky and Lewis (Map 4 topography). Based on this observation, a natural mass-wasting load of about 4.6 tons (15% of 31) is added to the total modeled load for Stahl, Clarence and Foundation. These additional loads are not reflected in Tables 6-1 and 6-2, and would result in an additional 44.8 tons to the total watershed values, thus increasing the total modeled mass wasting load in the upper watershed from 2253 to 2298 tons, with 1547 tons attributed to human-related mass wasting sites and 751 tons from natural mass wasting sites.

It is important to note that the sediment currently contributed from surface and toe slope erosion of historic mass failures is relatively small in comparison to the sediment contributed during and immediately after the events occurred. For example, in Williams Creek, 4.6 acres of mass failure was observed. Assuming the average depth of failure was 5 feet and assuming a dry bulk density of 1.6 g/cc, failures in Williams Creek would have moved 59,371 tons of material. Field observations of remnant failure material are evidence that not all of the material moved was delivered to the stream. Assuming only fifty percent of the failure was delivered during and shortly after the event, about 30,000 tons would have been delivered initially to Williams Creek. The total initial load throughout the watershed is estimated at 115,000 tons since the human caused mass wasting sites in Williams Creek represent about 26% of the total human caused mass wasting contributions based on the Table 6-2 results. While the mass wasting sites continue to contribute sediment to the stream channel network (594 tons annually in Williams Creek), the initial mass wasting pulse produced the majority of the coarse and fine sediment contributed to the channel network.

It is assumed that most of the fine sediment from the initial pulse has been transported out of the system, particularly the upper portions of the Grave Creek Watershed. However, the coarse material likely remains in the bed material load, as bedload transport rates tend to be relatively low (Dunne et all 1980; Watson et al 1998). As a result, the coarse sediment from these events, which remains in the system, has the potential to impact pool habitat due to pool filling by the excess bed material load as discussed in Section 5.4 and Appendix G.

Table 6-2: Summary of Sediment load from Mass Wasting Sites in the Grave Creek Watershed.														
	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass-Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
Stream	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)
Foundation*														
Human					2.2	100	39.4	100	2.2	100	39.4	100	41.6	100
Natural					0	0	0	0	0	0	0	0	0	0
Total					2.2	100	39.4	100	2.2	100	39.4	100	41.6	100
Clarence														
Human	8.1	100	143.2	100	3.8	100	67.5	100	11.9	100	210.7	100	222.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	8.1	100	143.2	100	3.8	100	67.5	100	11.9	100	210.7	100	222.6	100
Stahl														
Human	7.4	100	101.1	100	9.1	100	124	100	16.5	100	225.1	100	241.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	7.4	100	101.1	100	9.1	100	124	100	16.5	100	225.1	100	241.6	100
South Fork Stahl														
Human	2.4	100	71.4	100	1	100	28.8	100	3.4	100	100.2	100	103.6	100
Natural	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0.0	0
Total	2.4	100	71.4	100	1	100	28.8	100	3.4	100	100.2	100	103.6	100
Lewis														
Human	1.7	2	34.7	13	0.8	1	16.5	8	2.5	2	51.2	11	53.7	9
Natural	84.2	98	225.3	87	66.9	99	178.9	92	151.1	98	404.2	89	555.3	91
Total	85.9	100	260.0	100	67.7	100	195.4	100	153.6	100	455.4	100	609.0	100
Blue Sky														
Human	2.8	100	56.9	82	4.2	100	85.7	73	7	100	142.6	77	149.6	77
Natural	0.0	0	12.4	18	0	0	31.1	27	0	0	43.5	23	43.5	23
Total	2.8	100	69.3	100	4.2	100	116.8	100	7.0	100	186.1	100	193.1	100

Table 6-2: Summary of Sediment load from Mass Wasting Sites in the Grave Creek Watershed.

	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass-Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
Stream	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)	(t/y)	(%)
Williams														
Human	17.5	100	189.8	100	16.6	100	179.8	100	34.1	100	369.6	100	403.7	100
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Total	17.5	100	189.8	100	16.6	100	179.8	100	34.1	100	369.6	100	403.7	100
Middle and Upper Main stem														
Human	3.3	65	251.2	79	0.9	53	75.3	66	4.2	62	326.5	76	330.7	76
Natural	1.8	35	66.4	21	0.8	47	38.3	34	2.6	38	104.7	24	107.3	24
Total	5.1	100	317.6	100	1.7	100	113.6	100	6.8	100	431.2	100	438.0	100
Total Mass-Wasting Site Load to Lower Grave Creek														
Human	43.2		848.3		38.6		617.0		81.8		1465.3		1547.1	
Natural	86.0		304.1		67.7		248.3		153.7		552.4		706.1	
Total	129.2		1152.4		106.3		865.3		235.5		2017.7		2253.2	

* Foundation Creek was not surveyed during the in-stream inventory. The sediment loads for the inventoried portions of Clarence Creek were applied to the length of Foundation Creek in order to predict a sediment load for Foundation Creek.

6.2.3 Sediment Sources Identified Through Air Photo Interpretation

Discrete sediment sources were identified during air photo interpretation (Map 15). Initially, these sources were stratified by distance from riparian areas: proximal - within 150’, midslope - 150’-500’, and distal - greater than 500’. For each source, approximate area and primary cause (e.g. natural, harvest related, road related, etc.) were assigned. Many of the sources proximal to the riparian area overlapped with sites assessed in the in-stream source inventory. Sediment load from these sites is captured in the in-stream assessment. The remaining sites, located at mid and upper slopes, were determined to be beyond the sediment contributing distance to the stream network. Therefore sediment load from these sources was not calculated and assumed negligible.

While sediment loads were not calculated for these sources, a summary of the sediment sources identified through the air photo survey provides a general description of the distribution of sediment sources throughout the watershed and the associated causes (Table 6-3). This information provides insight into additional loading from historic harvest periods that may have accessed the stream network.

Table 6-3: Sediment Sources Identified from Air Photo Interpretation.

Stream	Harvest Related	Road/Harvest Related	Road Related	Natural	Other*	Total
Lewis			1	4		5
Blue Sky	1	2	1	13		17
Clarence	1	3		5		9
Stahl			1	2		3
South Fork Stahl		1				1
Williams	2	2	1	6		11
Main Stem Grave /Foundation	3	8	2	10	1	24
Total	7	16	6	40	1	70

*A sediment source at the confluence of Cat Creek within Grave Creek main stem could not be attributed to a load category.

6.2.4 Sediment Loading from Road Surface Erosion

Road surface erosion was modeled by the USFS using WEPP:Road (Appendix I). Results indicate that for the Grave Creek watershed, 203 tons of sediment from road surface erosion is delivered to the stream network (Table 6-4). Roads in lower Grave Creek contribute 49 tons of the sediment load from road surface erosion. The road networks in Stahl Creek and Clarence Creek produced 27 tons and 24 tons respectively of the total road surface sediment load.

Table 6-4: Summary of Sediment Delivery from Road Surface Erosion in the Grave Creek Watershed.			
Drainage	Sediment from Primary Roads (tons)	Sediment from Secondary Roads (tons)	Total Sediment Delivery (tons)
Foundation	0.0	2.8	2.8
Lewis	8.3	3.7	12.0
Blue Sky	0.0	17.6	17.6
Clarence	17.1	6.4	23.5
Stahl	20.2	6.4	26.7
Williams	4.2	10.6	14.9
Upper Main Stem Grave	7.7	5.9	13.6
Upper Middle Main Stem	0.3	1.7	2.0
Lower Middle Main Stem	21.2	19.6	40.8
Lower Main Stem Grave*	2.2	46.5	48.8
Total	81.3	121.3	202.7

Road density provides an indication of sediment loading, with location or distance from a stream and road condition influencing the amount of sediment load likely to reach a stream network. Figure I-1 demonstrates that for secondary roads in the Grave Creek watershed (which generally lack BMPs) road surface sediment load increases more rapidly with increasing road density than for primary roads. Most of the sediment is contributed from secondary roads, which generally lack adequate BMPs such as cross drains and graveled, paved or chip-sealed surface. BMP implementation, which is more common on primary roads, partially offsets sediment load increase from increasing road density.

The loading from forest roads during pre-1990s logging activities where BMPs were generally not applied was likely very much higher than the load today. Even the above modeled load has been reduced due to relatively recent BMP implementation on parts of the road network and due to continued revegetation and recovery of some secondary roads. This historic load would have been predominately fine sediment and may have generally been transported out of the Grave Creek watershed.

6.2.5 Sediment Loading and Routing from Disperse Timber Harvest Sources

Historical timber harvest activities, lacking in BMPs at the time, would have the potential to contribute significant sediment loads to the watershed. A significant portion of this load would be linked to the initial pulse from mass wasting sites discussed above. Other loads would be linked to hillslope erosion of fine sediment that may have been transported through the system by this time. Erosion from existing timber harvest locations is not believed to be a significant source of sediment loading except via mass wasting and roads as already captured in the modeling discussed above.

Existing and historical hydrological modifications from timber harvest, specifically peak flow increases, is another potential source of both fine and bedload material movement through the system. It is difficult to quantify what this load would be. Current PFI levels linked solely to timber harvest (Appendix C) are relatively low. Historically, PFI increases after the majority of the harvest activity occurred, would have been significantly higher. These past PFI increases could have contributed extra bedload to the system via channel scour or increased bank erosion, particularly where riparian harvest or other activities lacking BMPs occurred along stream channels. Even today, the PFI increases in some watersheds, while on the descending limb of the increase, may be contributing to extra bedload movement and scouring within the drainage systems, although the PFI values are probably within an acceptable range of natural variability at this time.

6.3 Sediment Loading Source Assessment by Sub-watershed

6.3.1 Williams Creek

The total existing sediment load from all quantified sources in Williams Creek is 735 tons per year, of which 419 tons are linked to human causes and 316 tons are linked to natural background loading. Mass wasting sites linked to human causes are the primary source of sediment in the Williams Creek, contributing 404 tons of the total sediment load. Road surface erosion contributes 15 tons of the total load for Williams Creek. Riparian modifications from timber harvest and roads and road encroachment are the primary causes of human related sediment contribution to Williams Creek.

Natural sediment loading includes the estimated natural background surface erosion rate of 285 tons per year, and an estimated 31 tons per year linked to natural mass wasting loads. As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that were not quantified.

6.3.2 Clarence Creek

The total existing sediment load from all quantified sources in Clarence Creek is 431 tons per year, of which 247 tons are linked to human causes and 184 tons are linked to natural background loading. Mass wasting sites account for 223 tons while roads account for the remaining 24 tons of the total human related load. Riparian modifications from timber harvest and roads and road encroachment are the primary causes of human related sediment contribution to Clarence Creek.

Natural sediment loading includes the estimated natural background surface erosion rate of 180 tons per year, and an estimated 5 tons per year linked to natural mass wasting loads. As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that were not quantified.

6.3.3 Stahl Creek and South Fork Stahl Creek

Because road sediment was not modeled separately, it is more appropriate to look at the combined total sediment loads of Stahl and South Fork Stahl together. The total existing sediment load from all quantified sources in the this combined drainage is 737 tons per year, of which 372 tons are linked to human causes and 365 tons are linked to natural background loading. Mass-wasting sites account for 346 tons of the total annual human related sediment load in Stahl and South Fork Stahl while roads account for 27 tons. Sediment sources identified in the Stahl Creek and South Fork Stahl were linked to multiple human-related causes including roads encroachment, bridges, bank armor and to riparian modifications associated with timber harvest and roads.

Natural sediment loading includes the estimated natural background surface erosion rate of 360 tons per year, and an estimated 5 tons per year linked to natural mass wasting loads. As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that were not quantified.

6.3.4 Lewis Creek

The total existing sediment load from all quantified sources in Lewis Creek is 771 tons per year, of which 66 tons are linked to human causes and 705 tons are linked to natural background loading. Mass wasting sites account for 54 tons of the total annual human related sediment load while roads account for 12 tones. Channel alteration and riparian modification from timber harvest and roads are the human contributions to the total sediment load.

Natural sediment loading includes the estimated natural background surface erosion rate of 150 tons per year, and an estimated 555 tons per year linked to natural mass wasting loads. Natural erosion associated with avalanche paths (Photo 5) is the dominant modeled cause of mass wasting in Lewis Creek (Table 6-2). As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that was not quantified, although it appears that the loading from the avalanche paths and mass wasting in these areas may account for much of this natural loading.

6.3.5 Blue Sky Creek

The total existing sediment load from all quantified sources in Blue Sky Creek is 586 tons per year, of which 167 tons are linked to human causes, and 419 tons are linked to natural background loading. Mass wasting sites account for 150 tons of the total annual human related sediment load while roads account for 18 tons. The human loads are related to riparian modifications associated with timber harvest and roads.

Natural sediment loading includes the estimated natural background surface erosion rate of 375 tons per year, and an estimated 44 tons per year linked to natural mass wasting loads. As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that was not quantified, although it appears that the loading from the avalanche paths and mass wasting in these areas may account for some of this natural loading.

6.3.6 Foundation Creek

In-stream sediment source inventories were not conducted in the Foundation Creek sub-watershed. Because of proximity, the sediment load rates for the inventoried portions of Clarence Creek were applied to Foundation Creek in order to predict a sediment load for Foundation Creek.

Based on this extrapolation, the total existing sediment load for Foundation Creek is 109 tons per year, of which 44 tons are linked to human causes and 65 tons are linked to natural background. Assuming similar conditions to Clarence Creek, human related mass-wasting sites would be related to 41 tons and road surface erosion would account for 3 tons for a total human yearly load of 44 tons. Like Clarence Creek, these sources would be linked to riparian modifications associated with timber harvest and roads.

Natural sediment loading includes the estimated natural background surface erosion rate of 60 tons per year, and an estimated 5 tons per year linked to natural mass wasting loads. As noted in Section 6.2.1, there is likely an additional natural sediment load from steep A and G type streams that were not quantified.

6.3.7 Grave Creek Sediment Loading

6.3.7.1 Upper and Middle Grave Creek

The total annual sediment load to portions of middle and upper Grave Creek watersheds includes the following:

- 438 tons of mass wasting directly to the main stem of Grave Creek, all of which was identified along portions of middle and upper Grave Creek. Of the 438 tons from mass wasting, 331 tons are linked to human causes and 107 tons are linked to natural causes.
- 56 tons from roads (Table I-3) where the load is directed to the main stem of middle or upper Grave Creek or within a tributary drainage not captured above.
- Depending on the location of interest along upper or middle Grave Creek, the total sediment loading also includes a significant portion of the 840 tons per year natural background surface erosion loading to the main stem Grave Creek (Table 6-1).
- The 97.6 tons per year of sediment loading from roads in the tributary watersheds can eventually reach portions of upper and/or middle Grave Creek.
- The 1,861 tons per year of sediment from mass wasting in tributary watersheds can eventually reach portions of upper and/or middle Grave Creek,

All together, a total of 4283 tons per year is the modeled/estimated loading within the Grave Creek Watershed above GLID. Of this, 1701 tons are attributed to human sources, and 2582 tons are attributed to natural background.

Not all loading is transported along the stream channel. Some may be deposited within floodplain areas or may have contributed to excess sediment in the channel that can be filling or otherwise impacting pool formation.

6.3.7.2 Lower Grave Creek

The total annual sediment load for the Grave Creek Watershed, some or all of which can reach lower Grave Creek, is 13,713 tons per year. This includes the 4283 tons from the watershed above GLID in addition to the 9433 tons from bank erosion and 49 tons from roads in the lower watershed. Of the 13,713 tons per year, 11,143 tons are linked to human causes and 2572 tons are linked to natural background loading.

This total load is in excess of the sediment load under which the once stable Grave Creek formed. In addition to the high sediment supply from bank erosion in lower Grave Creek, the elevated sediment supply produced from the tributaries and middle and upper Grave Creek main stem, exceeds the transport capacity of lower Grave Creek. Degraded riparian and channel conditions in lower Grave Creek further exacerbate the deficiency in transport capacity due to the shallow, over widened character of the channel.

SECTION 7.0
RESTORATION OBJECTIVES

Restoration objectives are developed to ensure compliance with Montana water quality standards, with focus on meeting targets and use support objectives identified in Section 5.2 and applied toward the impairment status update in Section 5.4. The restoration objectives address the significant sources of impairment identified and quantified in previous sections of this document. Where the impairment is linked to excess pollutant loading, the restoration objectives are developed in the context of a Total Maximum Daily Load (TMDL) and TMDL allocations that apply to the pollutant sources. In Grave Creek, excess sediment loading (Section 5.4) is identified as a cause of impairment. Because sediment is a pollutant, a sediment TMDL and sediment source allocations, also referred to as sediment load allocations, are required.

The water quality goals (TMDLs, allocations and other restoration objectives) developed in this section provide a basis for prioritizing water quality improvement or restoration activities and for measuring success of these activities in the Grave Creek Watershed. Sections 8.0 and 9.0 provide an implementation and monitoring strategy to help achieve the water quality goals defined in this section.

7.1 Sediment Load Allocations and Total Sediment TMDL Development for Grave Creek

7.1.1 Natural Variability, Adaptive Management and Uncertainty

As discussed in Section 5.2.1.1, natural variability and natural disturbances may make it impossible to satisfy some of the targets until the stream and/or the watershed recovers from the natural event. Sediment load allocations, on the other hand, are developed with consideration of natural events such as floods or fire. A major goal of BMPs and all reasonable land soil and water conservation practices is to limit sediment loading linked to human activities or structures during these natural events.

Adaptive management is applied toward the restoration objectives, specifically the sediment load allocations. This adaptive management is applied to restoration objectives in essentially the same manner as applied to targets and use support objectives (Section 5.2.1.1). Adaptive management addresses uncertainty in the development and application of load allocations. Some specific examples of applying adaptive management toward this uncertainty are identified below.

- A stream may still be impaired even after all load allocations are satisfied. This could lead to new allocations that require lower overall loading to the system, or to the development of new targets that are a better reflection of achievable water quality improvements.
- A stream may meet all sediment targets and be fully supporting of aquatic life even if all load allocations are not satisfied. This condition implies that the

allocations are reducing sediment loading more than required for beneficial use support, or implying that additional water quality improvements are possible and targets may need to be more protective.

- Future land management could lead to new sediment source categories not covered by the load allocations. This could require modification to the TMDL and/or development of new load allocations.
- Further monitoring, modeling and overall understanding of the watershed could lead to an adjustment in one or more load allocations and the sediment TMDL.

Even with a significant amount of data for the Grave Creek Watershed, there is still uncertainty in the development of loading values in Section 6.0 and the linkages between the sediment loading and impairments identified in Section 5.0. EPA sediment guidance further defines some of the uncertainty when relating sediment loading levels to use impacts or source contributions. The analytical connections can be difficult to draw for several reasons including the following:

- Sediment yields may vary widely at different spatial and temporal scales within a watershed making it difficult to draw meaningful “average” sediment conditions;
- Sediments are a natural part of all waterbody environments making it difficult to determine whether too much or too little loading is expected to occur in the future and how sediment loads compare to natural or background conditions; and
- A significant level of uncertainty is associated with sediment delivery, storage, and transport estimates.

The above uncertainties require an adaptive management approach to water quality protection and TMDL implementation in the Grave Creek Watershed.

7.1.2 Sediment TMDL Development and Load Allocations Approach

The technical definition of TMDL is “the sum of load allocations plus waste load allocations plus a factor of safety.” The load allocations apply to nonpoint sources and the waste load allocations apply to point sources covered by a Montana Pollutant Discharge Elimination System Permit. There are not any permitted sediment discharges in the Grave Creek Watershed and none are anticipated at this time. Therefore, waste load allocations are not considered a necessary part of the sediment TMDL. On the other hand, there are several nonpoint sources where sediment load allocation development is required.

The TMDL can be expressed through appropriate measures other than a given loading rate (40 CFR 130.2). The use of an alternative approach for sediment TMDL analysis is justified in guidance developed by EPA (EPA, 1999) given the uncertainties around sediment TMDL development. The approach used for the Grave Creek Watershed is to express the TMDL as a percent reduction in loading based on the percent loading reductions applied to controllable human sources. These percent reductions applied to controllable human sources are the basis for sediment load allocations that cumulatively define the TMDL. The percent reduction values used for load allocations can be based on departure from target conditions or estimates of human loading conditions above natural background and achievable reductions.

Loading conditions and sediment impairment indicators vary between the segment of Grave Creek below the GLID and Grave Creek above the GLID. The Grave Creek sediment TMDL includes development of sediment load allocations that are protective for all of Grave Creek. Furthermore, these sediment load allocations are applied throughout the watershed and therefore provide a level of protection to the Grave Creek tributaries.

It is worth noting that Grave Creek combines with Fortine Creek to form the Tobacco River. The Tobacco River has been identified as impaired for sediment (siltation) on the MDEQ 2004 303(d) list. Completion of sediment TMDLs for the Tobacco River and the remainder of the Tobacco Watershed is scheduled for 2006. The sediment load allocations developed for sources in the Grave Creek Watershed can also apply as sediment load allocations for the Tobacco River. Of course there will be additional sediment load allocations from other sources throughout the Tobacco River Watershed in addition to those associated with sediment sources within the Grave Creek Watershed.

7.1.3 Sediment TMDL for Grave Creek Below GLID

The total sediment TMDL for Grave Creek is expressed as a 60% reduction in the total yearly sediment loading from all existing human caused sources. This is a reduction in both coarse and fine sediment loading to ensure full protection of beneficial uses. This 60% value is based on information provided in Section 6.0 and a determination that approximate reductions in the range of 50% to 65% are achievable for the two major human caused loading sources in the watershed: mass wasting and bank erosion. The sediment load allocations and associated rationale behind the allocations are presented in Section 7.1.4 below.

7.1.4 Sediment Load Allocations

7.1.4.1 Load Allocation Approach

Allocations are developed for significant sediment sources or source categories consistent with the total sediment TMDL. The allocations are applied to sources at the watershed scale since excess sediment loading to a tributary can eventually enter downstream waters. This watershed approach provides a layer of protection for the tributaries to Grave Creek, which is important given some of the impairment indicators noted in several tributaries (Table 5-17).

The allocation approach used in this section is based on load reductions or load limits applied to controllable sediment sources. This also includes load allocations applicable to future activities/growth consistent with EPA guidance (EPA, 1999). This approach does not include development of load reduction allocations for natural background loading since natural background loading is not considered a controllable source.

The watershed characterization and source assessment information is used to identify four sediment source categories for developing sediment load allocations. These four sediment source categories are defined below:

- Human-induced sediment loading from accelerated stream bank erosion. This includes controllable bank erosion along lower Grave Creek linked to activities such as grazing or other land clearing activities that tend to impact riparian health. This category also accounts for reductions in bank erosion that can be achieved via improvements to stream morphology based on the stream capabilities. Both existing human uses and potential future impacts are addressed within this category.
- Sediment loading from road surface erosion. This includes fill slopes and cut slopes and culvert failures. This includes existing roads and potential future roads from forest activities or from private development. It also incorporates any loading from existing skid and jammer roads within the watershed.
- Sediment loading from human-induced mass wasting sites. This includes the existing mass wasting sites and addresses future human activities, such as timber harvest, that could lead to additional mass wasting if not properly managed.
- Sediment loading from all other forest management activities including peak flow increases and hillslope erosion.

In addition to the above source categories, the load allocations and restoration objectives must also take into account that there may be significant historic human caused sediment loads remaining in the system and impacting pool formation and overall habitat quality. This is an important consideration since a situation can exist where load allocations are being met, but more time is needed to allow for stream recovery. This is the suspected condition in parts of the Grave Creek Watershed.

7.1.4.2 Grave Creek Load Allocations

Table 7-1 presents the sediment load allocations for each of the four source categories. Sections 7.1.4.1 through 7.1.4.4 provide additional description and rationale for each load allocation. Section 7.1.4.5 provides discussion on the historic sediment loads remaining within the system.

Table 7-1: Sediment Load Allocations for Grave Creek.

Source Category	Load Allocation	Loading Values	Methods to Achieve Allocation
1) Human-induced sediment delivery from accelerated stream bank erosion.	63% reduction in existing annual sediment load from eroding banks associated with human disturbance.	Reduction from 9393 tons/year to about 3475 tons/year based on the Appendix J modeling approach.	Riparian and stream bank protection practices and BMPs including grazing management, stream buffers, SMZ law application, 310 Law implementation, proper design of bridges and road crossings; avoid riprap use, avoid stream and floodplain encroachment. Opportunities exist to accelerate recovery via active channel restoration/reconstruction (Section 8.0).
2) Sediment delivery from roads (surface erosion), including fill slope and cut slopes and culvert failures.	Keep load levels in the upper watershed (above GLID) at or below levels when streams were assessed in 2002. No increase in loading on private lands due to a lack of BMP implementation. The no-increase concept does not include short-term sediment increases from activities such as road decommissioning and/or BMP upgrades.	Approximate load of 203 tons/year based on the Appendix I modeling approach.	Existing roads should be maintained & improved where BMPs are lacking; roads not needed should be decommissioned, new roads built to BMP standards and new road construction counter-balanced with existing road improvement, continued erosion mitigation via revegetation, or active decommissioning. Opportunity exists for a net decrease by addressing known problems, some which have been addressed (Section 8.0). Reduction of culvert failure risks. Effective BMP implementation across all ownerships/jurisdictions.

Table 7-1: Sediment Load Allocations for Grave Creek.			
Source Category	**Load Allocation**	**Loading Values**	**Methods to Achieve Allocation**
3) Sediment delivery from mass wasting associated with human activities.	Levels consistent with recovery of existing human caused mass wasting sites and prevention of new ones, estimated at a 50% reduction in modeled loading after full recovery/revegetation of existing sites.	Reduction from 1547 tons/yr to about 774 tons/yr based on the Appendix J modeling approach.	Allow natural recovery; future road building, timber harvest, prescribed burning, thinning, and other land management activities shall be conducted with effective BMP implementation and in such a way as to prevent mass failures like those which have occurred in the past from lack of BMPs. Focused vegetation plantings and/or toe stabilization on exposed mass wasting sites is a potential option to facilitate recovery. Stabilization should avoid riprap type hardening methods.
4) Sediment delivery from all other forest management activities.	Keep values at levels that would not cause a concern via application of forestry BMPs, limit sediment/bedload increases via application of other reasonable land, soil, and water conservation practices. This approach recognizes that there may be some short-term fine sediment loading increases from future forestry and land management activities, but any such increases could fall within the definition of "naturally occurring" where land use indicators such as ECA or PFI are kept to reasonable levels consistent with forest plans and any existing DEQ guidance.	To remain at relatively insignificant levels consistent with the definition of "naturally occurring."	Continued application of forestry BMPs and other reasonable land, soil and water conservation practices.

7.1.4.1 Human-Induced Sediment Delivery from Accelerated Stream Bank Erosion (Lower Grave Creek Below GLID)

In comparison to other human related loads to Grave Creek below GLID in the watershed, bank erosion loading appears to be the most significant load that can be addressed via management practices. The proximity of this loading to the impairment conditions in lower Grave Creek contributes to the significance of this load.

The accelerated stream bank erosion allocation is focused on lower Grave Creek below the GLID. The degraded length in the lower watershed is comprised primarily of approximately 4 miles of the lower main stem, which are not included in Grave Creek Restoration Phases 1 or 2 (Reference Section 8.0). In Appendix J, it was estimated that more than 90% of the bank erosion is linked to human activities including grazing, private home and agricultural development, riparian harvest, roads and bridges. Increased bank erosion is also related to the channelization. It is estimated that the achievable bank loading reduction necessary to meet sediment targets is in the 45 to 65% reduction range. This range covers the percent reduction in bank erosion accomplished when the bank erosion hazard rating (BEHI) is reduced by one level for each bank with an extreme, high or moderate rating (Table J-1). Higher erosion reductions may be possible, but the history of stream manipulation and uncertainties regarding stream capabilities adds some uncertainty to the extent that bank erosion can be eliminated. The adaptive management approach will be utilized to evaluate the stream capabilities and can be used to modify the allocation in the future.

The reduction in bank erosion would be accomplished over time via implementation of riparian and stream corridor protection practices, and can include active restoration to accelerate recovery. This recognizes that some bank erosion may still occur due to natural causes and limited human interactions even after all reasonable land, soil and water conservation practices are applied and the stream has significantly recovered and/or been actively restored.

A very high percentage of the total maximum human related bank erosion is linked to riparian modification (Section 6.0). This may represent the most controllable portion of the sediment loading from accelerated bank erosion via the application of BMPs. Riparian health, if not protected, will not allow for natural recovery and will not allow for successful active restoration. Vegetation data collected at bank erosion sites and presented in Appendix J also support this conclusion. Therefore, this allocation applies to any land use activities limiting the potential recovery of the system via limitations to riparian health. This applies to all areas along the stream including areas where active channel restoration/reconstruction is pursued. In other words, where active restoration is successfully implemented and bank erosion reduction goals are accomplished, the riparian area will need to be maintained in a healthy state to limit bank erosion via the application of management practices and BMPs. The use of riprap or other permanent stream hardening techniques (Photo 20) will not be considered acceptable erosion reducing approaches for the purpose of meeting the allocation. In fact, these stream hardening activities will be considered a contribution toward increased bank erosion due to downstream effects and other negative results that can occur from riprap additions.

Some activities in the upper watershed can contribute to increased erosion. This includes excess sediment loading that can lead to aggrading conditions and excess bank pressures. The allocations for other sources discussed below address this concern.

7.1.4.2 Sediment from Roads (Surface Erosion)

The “no increase” road erosion allocation is applied at the scale of the Grave Creek Watershed above the GLID. The goal is to help keep total sediment load within reasonable limits to help ensure compliance with pool targets while at the same time helping to prevent any impairment conditions linked solely to excess fine sediment. Some flexibility can be applied within specific watersheds based on individual road modeling values for each watershed in comparison to percent fines results. This no increase applies to surface erosion loading conditions, including loading from skid trails and jammer roads, as they existed when most stream physical assessment work was performed in 2002. This is also consistent with the road modeling time frame.

There is allowance for increased loading from the lower part of the watershed based on appropriate BMP applications on private roads, particularly in any areas where there is increased subdivision. Because fine sediment was generally not identified as a unique problem throughout most of the watershed, this overall “no increase approach” should be protective. There is greater uncertainty about fine sediment impairment in Grave Creek below GLID due to a lack of data. The bank erosion allocation should address this concern given the very high load reductions involved with the bank erosion allocation, much of which would include fine sediment load reductions, in comparison to the loading from road erosion.

It should be recognized that while a sediment reduction from road surface erosion is not required in the allocation, opportunities for such a reduction are apparent. For example, Forest Service analysis of roads in the entire watershed using WEPP suggests that application of road BMPs, specifically doubling the frequency of cross drains (400 ft versus 800 foot spacing used to model existing conditions) will reduce sediment loading to Grave Creek drainage network by 8-28% depending on road characteristics. Such BMP implementation equates to 8 – 30 tons per year modeled reduction in potential loading to Grave Creek drainage network based on the results of the Forest Service analysis. Some of these BMPs have been implemented in recent years (Section 8.0).

Additionally, new road construction may require sediment reduction from existing roads in order to attain the no net increase allocation, although over time some of the recently decommissioned roads may result in a modeled load decrease as the ripped or decompacted road surfaces revegetate. In this way, the no net increase allocation allows for some future growth in the form of new roads. All new road construction should include effective application of BMPs, particularly at stream crossings and locations where roads are adjacent to streams. This applies to all roads and is not limited to roads associated with timber harvest activities. Sediment reduction may be attained via BMP implementation or road decommissioning and adherence to INFS guidelines associated with locating new roads at least 300 feet from a stream. These guidelines provide water quality protection and serves as a reasonable land soil and water conservation practice that helps ensure protection of the beneficial uses in the watershed.

Implementation of BMPs should be focused on those stretches of roads that have the potential to deliver sediment to the stream system. Short-term sediment increases from BMP implementation, road decommissioning or road building where all BMPs are followed will not be counted as increases to the net sediment load.

This allocation also applies to no increased loading from culverts not meeting current BMP standards. This load and overall loading risk was not quantified. Load reductions or controls are typically accomplished by reducing the risk of culvert failure by ensuring adequate flood flow capabilities in the 25 to 100 year event range and via application of maintenance and other BMPs.

7.1.4.3 Sediment Delivery from Mass Wasting Associated with Forest Management or Other Activities

Sediment loading from existing human caused mass wasting sites will continue to naturally decrease to a level that will result in an estimated 30 to 70% reduction from current modeled loading. In some locations there may be opportunities to assist recovery or to mitigate effects via replanting. Sediment loading from natural mass wasting events is not covered under this allocation as long as human activities do not increase the loading from the natural mass wasting locations.

Given the very high estimated loads from initial mass wasting (Section 6.0), this allocation cannot be satisfied unless future mass wasting linked to forestry or other human practices is effectively prevented. Future management activities will need to be effectively implemented by all landowners according to various guidelines designed to protect watershed resources, particularly riparian areas and steep slopes near streams and riparian areas. These measures include but are not limited to riparian habitat conservation areas (RHCAs) and riparian management objectives (RMOs) as defined by the Inland Native Fish Strategy (INFS), best management practices (BMPs) and Streamside Management Zone (SMZ) laws as defined by Montana DNRC, and the Kootenai National Forest Plan. Adherence to these and other applicable guidelines not listed, which apply to road building, timber harvest, and other management activities, should prevent occurrence of mass failures like those that have occurred in the past resulting from human management activities. Given the linkage of these events to past timber harvest in the upper portions of the watershed, INFS and other forest practices implemented by the Kootenai National Forest will be critical component of meeting this allocation.

It is recognized that it may be impossible to guarantee complete avoidance of human caused mass wasting, but there should not be any such sites contributing sediment to streams where BMPs and reasonable land, soil and water conservations practices could have prevented the mass wasting. These practices can include avoiding or limiting harvest in higher risk areas.

7.1.4.4 Sediment delivery from all Other Forest Management Activities

This allocation addresses other forest management activities such as clearing linked to timber harvest or recreational facilities, thinning of overgrown areas, prescribed fires, post-fire mitigation, etc. These activities, under existing conditions, were not considered significant sediment loads, in part due to a lack of recent timber harvest in the watershed. Nevertheless, future timber harvest and other activities are a possibility and should not be precluded based on the Grave Creek TMDL and this allocation as long as all BMPs and other protective efforts, such as INFS standards are pursued to ensure minimal sediment loading. If harvest approaches a level where sediment loading could be significant even with the application of all BMPs, INFS standards and other potential reasonable land, soil and water conservation practices, then the landowner proposing the activity may need to perform additional modeling and other investigations to ensure consistency with this allocation. The purpose of the modeling and investigations will be to ensure that the cumulative effects from the activities do not represent a significant source of sediment loading such that targets in Grave Creek or beneficial use support conditions in the watershed are at risk of not being met. There is uncertainty in knowing at what level harvest activity may have significant impacts even with application of protection measures. Tracking ECA and peak flow increases (PFI) is one indicator that should be applied.

Water quality monitoring in the project vicinity, before and after the project, may be a necessary reasonable land, soil and water conservation practice depending upon the scale of the project. In addition, inspections during and after the project may also be necessary to ensure proper application and maintenance of BMPs and other water quality protection practices/measures.

Timber harvest activities can impact water yield such that peak flows can be increased and lead to increased bank erosion and bed scour. Peak flow increases from human activities should not limit the success of active restoration projects, not hinder LWD recovery, or increase overall sediment loading in a way that jeopardizes target compliance or impedes recovery of the system from historical loading. Some literature recommendations (King, 1989) suggest a modeled water yield increase limit from human activities of no more than 8% for a stream like lower Grave Creek where there is increased bank erosion and other stream stability concerns. In more stable reaches such as middle and upper Grave Creek, as well as the tributaries, water yield values closer to 12% would be a more appropriate potential level of concern. These water yield values are not meant to be substitute load allocations, but instead are indicator levels at which further analysis may be necessary to ensure consistency with the allocation for forest management activities. Note that the 8% and 12% water yield values would result in different, possibly higher modeled peak flow increases.

7.1.4.5 Historic Sediment Loads Remaining in the Streams

There may be significant historical coarse sediment loads remaining within the system due to the lag time between sediment delivery to the system and when the sediment is moved through the system. It is recognized that movement of this sediment load through the system may be necessary to meet one or more of the sediment targets, particularly those related to pool formation. The strategy to control this historical load is to facilitate recovery to favorable conditions for sediment transport and subsequent pool formation and other habitat improvements. Recovery in Grave Creek below GLID may also involve active restoration to improve sediment transport conditions.

This historic load has not been completely quantified, but example calculations in Section 6.0 show that the initial load from mass wasting was extremely large. Even if only 10% of this load were coarse sediment, the load would still be much larger than any quantified existing yearly loads in the upper parts of the watershed. As discussed in Section 6.0, the fine sediment portion of this historic load appears to have been transported through much of the drainage system, at least in most of the watershed above the GLID.

No load allocation is developed for this historical loading since it is already within the stream system. Also, the activities that led to increased sediment loading are adequately addressed in the above sediment load allocations applied to the Grave Creek Watershed.

7.2 TMDL Seasonality and Margin of Safety

7.2.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development. Throughout this plan, seasonality is an integral factor. Water quality and habitat parameters such as fine sediment and bull trout redds are all explicitly recognized to have seasonal cycles. Specific examples of how seasonality has been addressed are as follows:

- Models that predict sediment loading, such as from road erosion, inherently incorporate runoff flows when erosion is greatest. WEPP Road results for example incorporate a climate data covering 30 years of precipitation variability.
- The application of percent fines targets at low flows with sampling occurring during the summer or early fall after flushing flows.
- The application of macroinvertebrate targets at low flows with sampling occurring during the summer or early fall for accurate population analyses.

- The application of pool targets at low flows with sampling occurring during the summer or early fall to standardize pool identification and pool depth and volume measurements.
- Minimum instream flow requirements (to be developed) will be evaluated during the low-flow part of the season when irrigation withdrawals and temperatures are greatest with additional focus on the time of year when bull trout need to migrate up Grave Creek.

7.2.2 Margin of Safety

Applying a margin of safety is a required component of TMDL development. The margin of safety (MOS) accounts for the uncertainty about the pollutant loads and the quality of the receiving water and is intended to protect beneficial uses in the face of this uncertainty. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (EPA, 1999). This plan addresses MOS in several ways:

- Consideration of seasonality as described above.
- A large amount of data and assessment information were considered prior to finalizing any impairment determinations.
- The monitoring strategy and application of targets and supplemental indicators addresses a variety of parameters to help ensure protection of the resource and ensure accurate determinations on success toward meeting the water quality targets.
- The adaptive management approach evaluates target attainment and watershed conditions via a comprehensive monitoring strategy outlined in Section 9.0. This can allow for refinement of targets and/or load allocations to ensure restoration of beneficial uses.
- Extensive effort went into reference condition development for a variety of parameters using several peer-reviewed sources of information.
- Targets were based on application of conservative statistical ranges using relatively large data sets in several situations.
- Load allocations and TMDLs address both coarse and fine sediment loading at a watershed scale and provide a layer of protection for the tributary drainages.

7.3 Additional Restoration Objectives Applied to the Grave Creek Watershed

TMDL development and sediment load allocations are required only for beneficial use impairments that are linked to a pollutant (sediment, for example). Table 5-16, Section 5.4.1.3 and Section 5.4.2.1 summarize several existing or potential impairment conditions linked to other use support objectives that address “pollution” vs. “pollutants”. These other use support objectives include LWD frequency, minimum flow levels (lower Grave Creek), and fish passage. These conditions are addressed via additional restoration objectives to ensure a comprehensive approach is identified to help ensure full support of all beneficial uses. These additional restoration objectives are defined in the following sections.

7.3.1 Large Woody Debris Recruitment

LWD is low in many streams in the Grave Creek Watershed, although at this time the data is not sufficient to make an impairment determination due solely to low LWD levels. Nevertheless, the low values justify development of additional restoration objectives specifically for Grave Creek above GLID, Blue Sky Creek, and Foundation Creek. Increasing LWD in these and other streams in the Grave Creek Watershed would result in improved aquatic habitat by helping with pool development and improving overall habitat complexity. The primary approach to achieving higher LWD levels is passive management that relies on avoiding riparian harvest and/or avoids a reduction in LWD recruitment. Avoiding future riparian harvest will leave larger trees near the stream network where they may be recruited to Grave Creek. Other options can include placing and anchoring more large wood in the channel in the form of woody debris jams or implementing thinning approaches to facilitate the growth of mature trees in riparian areas to increase future large woody debris recruitment to the channel. Caution is advised for any wood placement or thinning activities since access and channel related work could cause more negative impacts in some areas than the positive impacts of increased LWD or LWD recruitment.

7.3.2 Fish Passage

A fish passage limitation has been identified in Foundation Creek at the main road-crossing culvert (Photo 21). No impairment determination is made at this time since the level of impact from this fish passage barrier is not documented. The initial goal is to identify the fishery impacts from this fish passage barrier. If fish passage is desirable and the barrier is limiting habitat utilization by native fish, the restoration objective is to mitigate the impacts via culvert replacement or other measures. This restoration objective is also applied to any other human caused fish passage barriers identified in the watershed.

7.3.3 Flow Alteration (Dewatering) in Lower Grave Creek

Flow alteration from dewatering is an impairment in Grave Creek below the GLID, consistent with the existing 303(d) list. A minimum in-stream flow is important for maintaining habitat connectivity and avoiding elevated water temperatures detrimental to cold-water fish. This lack of connectivity and higher water temperatures may have negative impacts on fish passage for spawning bull trout or other species. In severe instances, a complete loss of flow or very low flows will limit and may even be lethal to aquatic life populations and can severely limit cold-water fish habitat.

The restoration objective is to meet minimum in-stream flow levels and work with water users on ways to accomplish this. This can be done via irrigation efficiency improvements, water leasing, or other arrangements. It is expected that meeting the sediment TMDL targets will improve channel morphology such that a given low flow will have deeper pool and riffle habitat and colder water. These improved channel conditions may even result in lower flow requirements to meet a given in-stream flow based on a wetted perimeter or other flow objective. Recognition of legal water rights is an important consideration when pursuing in-stream flow improvements.

SECTION 8.0 WATER QUALITY AND HABITAT RESTORATION PLAN IMPLEMENTATION STRATEGY

An important component of this Water Quality Protection Plan will involve supporting and documenting the implementation efforts of the major land stewards in the basin. Achieving the targets and allocations set forth in this plan and as part of the TMDL development process will require a coordinated effort between land management agencies and other important stakeholders including the County Government and Conservation District, private landowners, and representatives from conservation, recreation and community groups with water quality interests in the Grave Creek Watershed. Coordination of water quality protection in the Grave Creek Watershed is being facilitated via the Kootenai River Network (KRN) in cooperation with the Friends of Grave Creek Watershed group and the Grave Creek technical advisory personnel that worked on development of this plan.

A watershed group such as KRN and/or the Friends of Grave Creek can encourage stakeholder involvement, and help provide for a feedback mechanism whereby stakeholders can discuss and document water quality improvements being made. The group can provide peer input to monitoring plans and analysis of results, and help identify new water quality concerns and methods to document impacts. The group can also compile reports, and serve as a repository for data being collected throughout the Grave Creek Watershed and can also pursue funding and support for water quality implementation projects.

The Kootenai River Network (KRN) is committed to supporting water quality restoration projects throughout the Kootenai River basin. Grave Creek is one of the KRN's focus areas due to the importance of Grave Creek to the threatened bull trout and westslope cutthroat trout. KRN has played an active role in coordinating restoration efforts among various landowners and agencies. KRN has demonstrated its dedication to water quality and habitat restoration in Grave Creek by providing support for the development of this Grave Creek Habitat and Water Quality Restoration Plan, and the KRN will continue its support and help with the implementation strategy described in this section.

8.1 Introduction

The following section outlines a conceptual Water Quality and Habitat Restoration Plan (WQHRP) for the Grave Creek Watershed. This WQHRP is intended to be an evolving document and will be updated as new information regarding resource conditions is collected. As described in preceding sections of this assessment, Grave Creek has been subjected to a variety of direct and indirect natural and anthropogenic disturbances. Documented impacts to the channel date back to the middle to late 19th century when the valley was settled by early settlers. With this in mind, it is not realistic to expect a quick reversal from these impacts in the short-term. The proposed WQHRP attempts to restore water quality and habitat conditions by incorporating a watershed scale approach that first identifies the causes and sources of impairment, such as the approach applied in Sections 1.0 through 7.0, and secondly implements projects that will reduce the sources of sediment. It is imperative that the causes and sources of channel disequilibrium, specifically in lower Grave Creek be addressed at the watershed scale. It is not unrealistic to assume that the components outlined in this WQHRP will require more than 10 years to fully implement, in addition to on-going monitoring (Section 9.0) and adaptive management strategies.

Restoration of water quality and habitat conditions in the Grave Creek Watershed can be achieved through a diverse assortment of restoration actions and management strategies. The goals of the TMDL and WQHRP plan parallel restoration efforts currently underway and completed in the watershed. Sections 8.2.1 and 8.3.1 summarize completed and ongoing restoration projects in the Grave Creek Watershed. Additional strategies to achieve water quality goals and TMDL targets are presented in Sections 8.2.2 and 8.3.2.

Management or restoration strategies fall into two categories: 1) watershed-wide management activities to promote overall upland and stream health and 2) targeted strategies to address observed impairments primarily on lower Grave Creek. Each restoration strategy will need to be assessed on a site-specific basis to determine its feasibility with respect to site constraints, cost, environmental benefit, and stakeholder support. Restoration strategies will be prioritized based on benefit and feasibility. Implementation and effectiveness monitoring of the restoration strategies is outlined in Section 9.0. Monitoring and adaptive management, as described in Sections 5.0 and 7.0, are critical to achieving and/or updating water quality goals and to the overall success of the restoration strategies.

8.2 Watershed-wide Restoration Strategies

As demonstrated in Sections 4.0 and 5.0, Grave Creek is currently functioning below geomorphic and biological potentials. This condition may also be occurring in one or more tributaries. Impairments described in Section 5.0 and water quality restoration goals outlined in Section 7.0 provide much of the basis for future water quality restoration strategies presented in this plan. Restoration strategies recently implemented by the Kootenai National Forest are described and additional strategies, which apply across the Grave Creek Watershed, are presented. Strategies specific to lower Grave Creek are presented in Section 8.3. In this section, water quality strategies for middle and upper Grave Creek focus on facilitating further recovery and related fish habitat improvements such as increasing pool frequency and large woody debris concentration. Strategies also include maintaining low levels of surface fines and substrate fines, maintaining a diverse macroinvertebrate community, and maintaining fish passage where desirable. Overall, restoration strategies will also concentrate on improving habitat conditions and increasing bull trout spawning access and spawning redd conditions.

Recommendations for improving stream corridor conditions include passive and active restoration techniques applied at site-specific locations and at the reach scale. A number of potential restoration strategies have been identified. To varying degrees, these strategies can be applied to meet the goals of the WQHRP. They include: 1) forest management practices, 2) riparian management plans, 3) addressing roads and stream crossing problems, and 4) fish habitat improvement including fish passage barrier removal (if deemed desirable) and active and passive LWD recruitment.

8.2.1 Completed and Planned Watershed-Wide Grave Creek Water Quality and Habitat Restoration Strategies

Recently the Kootenai National Forest completed a variety of road and watershed improvement projects and has identified needs for other such projects. In August 2002, all culverts on the Grave Creek Road were assessed and BMP upgrades were implemented.

In Williams Creek, 9 culverts were either removed or assessed as functioning properly. An additional 4 culverts were identified for work. There is an additional crossing, which is a bridge, and another 6 crossings that need to be assessed. In addition, the Williams Creek road is now closed and maintained as a trail. The road surface is revegetating and total surface area available for erosion is decreasing. Most of this work was accomplished since 1998.

In Clarence-Stahl watershed, 8 culverts have been removed, 3 in Upper Clarence Creek and 5 on South Fork Stahl Creek. Three bridges exist. Another 4 – 5 crossings need to be assessed. Each tributary also has a short road system that is now maintained as trail. The road surface on these routes is revegetating and total surface area available for erosion is decreasing.

Several structures were also removed in the Blue Sky Creek watershed including a bridge in Upper Blue Sky Creek, a culvert upstream of the Kopsi confluence, and a bridge in Upper Kopsi Creek. In addition, the Blue Sky Creek road is now closed and maintained as a trail. The road surface is revegetating and total surface area available for erosion is decreasing.

Two culverts have been removed on the Lewis Creek road system. Portions of the road system in Lewis Creek are maintained as trail resulting in road surface revegetation and sediment reduction.

In lower Grave Creek, approximately 7 crossings on Road 7019 were evaluated and upgrades were implemented in August 2003.

Recently the Grave Creek Road above Clarence Creek received numerous BMP upgrades. Additional recent improvements include gravelling the surface of the Grave Creek campground road in 2003, 4 miles of BMP improvements on Road 7019 also in 2003. Also in 2001 several stream crossings were removed from the South Fork Stahl

Creek and several other crossing in Clarence Creek were removed. Road 114 was chipsealed from milepost 3 – 10.2 and 0.4 miles at the Foundation Creek Curve in 2002. BMP improvements were made throughout that reach of road. In 2001, 9 perennial stream crossing were removed from the Williams Creek road,

8.2.2 Additional Watershed-Wide Grave Creek Water Quality and Habitat Restoration Strategies

8.2.2.1 Forest Management Practices

In general, many of the most damaging forestry practices of the past – log drives, in-stream slash disposal, and riparian clear cutting – have been abandoned by the timber industry. In the Grave Creek Watershed, timber sales are planned and laid out by the Kootenai National Forest (KNF). KNF abandoned the practice of riparian clear cutting in 1991 when the Montana Streamside Management Zone (SMZ) law was enacted.

Future management (harvest, road building, fuels treatments, etc.) will be conducted by all landowners acc4ording to Forestry Best Management Practices (BMPs) for Montana (MDNRC, 2002) and the Montana streamside management zone (SMZ) law (MDNRC, 2002a). Additionally, KNF will continue to comply with the Inland Native Fish Strategy (INFS) and Forest Plan standards. This includes road building and maintenance (also discussed below), as well as prescribed burning, forest thinning and timber harvest.

Compliance with the voluntary forestry BMPs, Soil and Water Conservation Practices handbook, and the SMZ law is a strategy to help achieve sediment- and habitat-related water quality goals, including meeting the sediment load allocation by preventing mass wasting, keeping forest management-related sediment from entering streams, and preventing excess fine sediment loading and potential pool filling. The Forest Service is mandated through a Memorandum of Understanding (MOU) with the Water Quality Bureau (now MDEQ) to comply with SWCPs. Compliance will also help with improving habitat conditions by fostering LWD recruitment.

In particular, the Forest Service's mandatory compliance with SMZ law and the KNF Forest Plan Appendix 28 (Riparian Area Guidelines) will help in meeting LWD targets in the upper watershed and will eventually help in meeting pool targets as well. Under both, vegetative buffers strips are required and will help achieve sediment-related water quality goals. The area of disturbance can be reduced through appropriate selection of harvesting systems (i.e., cable logging from roads on steep slopes rather than using tractors) and by reducing the number of roads needed. These also limit the amount of harvest that can occur within certain stream buffer distances. INFS provides additional protective measures for streamside vegetation within the National Forest.

Forestry BMPs are particularly important for achieving sediment-related targets, allocations and the TMDL. In the upper watershed, steep slopes and highly erodible soils have the potential to deliver high sediment loads to streams if bare mineral soil is exposed and inadequate erosion control applied. Since vegetative cover plays a critical role in preventing hillslope erosion, the management strategies address land use practices that have the potential to expose bare mineral soil in critical areas. The plan aims to decrease production and delivery of sediment from erosion-prone hillsides identified as sediment sources. The strategy to prevent or reduce erosion and sediment delivery in these areas is to implement best management practices (BMPs) when conducting forestry, grazing, and other land management activities.

Additional restoration strategies may include a voluntary program that requires that landowners be aware of unstable or erosion-prone areas when conducting activities. If activities in these areas cannot be avoided, appropriate techniques should be used to minimize the extent of the disturbance, apply erosion control practices on disturbed soils.

Where disturbance occurs, forestry BMPs require that erosion be controlled with practices such as grass seeding and straw mulch application. Logging slash (tree limbs, etc.) is often placed on the ground in erosion prone areas to create ground cover and prevent erosion. Lastly, streamside buffers are retained to encourage deposition of any erosion prior to entering streams.

Additionally, tracking progress toward meeting targets and allocations is a high priority. Supplemental indicators such as ECA, water yield, peak flow increases, road density and road density in riparian areas, should be tracked to help evaluate potential water quality impacts (or lack thereof) from timber harvest activities in drainages where harvest occurs. This could be coordinated with tributary monitoring recommendations in Section 9.0. Implementation strategies for other harvest-related source categories like road sediment and culverts are addressed separately below because these impacts are also associated with other land use categories.

8.2.2.2 Riparian Management

As development pressure increases along the banks of Grave Creek, particularly in lower Grave Creek, there is likely to be additional reduction in riparian vegetation and floodplain function if appropriate measures are not taken to prevent such a reduction. This would lead to additional channel instability, more streambank erosion, increased temperatures, and probable increased loading of nutrients and sediment. Impacts from private land development, especially where a structure is located adjacent to or on the bank of a stream can be harder to mitigate once they occur in comparison to many of the impacts associated with logging or other land use practices.

Many of the impacts associated with private land development are associated with roads and stream crossings. These impacts and potential solutions are discussed in the following sub-section (8.2.2.3).

The targets and allocations that apply to private land development tend to focus on riparian health and associated indicators of riparian health. Water quality protection includes avoiding bank erosion from human causes, improving riparian health and increasing canopy density, avoiding the need for riprap and other “stabilization” work, and avoiding placement of structures in the floodplain or close to streambanks. Construction of structures such as houses, barns, roads, and corrals within the zone of historical channel migration is of major concern since this can lead to an eventual need for hard riverbank stabilization to avoid the loss of structures as the river migrates laterally through the floodplain.

To meet the TMDL targets, TMDL allocations, and other restoration objectives and reduce water quality threats, especially as they relate to riparian removal and floodplain or streambank encroachment, the following actions are recommended:

- A comprehensive educational effort needs to be undertaken to stress the importance of riparian protection. Education can focus on grazing management practices, home and structure location consideration, and other factors applicable in the Grave Creek Watershed. The Grave Creek Watershed TAG and the Kootenai River Network, and Fish and Wildlife Service’s Partners Program is currently pursuing this as a high priority effort.
- Additional floodplain and streambank protection regulations should be evaluated and updated to ensure protection of the resource. Stakeholders can work with the Planning Offices of Lincoln County to help develop effective regulations that can be part of the County Growth Plans, Subdivision Regulations, or Floodplain regulations. It is important to note that these types of land use planning and regulatory decisions are made at the local (i.e. county) versus the State level.
- The effectiveness of voluntary versus regulatory measures could be tracked. This would include evaluating the effectiveness of county regulations aimed at protecting riparian and floodplain areas and streambanks. Updated aerial photographs, when available, should be analyzed to provide measures of impact indicators such as canopy cover or structures within a certain distance from a stream. Field assessments can also be performed, with landowner involvement, to further analyze the effectiveness of water quality measures particularly along lower Grave Creek. This information can then be used as a feedback mechanism to measure success and to help identify whether or not an increased focus is needed on regulatory versus voluntary protection measures regarding riparian, floodplain, and/or streambank protection.
- Land use impact indicators should be tracked along with water quality data to ensure that proper statistical analyses are performed to help track impacts. Riparian composition and density is one of the more critical land use indicators to monitor along lower Grave Creek. This should include temperature monitoring as well as consideration of nutrient and sediment loading.

In addition to the above activities, the Lincoln Conservation District will continue to provide oversight and protection of riparian resources and stream health through the 310 law.

8.2.2.3 Road Maintenance, Construction and Stream Crossings

Roads and stream crossing assessments in Grave Creek Watershed need to be completed. KNF has completed partial assessments and removal or upgrades of most culverts in the watershed. KNF has also implemented road BMPs, particularly on the main Grave Creek road. Evaluation of the crossings and roads not assessed should include status of road BMPs and improvement needs, including removal of existing structures and sizing and installation of new structures, improving blading practices, and reconfiguring roadbeds and ditches as necessary to decrease sediment load to streams. Improvement needs should be prioritized and implemented.

Roads

Sediment from roads should be minimized to avoid excess fine sediment problems throughout middle and upper Grave Creek and within tributaries to Grave Creek. While sediment delivery from forest roads is typically highest in the first few years after construction, and declines rapidly thereafter, there are many opportunities for reducing sediment delivery from roads in the Grave Creek Watershed. The plan promotes actions that will improve road conditions. In response, the following is a list of recommendations to help protect water quality and satisfy allocations:

1. The USFS should continue to prioritize sediment contributing road sections and stream crossings for upgrading and sediment load mitigation. For example, the Williams Creek road prism should be further evaluated for additional decommissioning in places where fill encroaches on the floodway/active channel (Section G.5.2.1). Specific locations and methods of sediment reduction will be left up to the judgment of the land managers. This process should be pursued as a coordinated effort so that total road sediment reductions can be tracked in a consistent manner.
2. Assessments should occur for roads within watersheds that have experienced recent timber management operations and recent restoration activities. The information gathered during these assessments will allow timely feedback to land managers about the impact their activities could have on water quality and achievement of TMDL targets and allocations, and to monitor the effectiveness of restoration implementation. This feedback mechanism is intended to keep sediment load calculations current and avoid impacts that go undetected for an extended period.
3. An effort should be made to work with small landowners and county representatives to identify significant sediment contributions from private (non-industrial) and county roads and to help develop methods to mitigate the sediment load. This assistance could also include identification of funding sources for BMP implementation where appropriate.
4. Existing and potential future private landowners should be provided information on how to design roads and mitigate impacts associated with road sediment delivery. This could include support from realtors, USFS, KRN, USFWS and

other landowners planning to subdivide to incorporate this information up front to potential new home owners/builders in the watershed.

5. This plan also encourages the careful design and placement of new roads in subdivisions as well as routine maintenance of all subdivision roads to reduce sediment loading to streams. The goal is to apply the same or similar BMP standards to county and other private roads as are applied to roads built for timber harvest purposes.

Culverts

New or replaced culverts or culverts on upgraded roads throughout the watershed should be sized for a 25, 50 or 100-year flood event. The 25-year event design is consistent with state BMPs, although in areas of high existing culvert density, new culverts should be designed for a 50 to 100-year event instead of a 25-year event. Other design considerations should include avoiding negative impacts to local fish habitat from stream constriction and avoiding floodplain restrictions by using bottomless arches or other appropriate designs. Where appropriate, culverts should also be designed and installed to prevent fish passage restrictions.

The Kootenai National Forest is currently pursuing the above goals for new and upgraded culverts by ensuring passage of a 100-year flood event to meet their native fish protection requirements. The Forest Service is also performing a fish passage inventory for culverts located on fish bearing streams throughout the watershed.

An analysis of existing culverts and the potential for culvert failure should be undertaken in conjunction with ongoing Forest Service efforts. Each crossing could be assigned a priority for restoration based on the risk of failure, the amount of sediment loading from a failure, and the level of disturbance associated with culvert replacement or upgrade.

Detailed on-the-ground assessments would need to be completed as part of the prioritization. The Grave Creek TAG could assist with prioritization and also assist small landowners with resolution to problems on private property, including potential funding assistance via 319 or other water quality grants. Fish passage would also need to be considered as an additional component to the prioritization process. Input from biologists will be critical to determine the relative value of providing fish passage in each situation.

Bridges

Additional information should be gathered to identify locations where bridge crossings are contributing to negative stream impacts, especially sediment loading conditions and localized negative impacts to aquatic life. This study should identify all bridge crossings along with potential impacts, solutions, and cost considerations. A decision can then be made regarding any bridge mitigation projects to pursue.

Other Stream Crossing Considerations

The following are additional requirements and considerations to help mitigate impacts from stream crossings and further protect aquatic life.

- In accordance with State Law, Lincoln Conservation District and Montana Fish, Wildlife and Parks, will continue to work to protect fish and aquatic habitat through 310 and 124 permits.
- A watershed or stakeholder group can help provide technical solutions, when requested, to 310 related issues and concerns.

Fish Passage Barrier Removal

Identifying fish passage barriers on existing roads is an important goal. Currently the Forest Service believes only one stream crossing culvert exists within the potential bull trout spawning area, on Foundation Creek. This culvert should be evaluated for fish passage. Existing laws and standards prohibit the creation of new fish habitat barriers. Exceptions may be made under special circumstances, for example when it is deemed desirable to isolate pure populations of fish.

In-stream Structures

There may be opportunities to improve stream conditions by removing in-stream structures that may be inhibiting stream function. Structures include check dams and gabion structures identified at various locations in tributaries and on the main stem Grave Creek. Caution is advised for any in-stream structure removal since access and channel related work could cause more negative impacts in some areas than the positive impacts.

8.3 Lower Grave Creek-Specific Restoration Strategies

As described in Section 5.0, past and recent investigations on Grave Creek indicate the main stem is impaired for sediment and aquatic habitat, particularly in lower Grave Creek. Indicators of impairment include reduced pool cover, reduced LWD, and an overly wide stream. Restoration projects currently underway on lower Grave Creek are addressing these aquatic habitat limitations.

8.3.1 Completed and Planned Lower Grave Creek Water Quality and Habitat Restoration Strategies

Numerous restoration activities have been implemented in the Grave Creek Watershed to improve water quality, channel stability, fish passage, riparian conditions, and minimize fish entrapment and the effects of water uses on flow alterations. A majority of the efforts have been sponsored by the Kootenai River Network and completed on private lands in the lower agricultural reaches of the watershed. The Kootenai National Forest has completed numerous projects over the past several years on national forest system lands, a majority of which consisted of BMP upgrades, culvert removals, and road closures. Many of these projects are identified in Section 8.2 above. Project summaries for work in lower Grave Creek are provided in the following sub-sections.

Glen Lake Irrigation District Dam Removal

In 2000, MFWP in conjunction with the USFWS, USFS, and KRN implemented a dam removal, ditch screening, and fish passage restoration project on Grave Creek at the Glen Lake Irrigation District's (GLID) point of diversion on the main stem Grave Creek. The project involved removal of a failing wooden dam that impeded upstream migration of adult bull trout and other species during low flow conditions. Following dam removal, the channel was reconstructed to restore migratory habitat for the target fish species.

A secondary project component included installation of static plate fish screen to prevent loss of young of year (Y-O-Y) and juvenile bull trout to the irrigation ditch network. This involved installation of water control structures (e.g. Waterman headgates) to more accurately and efficiently control the rate of water diversion into the canal. A safety measure was also installed to ensure fish passage during periods when the channel would be dry because of excessive irrigation withdrawals. Since implementation, the bull trout redds enumerated for the major tributaries in the watershed have increased significantly. While the positive response is partially attributed to improved fish passage capabilities at the GLID site, other basin management strategies implemented by Bonneville Power Administration, the USFWS, and MFWP likely contributed to the increased numbers.

Demonstration Channel and Fish Habitat Restoration Project

The Grave Creek Demonstration Project reconstructed approximately 840 feet of stream channel using natural channel design techniques. The project effectively stabilized a large eroding terrace and significantly improved migratory bull trout habitat through creation of deep, complex pool habitat. Post-project implementation monitoring conducted by MFWP in 2002 indicated that total pool length increased by 18.6 percent, and both mean and maximum pool depths by 38.8 and 53.5 percent, respectively. Large woody debris stems and rootwads incorporated in bank stabilization structures also increased available cover for rearing and migrating salmonids, including federally threatened bull trout, within the project area (MFWP, unpublished data).

Riparian Fencing Project

A portion of the north side of lower Grave Creek was fenced with assistance from the NRCS Wildlife Habitat Incentives Program (WHIP). Approximately 5,900 feet of fencing was completed in the fall of 1999. This coincided with fencing on the south side of Grave Creek, assisted by USFWS during the spring of 2000.

The purpose of fencing was to provide management of riparian grazing along Grave Creek. Prior to completion of fencing, livestock had uncontrolled access to the riparian area and creek. The USFWS commissioned a Range Management Specialist from British Columbia during 2002 to work with the landowners in developing a grazing management plan for the ranch. Timing and suitable levels of grazing for the riparian area were identified in the grazing plan. Grazing is now conducted using grazing guidelines, which focus on indicator grass species. Stubble height is used to determine whether riparian grazing is effective and used at an appropriate level. Woody species are also monitored to determine if grazing has an adverse effect on the riparian community.

Phase 1 Restoration Project

Grave Creek Phase 1 was implemented during fall 2002 and included complete reconstruction of approximately 4,300 feet of channel. Prior to construction, this section of Grave Creek was characterized by a braided condition with multiple channels and degraded fish habitat due primarily to channel widening because of riparian modifications within the floodway of Grave Creek. The primary goal of the project was to increase the quality and quantity of available pool habitat for migratory adult bull trout. MFWP conducted pre construction and as-built surveys in 2000 and 2002 to document changes in pool habitat characteristics. The pre-construction channel was over-widened and shallow with bankfull widths ranging from 45-240 feet, and a mean width to depth ratio of 93.5. The designed channel reduced the mean bankfull width and width to depth ratio to 52 feet and 22, respectively. Post-construction project monitoring indicated an almost nine fold increase in the total number of pools present in the restored section of Grave Creek (3 to 26), increasing critical pool habitat for adult migratory bull trout by 230% relative to baseline conditions. Maximum pool depths were increased by 152% from pre-restoration conditions (MFWP 2003, Lake Koocanusa and Kootenai River Basin Bull Trout Monitoring Report). Construction techniques were based in natural channel design philosophy and included re-establishing the proper plan form, cross-sectional and longitudinal profile dimensions. This project also included installation of fish screen to preclude loss of fish to an irrigation canal.

Phase 1 Riparian Grazing Management Plan

In November 2002, the KRN completed a grazing management WQHRP for a ranch located within the Grave Creek Phase 1 project area. The WQHRP provided an annual grazing strategy for the ranch operation and considered the short term and long-term requirements of the cowherd, the land, and Grave Creek. The WQHRP provided an approach to grazing management that ensured the continued vitality of the ranch operation and the viability of riparian restorations efforts along Grave Creek. This project included 5,550 feet of riparian fencing. The partners for Fish and Wildlife program and Natural Resources Conservation Service assisted with costs for materials and the landowner contributed labor. Since construction, the landowner has continued to fence other sections of Grave Creek and has set up temporary fencing to prevent cattle from relocating downstream along the banks. Offsite watering capabilities have also been incorporated as part of the grazing management improvements.

Phase 2 Restoration Project

In September and October 2004, Phase 2 of the Grave Creek Restoration Project was implemented. Approximately 3,500 feet of channel restoration was completed. As part of this project, an aggressive revegetation effort will be implemented in Spring 2005 to begin the process of restoring the historical structure and composition of the riparian corridor.

Installation of Center Pivot Irrigation System

Water conservation strategies in the lower watershed are being addressed. In addition to the upgrades at the GLID point of diversion, the NRCS in cooperation with the USFWS and a landowner have converted 60 acres of pasture from flood irrigation to sprinkler irrigation through the installation of a center pivot system. This project reduced the withdrawal from Grave Creek by 1 CFS.

8.3.2 Additional Lower Grave Creek Restoration Strategies

Additional water quality strategies for lower Grave Creek focus on reducing width-to-depth ratios, increasing sinuosity, keeping percent fines low, increasing pool frequency, maintaining a diverse macroinvertebrate community, and maintaining adequate in-stream flows. In addition, restoration strategies will also concentrate on increasing the meander length ratio and increasing large woody debris frequency.

Recommendations for improving habitat conditions in lower Grave Creek include passive and active restoration techniques applied at site-specific locations and at the reach scale. A number of potential treatments have been identified. To varying degrees, these treatments can be applied to meet the goals of the WQHRP. Treatments include: 1) addressing dewatering, 2) site revegetation (floodplains, rip-rap slopes, streambanks), 3) bank stabilization through natural channel design techniques, 4) channel reconstruction, 5) meander reactivation, 6) fish habitat improvement, and 7) grazing management. In addition, the watershed-wide strategies described in Section 8.2.2 which are applicable to lower Grave Creek include: forest and riparian management practices, addressing roads maintenance, construction and stream crossing problems, and additional fish habitat improvement.

In-stream Flows

Flow alteration is a major concern in lower Grave Creek. To further investigate the effects of flow alterations on habitat availability during various flow regimes, a wetted perimeter study is recommended as part of the WQHRP to determine how improvements to stream morphology can reduce flow requirements to support aquatic life. The wetted perimeter method (WPM) is a fixed flow hydraulic rating method based on the hydraulic relationship between flow (i.e. discharge) and wetted river perimeter at selected transects (Stalnaker et al., 1994). Using the relationship, the flow corresponding to the wetted perimeter, which is needed to minimally protect all habitats, can be estimated. Additional data should be collected to help evaluate impacts from dewatering.

One of the use support objectives (Section 5.2) addresses the lack of flow during summer in the lower part of Grave Creek. The goal of this objective is to increase flow to Grave Creek to provide improved habitat for aquatic life. This can be particularly important in this stream since Grave Creek serves as a migration corridor for spawning bull trout.

Although increased flows would improve aquatic life and cold-water fish use support in Grave Creek, any attempts to satisfy this goal must be in recognition of Montana Law regarding TMDL development and water quality planning where it is stated: "Nothing in this part may be construed to divest, impair, or diminish any water right recognized pursuant to Title 85. (Montana Water Quality Act §§75-5-705)." BMPs to conserve irrigation water in conjunction with water leasing agreements are two possible means to help attain this goal.

Revegetation

For lower Grave Creek, the predominant stream type potential is characterized by a slightly entrenched, meandering, gravel-dominated riffle-pool 'C' channel type with a well-developed, vegetated floodplain. These stream types are typically found in glacial valleys characterized by glacial and Holocene terraces. This type of channel is sinuous, with bank stability related to dense rooting of shrubs and a riparian forest overstory dominated by black cottonwood and western cedar. These channel types, as observed within the project area, are prone to increased bank erosion and sediment delivery when the vegetation is disturbed or the channel modified. Therefore, revegetation and protection of existing or new vegetation is a significant restoration goal along lower Grave Creek.

Stream banks supporting mature, native vegetation are among the most stable reaches on Grave Creek. These banks also provide for sustained large woody debris recruitment. Laterally eroding banks may make a one-time contribution of LWD, but after banks erode there is decreasing floodplain area to support a riparian area. Vegetation that does establish never has the chance to mature before it is also contributed (as small material) to the widening channel.

Revegetation treatments offer the most passive method to establishing long-term channel stability, riparian succession, and habitat diversity. Revegetation is also an essential component to active channel restoration. Active channel restoration must include revegetation treatments along with riparian management BMPS, otherwise risk of failure is unacceptably high. The primary advantage of riparian plantings is that installation can be accomplished with minimum impact to the stream channel, existing vegetation, and private property. In addition to providing shade (and possible reduced water temperature) and cover for aquatic species, riparian plantings can develop root masses that penetrate deep into the soils, increasing bank resilience to erosion. Other advantages include cost effectiveness and the range of applications offered by new revegetation technologies.

The most significant disadvantage to vegetative treatments is that results are not immediate and time is required to establish a mature gallery (i.e. multi-storied) forest that provides the benefits described previously. As such, revegetation is not an appropriate treatment for areas that are subject to high shear stress, perched too high relative to the water table (i.e. aggraded), or vulnerable to grazing impacts. The most appropriate applications for revegetation on Grave Creek are floodplains, streambanks, and the adjacent floodway riparian zone. Revegetation treatments would coincide with channel shaping and channel reconstruction techniques further described in this section. In several locations, revegetation is not an option due to the high degree of channel instability. In these locations, it will be necessary to establish the proper channel dimensions to ensure the plan form pattern is maintained for a sufficient period to allow the plants to mature.

Bank Stabilization

Bank stabilization using natural channel design techniques can provide both bank stability and habitat potential. The primary recommended structures are large woody debris jams. These natural arrays can be constructed to emulate historical debris assemblages that were introduced to the channel by the adjacent cottonwood dominated riparian community types. When used in concert, woody debris jams and straight log vanes can benefit the stream and fishery by improving bank stability, reducing bank erosion rates, adding protection to fill slopes and/or embankments, reducing near-bank shear stress, and enhancing aquatic habitat and lateral channel margin complexity.

The use of riprap or other “hard” approaches is not recommended, is not consistent with water quality protection or implementation of this plan, and is specifically not consistent with meeting any load allocation applied to the land use activity linked to the riprap usage. In fact, riprap or similar usage, unless absolutely required, will be considered an increase to sediment loading in the system via increased downstream erosion and increased bed scour.

Stream Channel Shaping / Reconstruction

Channel shaping and reconstruction would be focused in areas of extreme channel braiding. Treatments would include floodway revegetation and bank stabilization as described in the preceding sub-sections. A majority of the excessive bedload present in the main stem lower Grave Creek is derived from bank and terrace erosion. Effective channel restoration along segments of Grave Creek, working from upstream to downstream, will reduce these sources to a degree where the channel can maintain equilibrium with the flow and sediment produced in the watershed. Channel reconstruction involves the realignment of the channel bed along with channel shaping, bank stabilization, and revegetation. Based on initial results from the Phase I

Restoration Project, active channel reconstruction appears to be the most optimal method to restore the river to its potential condition in several reaches of lower Grave Creek. With channel reconstruction, it is possible to restore the potential meander pattern of a river and adjust the bed elevation so that the floodplain and active channel are hydrologically reconnected. Channel reconstruction would include reconstructing a stable, single-threaded primary channel sized to accommodate the estimated bankfull series, and partially filling existing braided channels to floodplain elevation. Portions of the braided channel area would be maintained as backwater refuge for fish and wetland development. Fill material would be extensively revegetated with native plants. As stated previously, active channel restoration must include revegetation treatments along with riparian management BMPS, otherwise risk of failure is unacceptably high.

Perhaps one of the most beneficial advantages associated with reconstructing braided channel segments to single-threaded systems would be a reduction in the rate of lateral channel migration. Other advantages with complete channel reconstruction include improved sediment transport competency, complex and diverse aquatic habitat creation, an increase in floodway capacity and flood relief, and long-term bank stability.

Meander Reactivation

One objective of the Plan was to identify areas of potential meander reactivation. Preliminary examination suggests there are numerous opportunities to reactivate disconnected meanders. Depending on the condition of riparian vegetation and ability to reconnect the historical floodplain to the active channel, the cost to reactivate meanders could be substantially less than total channel reconstruction.

Fish Habitat Improvement

Fish habitat improvement would be incorporated in all restoration applications. However, there are segments along the main stem that are functioning at their physical potential, but are not at their biological and overall water quality potential and thus could benefit from added fish habitat complexity to increase biological complexity. These stream segments are located from Fortine Creek upstream approximately one mile. Possible fish passage barriers should be evaluated and appropriate treatment defined and implemented. Addressing revegetation will likely reduce stream temperatures and thus improve fish habitat. Similarly, channel shaping and reconstruction will increase sediment transport capacity, and increase pool frequency, which will also improve fish habitat.

Grazing Management

Development of riparian grazing management plans is a goal for landowners in the watershed who do not currently have such plans. Private land owners may be assisted by state, county federal and local conservation groups to establish and implement appropriate grazing management plans. Note that riparian grazing management does not necessary eliminate all grazing in these areas. Nevertheless, in some areas, a more restrictive management strategy may be necessary for a period in order to accelerate re-establishment of a riparian community with the most desirable species composition and structure.

SECTION 9.0
WATER QUALITY AND FISH HABITAT MONITORING PLAN

Monitoring is an important component of watershed restoration, a requirement of TMDL development, and the foundation of the adaptive management approach. This monitoring plan for the Grave Creek Watershed is a multi-strategy effort designed to address specific TMDL goals such as attainment of restoration targets and load allocations. Participation of a number of planning partners including a variety of state and federal agencies, stakeholders, and additional parties provides a key element to this plan that increases its value by providing a multi-disciplinary approach and valuable local knowledge.

The principles of adaptive management provide a foundation for the monitoring plan presented here. A well-designed monitoring plan facilitates the adaptive approach by providing feedback on the effectiveness of restoration activities, the relative contributions of sediment from various sources, and feasibility of attaining targets. Within this adaptive framework, monitoring results provide the technical justification to modify restoration strategies, numeric targets, or load allocations when appropriate. Similarly, lessons learned from monitoring results may be applied in various watersheds to facilitate diverse watershed planning efforts.

To assess overall progress toward meeting the restoration targets identified in Section 5.0, this monitoring plan includes examination of a combination of physical stream conditions (both channel and riparian) and biological community measures. The monitoring strategy is focused on implementation monitoring including some additional assessment and watershed characterization activities to help facilitate implementation. Implementation monitoring is required to assess the effectiveness of specific future restoration activities, to assess whether compliance with water quality standards has been obtained by evaluating progress toward meeting restoration targets, and to assist with any adaptive management decisions as needed. Implementation monitoring to assess progress toward meeting restoration targets is required by TMDL rules (§§75-5-703(7) & (9)), and is also an integral component of the implicit margin of safety incorporated in the sediment TMDLs (Section 7.0).

Implementation monitoring focused on compliance with TMDL targets will be done at least once every five years as defined by the TMDL regulations, with additional monitoring performed as needed to ensure timely evaluation of completed restoration activities. MDEQ is responsible for the implementation monitoring focused on tracking TMDL and water quality restoration progress, although other entities may perform significant aspects of the monitoring and it is expected that the overall effort will be closely coordinated with the Kootenai National Forest and Kootenai River Network.

In many cases, more sampling may be desirable to better measure progress. Because some target development is based on local reference conditions, monitoring may also need to include measurements in reference streams to ensure an appropriate baseline comparison condition. Changing watershed conditions in reference streams could justify modification to target or supplemental indicator values. Significant environmental factors such as drought, floods, or fires can affect both reference and impaired stream conditions throughout a watershed, and may be important factors in determining target achievability. This is particularly true for the McNeil Core and other fine sediment sampling where yearly sampling on many streams helps establish overall watershed trends and can help evaluate relative impacts from natural events.

9.1 Monitoring of TMDL Targets

As defined by Montana State Law (§§75-5-703(7) & (9)), MDEQ is required to evaluate progress toward meeting TMDL goals and satisfying water quality standards associated with beneficial use support at least every five years. Implementation monitoring is, therefore, necessary to assess progress toward meeting the targets developed in Section 5.0. Where targets are not being met, additional implementation monitoring may be necessary. This additional implementation monitoring may evaluate the status of supplemental indicators and the progress toward meeting allocations, and could result in modifications to the targets as part of adaptive management. Implementation monitoring is also an integral component of the implicit margin of safety incorporated in the TMDLs developed in this restoration plan. Although MDEQ is responsible for aspects of implementation monitoring, other agencies and entities often perform significant aspects of the monitoring.

Table 9-1 identifies monitoring and assessment recommendations for all Grave Creek stream reaches. The table also includes recommendations for inclusion of tributary monitoring as a preferred option where resources are available. This additional tributary information can be critical for future determinations regarding fish habitat potential for middle and upper Grave Creek reaches in addition to important tributaries to Grave Creek. The focus of Table 9-1 is on targets and some of the supplemental indicators such as LWD and bull trout redds. The goal is to obtain samples or perform monitoring in representative locations as well as locations where potential impairment conditions would most likely exist. All monitoring efforts are to be done using standard MDEQ sampling and analyses protocols where applicable or sampling and analyses protocols approved by MDEQ. Based on further stakeholder input and MDEQ approval, some of the Table 9-1 details such as monitoring locations or methodologies may be modified. The monitoring is applied to all Grave Creek segments and tributaries with focus on those targets or reference values that were not met or were lacking in data (Sections 5.3 and 5.4). For this reason, any monitoring focused on percent fines type sampling may be significantly reduced based on MDEQ direction since there was a general lack of impairment indications linked to percent fines in the watershed above GLID.

MDEQ efforts to evaluate progress toward meeting TMDL goals and satisfying water quality standards does not need to always include incorporate monitoring of all target and indicators. In some situations, the MDEQ may determine that not enough progress or opportunity for stream recovery has been made to warrant evaluations of all targets and/or indicators. For example, it may not be necessary or desirable to evaluate sinuosity and meander length ratio in lower Grave Creek if the stream is still overly wide and lacking fish habitat along significant lengths.

On the other hand, some parameters were lacking baseline values and it may be desirable to obtain data for these parameters prior to the five year evaluation. These include macroinvertebrate sample results throughout many areas of the watershed and percent fines values in some reaches of lower Grave Creek. Also, as noted in Section 5.4.3, it may be desirable to obtain routine data for pool frequency, residual pool depth, and LWD linkages to help develop and incorporate trend information and expand on applicable fish habitat knowledge. These monitoring recommendations are incorporated into Section 9.4 below.

Table 9-1: Monitoring Locations and Parameters to Help Evaluate Target Compliance and Beneficial Use Support.

Waterbody	Parameter (s)	Desired Location(s)	Sample Method	Sample Period
Grave Creek and tributaries	Pools frequency	Same as for 2002/03 and other recent assessment work or agreed upon representative sampling of stream reaches. Incorporate any linkages to LWD.	R1/R4 Methods used for recent assessment work or equivalent; consider using multiple methods for comparison to reference reach data sets	Low flow
Grave Creek and tributaries	Macroinvertebrate assemblages	Two to four representative riffle locations in lower, middle and upper Grave Creek main stem and in tributary reaches. . Focus additional sampling in areas of higher percent surface fines in riffles	Standard MDEQ protocol	Low flow, summer to early fall; between June 21 to September 21 per existing MDEQ protocol
Grave Creek and tributaries	Percent substrate fines[1]	Existing sample locations used by Fish Wildlife and Parks; additional locations in upper Grave above Lewis Creek and in tributaries in locations of bull trout and/or cutthroat trout spawning, pebble count Type II Target surrogates may be acceptable alternative	Existing McNeil Core procedure used by Fish Wildlife and Parks	Low flow
Grave Creek and tributaries	Percent surface fines[1]	Representative riffle and/or pool tail locations in Grave Creek main stem and tributaries with focus on areas where data is desirable to supplement a lack of McNeil Core sample data	Wolman Pebble Count Method	Low flow
Grave Creek and tributaries	Percent surface fines[1]	Representative pool tailout locations in Grave Creek main stem and tributaries with focus on areas where data is desirable to supplement a lack of McNeil Core sample data	R1/R4 Methods used for 2003 assessment work (49-point grid-toss)	Low flow

Table 9-1: Monitoring Locations and Parameters to Help Evaluate Target Compliance and Beneficial Use Support.

Waterbody	Parameter (s)	Desired Location(s)	Sample Method	Sample Period
Grave Creek and tributaries	Width-to-depth	Lower Grave Creek C Reaches; representative reaches in upper Grave or tributaries as needed to assist with overall stream health evaluations	Rosgen Level III Survey Methods;	Low flow
Grave Creek	Residual Pool Depth; Possibly Pool Length or other measures	Same as for 2002/03 assessments work or agreed upon representative sampling of stream reaches	R1/R4 Methods or equivalent	Low flow
Grave Creek (lower)	Sinuosity	Lower Grave Creek C Reaches	Rosgen Level III Survey Methods or photo interpretation	NA
Grave Creek (lower)	Meander Length Ratio	Lower Grave Creek C Reaches	Rosgen Level III Survey Methods or photo interpretation	NA
Grave Creek and tributaries	Large Woody Debris	Same as for 2002/03 assessments work or agreed upon representative sampling of stream reaches	R1/R4 Methods or equivalent	Low flow
Grave Creek and tributaries	Bull trout redd counts	Continuation of ongoing FWP effort and locations; additional tributaries if appropriate	Existing procedure used by Fish Wildlife and Parks	Late summer to early fall

1 -Monitoring for these percent fines type indicators may be significantly reduced based on MDEQ direction since there was a general lack of impairment indications linked to percent fines in the watershed above GLID.

9.2 Monitoring of TMDL Allocations and Supplemental Indicators Linked to Land Use

As discussed above, implementation monitoring can include assessment of both target compliance and efforts to successfully pursue activities that would reflect progress toward achieving allocations. This monitoring may focus on:

- Forest and private roads and implementation of BMPs;
- Riparian health along the lower main stem and BMP implementation;
- Recovery of riparian areas in the upper watershed and recovery of mass wasting sites or identification of any new mass wasting sites;
- The effectiveness of BMPs and a range of water quality protection activities associated with future harvest or forest management activities;
- Land use or land modification data such as potentially significant changes in ECA (from timber harvest and natural events), peak flow, and/or road density; and
- Bank erosion loading determinations or other measurement approaches along lower Grave Creek.

These types of monitoring activities should be done in cooperation with landowners including private landowners and Kootenai National Forest representatives.

9.3 Project Effectiveness Monitoring

An additional type of monitoring involves efforts to assess the effectiveness of specific restoration or water quality improvement activities. All water quality projects should have some form of monitoring to assess overall effectiveness. In some situations, the monitoring can provide feedback for future projects or feedback on maintenance requirements. This monitoring can take on many forms, and can be as simple as before and after photos.

As describe in Section 8.0, many restoration activities have been or are scheduled to occur in the Grave Creek Watershed. These activities should be monitored for implementation and effectiveness. Monitoring of channel restoration projects on lower Grave Creek main stem should be conducted using some of the same methods as used previously by Montana Fish, Wildlife and Parks for the Phase I Restoration Project (Section 8.3.1). Other restoration activities to be monitored include: active channel restoration, passive restoration (natural recovery), revegetation, new irrigation pivot systems, irrigation diversions, and riparian and grazing management plan effectiveness. Monitoring results should be used to refine future restoration activities and to guide adaptive management of ongoing land-uses and attainment of water quality improvement goals.

9.4 Additional Monitoring and Assessment

During this TMDL and water quality and habitat restoration improvement planning efforts, a number of supplemental monitoring activities emerged as priorities. These priorities include efforts to track progress toward satisfying the use support objectives of minimum flow and fish passage not otherwise addressed by the TMDL target monitoring discussed above. These and other monitoring recommendations are listed below.

- Evaluation of the flow regime and dewatering in lower Grave Creek is a high priority. The role of channel over-widening, aggradation, and irrigation withdrawal in influencing maintenance of surface flows should be evaluated.
- Culverts and other potential fish passage barriers should continue to be evaluated for passage capabilities as is currently being assessed by the Kootenai National Forest. New culvert and crossing installations or replacements should be conducted with fish passage in mind. Culvert size and slope should allow for fish passage. The fish passage limitation on Foundation Creek should be assessed for impacts to fish habitat utilization.
- A better understanding of fish communities and fish habitat use would provide greater insight into beneficial use support requirements in the watershed and could help focus target compliance monitoring Fisheries investigations may include population estimates, redd counts, and fish movements through the basin. Fisheries

evaluations can assist in assessing the effectiveness of restoration activities as part of an adaptive approach.

- As identified in Section 9.2 above, predicted water yield and peak flows should be tracked in drainages with significant harvest. Also, a method to identify and track harvest in sensitive areas could be useful for identifying potential impacts, including evaluation of potential mass wasting, success of all forestry BMPs, and various management practices aimed at water quality protection.
- It would be useful to track the transport rate of large woody debris. In particular, this could help determine the residence time of LWD from natural sources such as avalanches versus from logging activities. Research has shown that large woody debris in harvested watersheds consists of typically shorter logs (logging remnants) that are more mobile at lower flows. Woody debris in wilderness watersheds was observed to consist of generally longer more fully intact wood that is more stable at lower flows and only mobile at higher flows. Increased mobility translated to reduced residence time, and therefore less stable pools. In addition, pool volume associated with smaller, sawed off wood was reduced. Residence time of large woody debris in wilderness/non-harvested watersheds was much greater than in harvested watersheds and resulted in large, more frequent, and more stable pools (Ferree, 1999).
- Efforts in other TMDL areas are underway to link pebble count results to McNeil core data. Additional pebble counts and possibly additional grid toss data should be pursued in conjunction with McNeil core sampling to help with this overall effort since pebble count data and grid toss results can apply as Type II targets to indicate potential spawning impacts where McNeil Core data is lacking.
- Temperature data, using a similar method as reported in Appendix G, should be collected in lower Grave Creek to supplement existing limited data.
- Cross section benchmarks could be added to help evaluate overall stream stability over time.
- Additional investigation of reaches with width to depth ratios below indicator values (Table 5-11) could be pursued to evaluate potential instabilities. Rosgen A reaches with high width to depth values could also be evaluated for instability.

In addition to the above recommendations, additional analysis of existing data from the Grave Creek Watershed and/or data from reference streams may be desirable. Also, future monitoring could include monitoring of reference streams for some of the parameters in Table 9-1 to improve reference range values and possibly update target values using data from comparable periods.

SECTION 10.0
PUBLIC AND STAKEHOLDER INVOLVEMENT

Public and stakeholder involvement is a component of water quality restoration planning and TMDL development. This involvement is supported by EPA guidelines, the Federal Clean Water Act and Montana State Law. Public and stakeholder involvement is desirable to ensure development of high quality, feasible plans and increase public acceptance. Stakeholders, including the Kootenai River Network (KRN), the Kootenai National Forest, the U.S. Fish and Wildlife Service, and the Natural Resource Conservations Service were involved with initial project planning and grant application for the development of this document. As noted in Section 1.0, development of this plan was facilitated via the KRN. The KRN is a cooperative international partnership of individuals, diverse citizen groups, and agencies dedicated to the utilization, restoration, promotion, and protection of water resources in the Kootenai-Kootenay River watershed. The KRN has been and will continue to encourage ongoing involvement by the public and stakeholders in the implementation of water quality protection activities in the Grave Creek Watershed, including implementation of this Grave Creek Water Quality and Habitat Restoration Plan and Sediment TMDL.

During document development, the above stakeholders, along with the Montana Department of Environmental Quality (MDEQ), the Montana Fish Wildlife and Parks and the Lincoln County Conservation District (CD), met several times to discuss and provide comments on the draft document strategy, outline and technical components. Also during document development, the KRN and the Lincoln County CD facilitated a public meeting on June 8, 2004, in Fortine, Montana. Topics covered by this public meeting included Grave Creek water quality and TMDL plan development as well as upcoming water quality and TMDL plan development for the Tobacco River Watershed.

A stakeholder review draft was subsequently provided to the above-identified stakeholders for review. This review also included additional internal peer reviews by MDEQ management and a MDEQ water quality standards representative. Significant stakeholder comments were provided and addressed, and during development of the final public review draft, several stakeholders were consulted in their areas of expertise on specific sections of the document. Also, a stakeholder meeting was held to discuss various aspects of the document and related comments.

An important opportunity for public involvement was the 30-day public comment period. This public review period was initiated on November 24, 2004 and extended to December 20, 2004. A public meeting on December 7th in Fortine, Montana provided an overview of the Water Quality Protection Plan and TMDLs for the Grave Creek Watershed and an opportunity to solicit public input and comments on the plan. This meeting and the opportunity to provide public comment on the draft document were advertised via a press release by MDEQ. This press release went to a local radio station and several local and state newspapers. Also, local landowners were contacted by the KRN to facilitate public comment and meeting attendance.

Through the public comment process, significant comment was received by 9 different individuals, groups, agencies, or other entities. Appendix K includes a summary of the public comments received and the MDEQ response to these comments. As noted in the introduction of Appendix K, many of the comments led to significant modifications captured within the final version of the this plan.

MDEQ also provides an opportunity for public comment during the biennial review of the 303(d) list. This includes public meetings and opportunities to submit comments either electronically or through traditional mail. MDEQ announces the public comment opportunities through several media including press releases and the Internet.

SECTION 11.0 REFERENCES CITED

Andrews, E. D., and J. M. Nankervis. 1995. Effective Discharge and the Design of Channel Maintenance Flows for Gravel-Bed Rivers. In: J. E. Costa; A. J. Miller; K. W. Potter; and P. R. Wilcock (editors), Natural and Anthropogenic Influences in Fluvial Geomorphology, Geophysical Monograph 89, Amer. Geophysical Union, p. 151-164.

Ayres, H. B. 1899. The Flathead Forest Reserve. USGS Twentieth Annual Report, Part V – Forest Reserves. US Government Printing Office, Washington, D.C.

Baxter, C. V., and F. R. Hauer. 2000. Geomorphology, Hyporheic Exchange, and Selection of Spawning Habitat by Bull Trout (Salvelinus confluentus). Can. J. Fish. Aquat. Sci., 57: 1470-1481.

Baxter, J. S., and W. T. Westover. 1999. Wigwam River Bull Trout - Habitat Conservation Trust Fund Progress Report (1998). Fisheries Project Report KO 54, viii + 21 p. + 1 Appendix.

Baxter, J. S., and W. T. Westover. 2000. An Overview of the Wigwam River Program (1995-1999). Habitat Conservation Trust Fund Progress Report Final Report. Fisheries Project Report KO58.

Bohn, Bryce A. 1998. US Forest Service, Unpublished Report. Watershed Analysis as a Strategy to Determine Aquatic Restoration Priorities: An Example on the Grave Creek Watershed in Northwest Montana. U.S. Forest Service, Fortine Ranger District, Kootenai National Forest. May 1998.

Bohn, Bryce A., and J. L. Kershner. 2002. Establishing Aquatic Restoration Priorities Using a Watershed Approach. J. of Env. Management (2002) 64, 355-363.

Bonde, J. H. 1987. The Libby Dam/Lake Koocanusa Project. Prepared for the U.S. Army Corps of Engineers, Seattle District. Shapiro and Assoc. Seattle, WA.

CEIC, 2002. Montana Department of Commerce. 2000. Census 2000 data. http://ceic.commerce.state.mt.us/Census2000.html.

Chisholm, I.; M. E. Hensler; B. Hansen; D. Skaar. 1989. Quantification of Libby Reservoir Levels Needed to Maintain or Enhance Reservoir Fisheries-Summary Report. Montana Department of Fish, Wildlife and Parks. Project Number 83-467. Libby, Montana.

Coffin, D. L.; A. Brietkrietz; and R. G. McMurtrey. 1971. Surficial Geology and Water Resources of the Tobacco and Upper Stillwater River Valleys, Northwestern Montana. Montana College of Mineral Science and Technology. Butte, Montana. 48 pp.

Daley, R. J.; E. C. Karmach; C. B. J. Gray; C. H. Pharo; S. Jasper; and R. C. Wiegand. 1981. The Effects of Upstream Impoundments on the Limnology of Kootenay Lake, B.C. Scientific Service No. 117. National Water Research Institute, Inland Waters Directorate. Vancouver, British Columbia. 96 pp.

Dunham, J.; B. Rieman; and G. Chandler. 2003. Influences of Temperature and Environmental Variables on the Distribution of Bull Trout within Streams at the Southern Margin of its Range. North American Journal of Fisheries Management 23:894-904.

Dunne, Thomas; William E. Dietrich; Neil F. Humphrey; and Donald W. Tubbs. 1980. Geologic and Geomorphic Implications for Gravel Supply. Conference Held: October 6-7 1980. A renewable Resource in the Pacific Northwest. Seattle, Washington.

Elliot, W. J.; D. E. Hall; and D. L. Scheele. 1999. WEPP: Road WEPP Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery. Technical Documentation. http://forest.moscowfsl.wsu/fswepp/docs/wepproaddoc.html.

Elliot, W. J.; D. E. Hall; and D. L. Scheele. 2000. WEPP: Road WEPP Interface for Disturbed Forest and Range Runoff, Erosion and Sediment Delivery. Technical Documentation. http://forest.moscowfsl.wsu.edu/fswepp/docs/distweppdoc.html.

Ferree, Johathan D. 1999. Geomorphic Change Over a Twenty-Year Interval in Harvested and Unharvested Watershed of the Oregon Coast Range. Master's Thesis, University of Wyoming, ppxx.

Ferreira, R. F.; D. B. Adams; R. E. Davis. 1992. Development of Thermal Models for Hungry Horse Reservoir and Lake Koocanusa, Northwestern Montana and British Columbia. U.S. Geological Survey, Water-Resources Investigations Report 91-4134.

Flanagan, D. C.; and S. J. Livingston. 1995. WEPP User Summary. NSERL Report 11, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, IN.

General Land Office Map Dated March 16, 1896.

Harrison, J. E.; E. R. Cressman; J. W. Whipple. 1992. Geologic and Structure Maps of the Kalispell 1º x 2º quadrangle, Montana and Alberta and British Columbia. U.S. Department of the Interior, Geological Survey, Miscellaneous Investigations Series. Map I-2267.

Hauer, R.; J. T. Gangemi; and J. Stanford. 1997. Long-Term Influence of Libby Dam Operation 139 on the Ecology of Macrozoobenthos of the Kootenai River, Montana and Idaho. Flathead Lake Biological Station. Yellow Bay, MT; Prepared for Montana Fish, Wildlife and Parks. Helena, MT. 61 pp.

Hensel, D. R., and R. M. Hirsch. 1995. Statistical Methods in Water Resources. Studies in Environmental Science 49. Elsevier Science Publishers B.V., Amsterdam, The Netherlands.

Jakober, M. J.; T. E. McMahon; R. F. Thurow; and C. G. Clancy. 1997. Role of Stream Ice on Fall and Winter Movements and Habitat use by Bull Trout and Cutthroat Trout in Montana Headwater Streams. Transactions of the American Fisheries Society 127: 223-235.

Johnson, O. 1950. The Story of The Tobacco Plains Country. The Caxton Printers, LTD. Caidwell, Idaho.

King, John G. 1989. Streamflow Responses to Road Building and Harvesting: a Comparison With Equivalent Clearcut Area Procedure. USDA Forest Service, Intermountain Research Station, Research Paper INT-401.

Knudson, K. 1994. Water Quality Status Report: Kootenay (Kootenai) River Basin British Columbia, Montana and Idaho. Kootenai River Network. Libby, MT. and Ecological Resource Consulting, Helena, MT. 57 pp.

Kondolf, G. M. 2000. Assessing Salmonid Spawning Gravel Quality. Transactions of the American Fisheries Society 129:262-281.

Kramer, R. P.; B. W. Riggers; and K. Furrow. 1993. Basinwide Methodolgoy. Stream Habitat Inventory Methodology, Lolo National Forest.

Leopold, L. 1994. A View of the River. Harvard University Press.

Leopold, L. B.; M. G. Wolman, and J. P. Miller. 1964. Fluvial Processes in Geomorphology. Freeman, San Francisco, CA. 522 pp.

Limerinos, J. T. 1970. Determination of Manning Coefficient from Measured Bed Roughness in Natural Channels, Water Supply Paper 1898b, U.S. Geological Survey.

Marotz, B. and J. Fraley. 1986. Instream Flows Needed for Successful Migration, Spawning, and Rearing of Rainbow and Westslope Cutthroat Trout in Selected Tributaries of the Kootenai River. Final Report FY 1986. Prepared for the Bonneville Power Administration. Portland, Oregon.

Montana Bull Trout Scientific Group (MBTSG). 1996a. Lower Kootenai River Drainage Bull Trout Status Report (below Kootenai Falls). Prepared for The Montana Bull Trout Restoration Group. Helena, MT.

Montana Bull Trout Scientific Group (MBTSG). 1996b. Upper Kootenai River Drainage Bull Trout Status Report (including Lake Koocanusa, Upstream of Libby Dam). Prepared for The Montana Bull Trout Restoration Group. Helena, MT.

Montana Bull Trout Scientific Group (MBTSG). 1998. The Relationship Between Land Management Activities and Habitat Requirements of Bull Trout. Unpublished Report. Prepared for the Montana Bull Trout Restoration Team, Montana Department of Fish, Wildlife and Parks, Helena, Montana. 78 pp.

Montana Department of Environmental Quality (MDEQ). 1999. Requirements for Non-Point Sources of Pollution Impacting High-Quality and Impaired Waters. MDEQ Internal Guidance. Helena, MT.

Montana Department of Environmental Quality (MDEQ). 2001. Circular WQB-7 Montana Water Quality Standards. http://www.deq.state.mt.us/wqinfo/Circulars/WQB-7.pdf.

Montana Department of Environmental Quality (MDEQ). 2002. Total Maximum Daily Loads Schedule. http://www.deq.state.mt.us/wqinfo/TMDL/TMDLSched2003real.pdf.

Montana Department of Environmental Quality (MDEQ). 2002a. Appendix A: Water Quality Assessment Process and Methods. 39 pp. http://www.deq.state.mt.us/wqinfo/datamgmt/PDF/Sufficient CredibleData.pdf.

Montana Department of Environmental Quality (MDEQ). 2004. State of Montana 303(d) Water Quality Impairment List 2004. http://nris.state.mt.us/wis/environet/2004Home.html.

Montana Department of Environmental Quality (MDEQ). 2004a. Circular WQB-7: Montana Water Quality Standards. Helena, MT.

Montana Department of Environmental Quality (MDEQ). 2004b. Blackfoot Headwaters Planning Area Water Quality and Habitat Restoration Plan and TMDL for Sediment. 134 pp.

Montana Department of Environmental Quality (MDEQ). 2004c. Sufficient Credible Data/Beneficial Use Determination (SCD/BUD) Documentation for the Grave Creek. DEQ Files. DEQ, Helena, MT.

Montana Department of Environmental Quality (MDEQ). 2004d. Swan River Planning Area Water Quality and Habitat Restoration Plan and TMDL for Sediment.

Montana Department of Environmental Quality (MDEQ). 2004e. Wadeable Streams of Montana's Hi-Line Region: An Analysis of Their Nature and Condition, with an Emphasis on Factors Affecting A.

Montana Department of Natural Resources and Conservation (MDNRC). 2002. Best Management Practices (BMPs) for Forestry in Montana. Missoula, Montana.

Montana Department of Natural Resources and Conservation (MDNRC). 2002a. Streamside Management Zone Law (Montana Code Annotated Section 7-5-300). http://data.opi.state.mt.us/bills/mca_toc/77_5_3.htm. Missoula, Montana.

Montana Fish, Wildlife & Parks (MFWP). 1985. Stream Fishery Data Report.

Montana Fish, Wildlife & Parks (MFWP). 2003. Lake Koocanusa and Kootenai River Basin Bull Trout Monitoring Report. DJ Report No Element SBAS Project No. 3140.

Montana Fish, Wildlife & Parks (MFWP). 2003a. Mitigation for the Construction and Operation of Libby Dam Annual Report 2001-2002.

Montana Natural Heritage Program. 2003. Animal Species of Special Concern. January 2003. http://nhp.nris.state.mt.us/animal/index.html.

Montana State University. 2001. Water Quality BMPs (Best Management Practices) for Montana Forests. Publication #EB 158. 58 pp.

Montgomery, D. R., and J. M. Buffington. 1993. Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition, Washington State Department of Natural Resources Report TFW-SH10-93-002, 86p.

Montgomery, D. R., and J. M. Buffington. 1997. Channel-Reach Morphology in Mountain Drainage Basins. Geological Society of America Bulletin, 109(5), 596-611.

Oliver, G. 1979. A Final Report on the Present Fisheries of the Wigwam River with Emphasis on the Migratory Life History and Spawning Behavior of Dolly Varden charr *Salvalinus malma* (Walbaum). Fisheries Investigations in Tributaries of the Canadian portion of Libby Reservoir. British Columbia Fish and Wildlife Branch, Victoria, BC.

Omang, R. J. 1992. Analysis of the Magnitude and Frequency of Floods and the Peak Flow Gaging Network in Montana. U.S. Geological Survey Water Resources Investigations Report 92-4048. Helena, MT.

Pfankuch, D. J. 1975. Stream Inventory and Channel Stability Evaluation: A Watershed Management Procedure. USDA-FS. Northern Region. R1-75-002. Government Printing Office, Washington, D.C.

Plum Creek Timber Company. 2000. Native Fish Habitat Conservation Plan. http://www.plumcreek.com/environment/fish.cfm.

Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. Gen. Tech. Rep. INT-GTR-346. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. Ogden, UT.

Rieman, B. E., and J. D. McIntyre. 1993. Demographic and Habitat Requirements for Conservation of Bull Trout. U.S. Forest Service, Intermountain Research Station. General Technical Report INT-302.

Rosgen, David 2001. Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II - 9-15, March 25-29, 2001, Reno, NV.

Rosgen, David. 1994. A Classification of Natural Rivers. Catena, 22, 169-199.

Rosgen, David. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

Rosgen, David. and L. Silvey, 1998, Field Guide for Stream Classification, Wildlife Hydrology Books, Pagosa Springs, CO.

Selong, J. H.; T. E. McMahon; A. V. Zale; and F. T. Barrows. 2001. Effect of Temperature on Growth and Survival of Bull Trout, with Application of an Improved Method for Determining Thermal Tolerance for Fishes. Transactions of the American Fisheries Society 130:1026–1037.

Stalnaker C. B.; B. L. Lamb; J. Henriksen; K. D. Bovee; J. Bartholow. 1994. The Instream Flow Incremental Methodology: a primer for IFIM. National Ecology Research Center, Internal Publication. National Biological Survey. Fort Collins, Colorado, U.S.A. 99 pp.

State of Montana. 2003. Montana Water Quality Act. Montana Code Annotated 2003. Title 75 Environmental Protection. Chapter 5 Water Quality. Part 3 Classification and Standards. http://data.opi.state.mt.us/bills/mca_toc/75_5_3.htm.

State of Montana. 2003a. Montana Total Maximum Daily Load Laws and Rules. Montana Code Annotated 2003. Title 75 Environmental Protection. Chapter 5 Water Quality. Part 1 General Provisions (75-5-101 MCA) and Part 7 Water Quality Assessment (75-5-701 MCA). http://www.deq.state.mt.us/wqinfo/TMDL/lawsRules.asp.

Suttle, Kenwyn B.; Mary E. Power; Jonathan M. Levine; and Camille McNeely. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. Ecological Applications. 14(4) 2004. pp. 969-974. Ecological Society of America.

Troendle, C. A., and W. K. Olsen. 1994. Potential Effects of Timber Harvest and Water Management on Streamflow Dynamics and Sediment Transport. In: Sustainable Ecological Systems Proceedings, United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, GTR RM-247, 34-41.

Troendle, C. A.; M. S. Wilcox; G. S. Bevenger; and L. S. Porth. 2001. The Coon Creek Water Yield Augmentation Project: Implementation of Timber Harvesting Technology to Increase Streamflow. Forest Ecology and Management 143:179–187.

U.S Fish and Wildlife Service (USFWS). 2002. Criteria Established for the Lake Koocanusa Core Area are Currently Being Met by the Grave Creek and Wigwam River Bull Trout Spawning Populations.

U.S. Army Corps of Engineers (USACOE). 1974. Final Environmental Impact Statement: Libby Dam Additional Units and Reregulating Dam. U.S. Army Corps of Engineers. Seattle, WA.

U.S. Environmental Protection Agency (USEPA). 1999. Protocol for Developing Sediment TMDLs. First Edition. Office of Water, 4503 F, Washington DC 20460. EPA 841-B-99-004.

U.S. Environmental Protection Agency (USEPA). 2000. Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II. EPA - 822-B-00-015. 120 pp.

U.S. Environmental Protection Agency (USEPA). 2004. Water Quality Assessment and TMDLs for the Flathead River Headwaters Planning Area, Montana, Public Review Draft. Helena, MT. Relyea et al. Personal Communication as Cited by EPA.

U.S. Fish and Wildlife Service (USFWS). 1998. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout. Federal Register 63:31647-31674.

U.S. Fish and Wildlife Service (USFWS). 2002a. Proposed Designation of Critical Habitat for the Klamath and Columbia River Distinct Population Segments of Bull Trout, Portland, Oregon.

U.S. Forest Service (USFS). 1974. Multiple Use Plan, Eureka-Grave Creek Planning Unit. Kootenai National Forest, Fortine Ranger District, Fortine, MT.

U.S. Forest Service (USFS). 1975. Stream Reach Inventory and Channel Stability Evaluation. R1-75-002. Government Printing Office #696-260/200, Washington, D.C. 26pp.

U.S. Forest Service (USFS). 1987. Kootenai National Forest Plan Volume 1. Kootenai National Forest.

U.S. Forest Service (USFS). 1991. WATSED Water & Sediment Yields. USDA Forest Service Region 1 and Montana Cumulative Watershed Effects Cooperative. Missoula, MT.

U.S. Forest Service (USFS). 1995. Inland Native Fish Strategy Environmental Assessment. Decision Notice and Finding of No Significant Impact. Intermountian, Northern and Pacific Regions.

U.S. Forest Service (USFS). 1995a. Soil Survey of Kootenai National Forest Area, Montana and Idaho. In cooperation with the Montana Agricultural Experiment Station. 122 pp. with Maps.

U.S. Forest Service (USFS). 1996. Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins. GTR PNW-GTR-382.

U.S. Forest Service (USFS). 1998. Unpublished Report. Riggers, B.W. A.Rosquist, R. Kramer, M. Bills. An Analysis of Fish Habitat and Population Conditions in Developed and Undeveloped Watersheds on the Lolo National Forest.

U.S. Forest Service (USFS). 1999. Vegetation Response Unit Characterizatoins and Target Landscape Prescriptions. Kootenai National Forest. Libby, MT.

U.S. Forest Service (USFS). 1999a. A Grave Creek Restoration Project Decision Memo. Kootenai NF 8p.

U.S. Forest Service (USFS). 2000. Section 7 Consultation Watershed Baseline: Lower Kootenai River, Montana. Prepared by Kootenai National Forest. 34 pp.

U.S. Forest Service (USFS). 2001. Unpublished Data Provided by Pat Price, Rexford Ranger District of the Kootenai National Forest.

U.S. Forest Service (USFS). 2002 Grave Creek Watershed: Summary of Findings from the Ecosystem Analysis at the Watershed Scale (EAWS). Lincoln County, Montana.

U.S. Forest Service (USFS). 2003. Unpublished Data Provided by Pat Price, Rexford Ranger District of the Kootenai National Forest.

U.S. Forest Service (USFS). 2004. Unpublished Data Provided by Steve Wegner, Libby Ranger District of the Kootenai National Forest.

Washington Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis. Version 4.0. Washington State Department of Natural Resources, Olympia, Washington.

Water Consulting, Inc. 2000. Conceptual Designs for Stabilization of Grave Creek near Eureka, Montana. Prepared for the Kootenai River Network, Libby, MT.

Watson, Greg; Steve Toth; Brian Sugden; Paul Wetherbee; Ron Steiner; Matt O'Connor; John Woods; Dean Sirucek; Liz Hill; Carol Purchase; and Paul Callahan. 1998. Goat Creek and Piper Creek Watershed Analysis. Plumb Creek Timber Co., Missoula MT.

Weaver, T. M., and J. J. Fraley. 1991. Fisheries Habitat and Fish Populations. Flathead Basin Forest Practices, Water Quality and Fisheries Cooperative Program. Flathead Basin Commission, Kalispell, Montana.

Weaver, T. M., and J. J. Fraley. 1993. A Method to Measure Emergence Success of Westslope Cutthroat Trout Fry From Varying Substrate Compositions in a Natural Stream Channel. North American Journal of Fisheries Management 13:817-822.

PHOTOS

List of Photos

Photo 1: Clarence Creek – Riparian Harvest

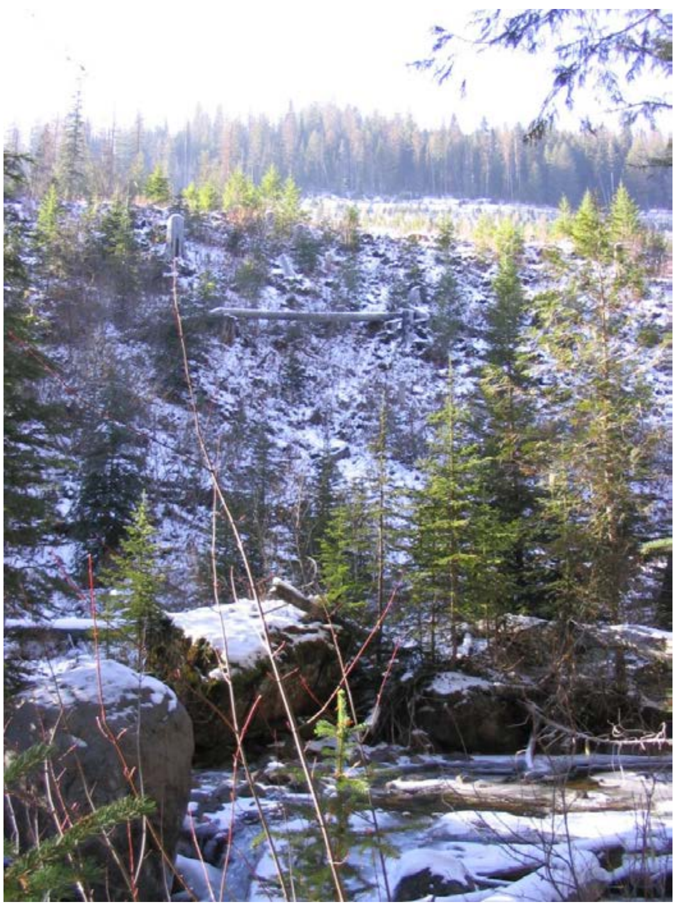


Photo 2: Stahl Creek - Riparian Harvest with No Buffer


Photo 3: Main Stem Middle - Cut logs In-Stream - Marginal Habitat


Photo 4: Main Stem Upper - Typical Avalanche Chute

Photo 5: Lewis - Typical Natural Avalanche Chute

Photo 6: Main Stem Upper - Road Fill Road Encroachment

Photo 7: Main Stem Upper - Bank Erosion

Photo 8: Stahl Creek - Riparian Harvest with No Buffer and with Mass Wasting

Photo 9: Blue Sky - Riparian Modification and Mass Wasting

Photo 10: Williams - Road Encroachment and Riparian Harvest with Mass Wasting

Photo 11: Main Stem Upper - Example of In-Stream LWD Removal

Photo 12: Main Stem Lower Below Canyon - Bank Erosion and Evidence of Aggradation

Photo 13: Main Stem Lower Above Canyon – Evidence of Aggradation

Photo 14: Main Stem Upper - Typical Reach Condition

Photo 15: Main Stem Upper – Mid-Channel Bar, Evidence of Possible Aggradation

Photo 16: Main Stem Upper - Check Dam

Photo 17: Main Stem Upper - Gabion for Fill Slope Protection

Photo 18: Main Stem Upper - Avalanche Slide - Woody Debris Contribution

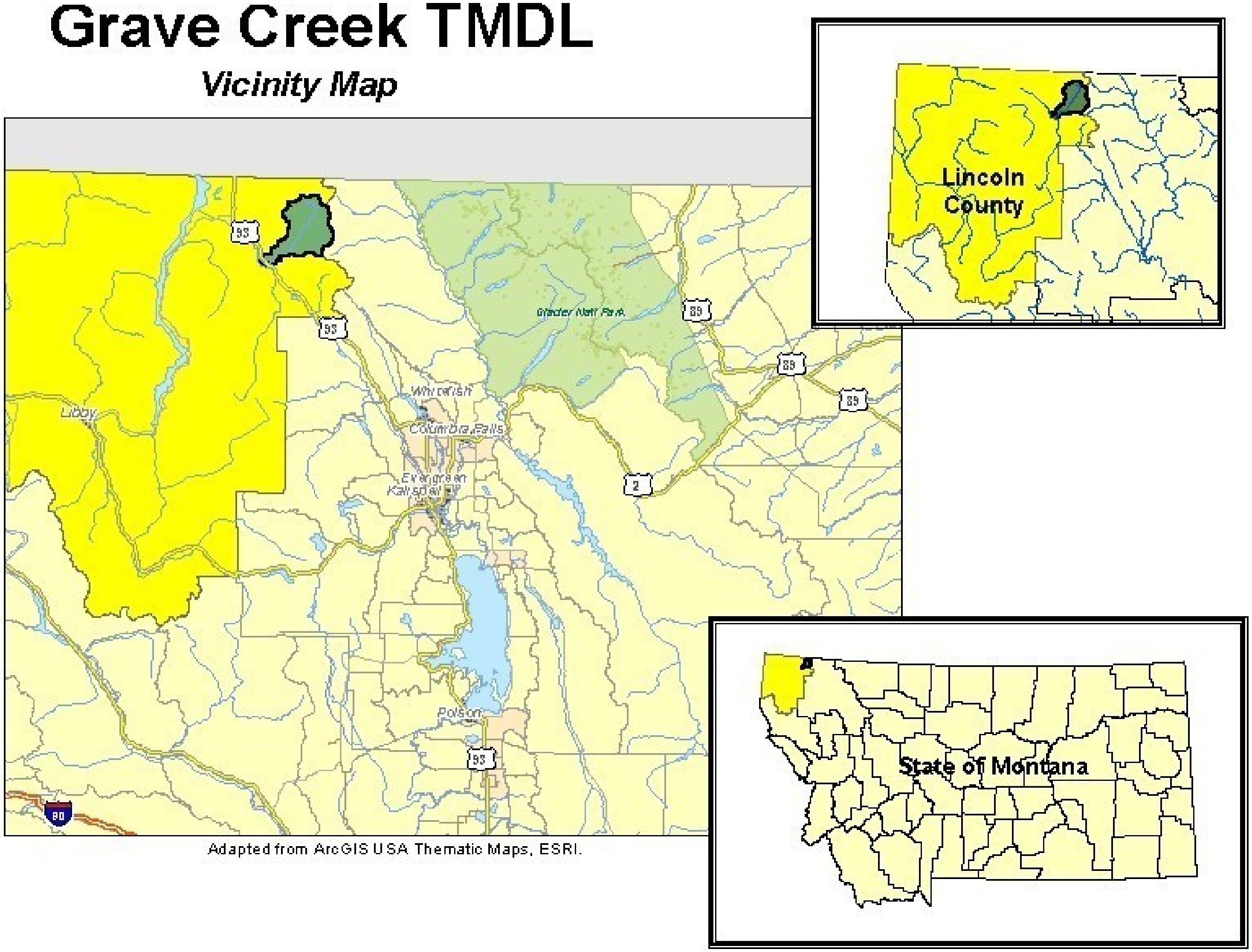
Photo 19: Main Stem Lower Below Canyon – Terrace Erosion

Photo 20: Main Stem Lower - Bank Armoring

Photo 21: Fish Passage Barrier on Foundation Creek

MAPS

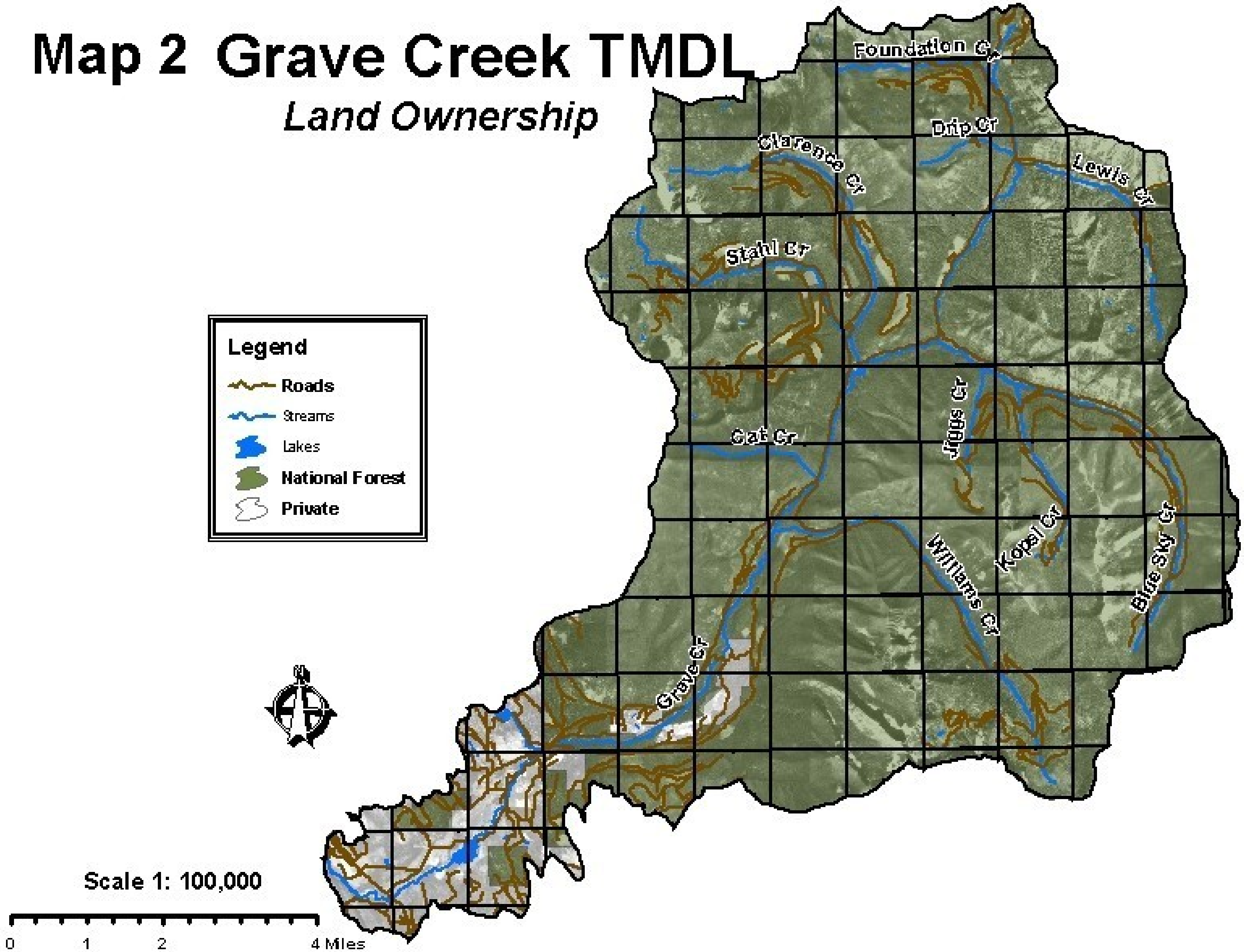
Map 1
Grave Creek TMDL
Vicinity Map



Adapted from ArcGIS USA Thematic Maps, ESRI.

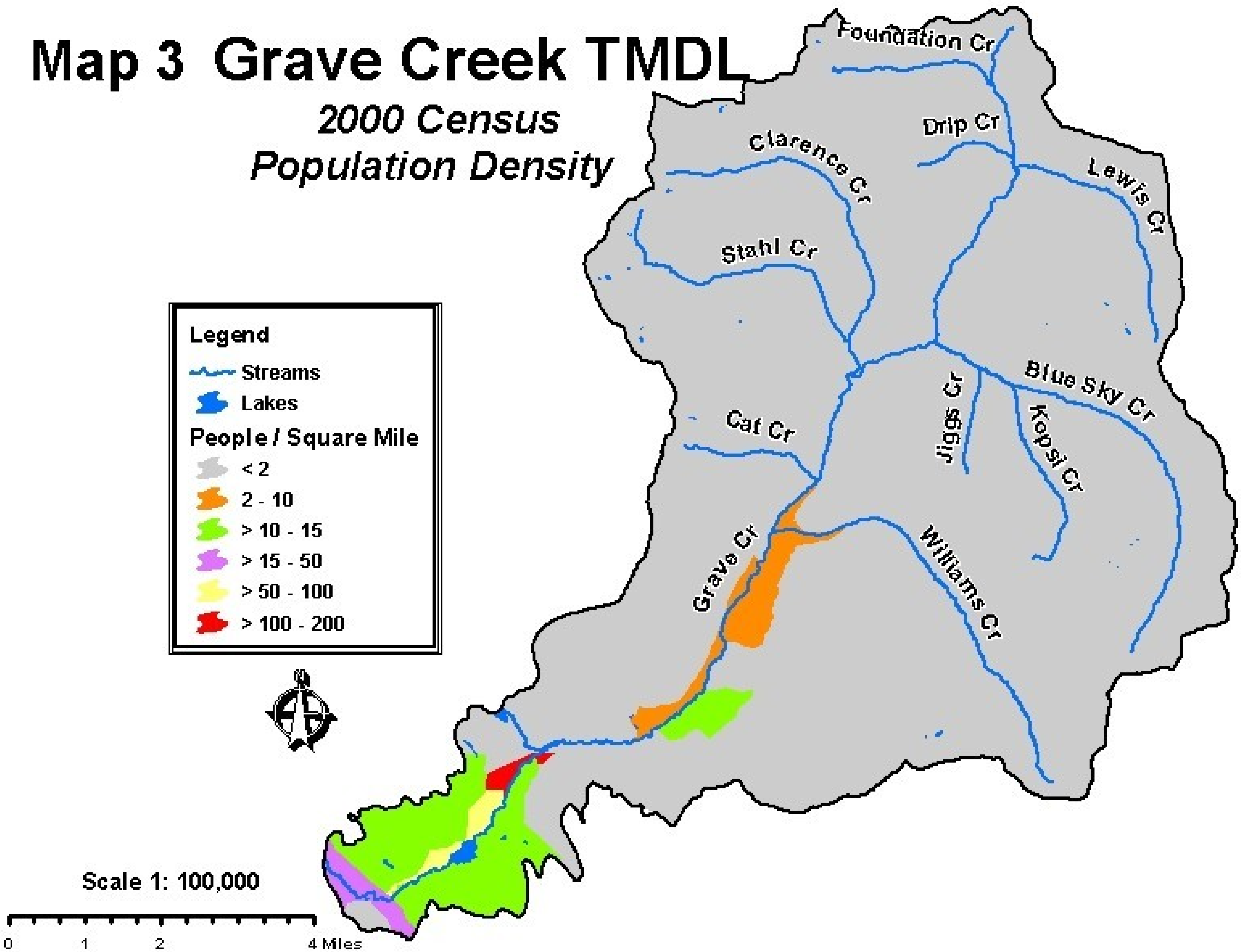
Map 2 Grave Creek TMDL

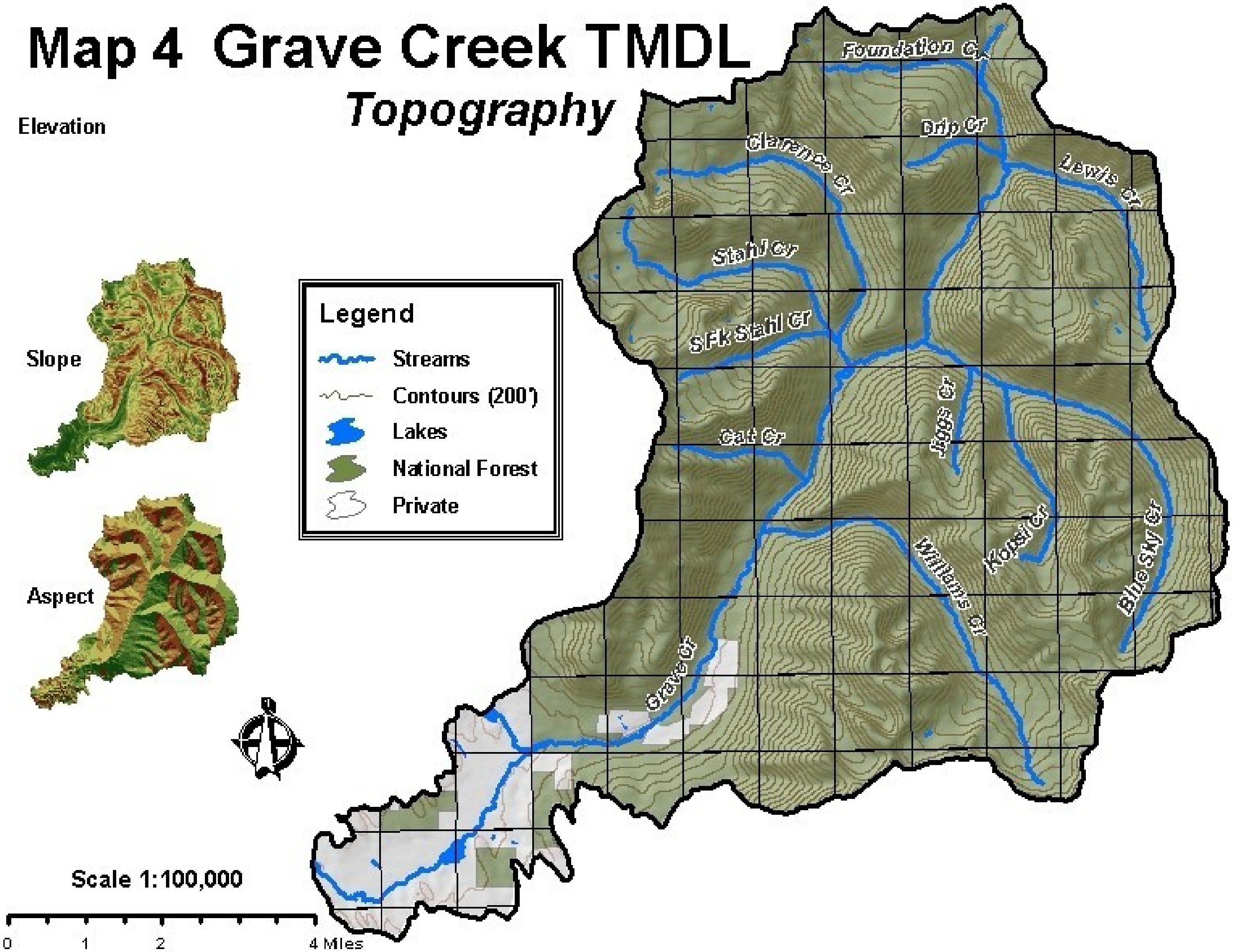
Land Ownership

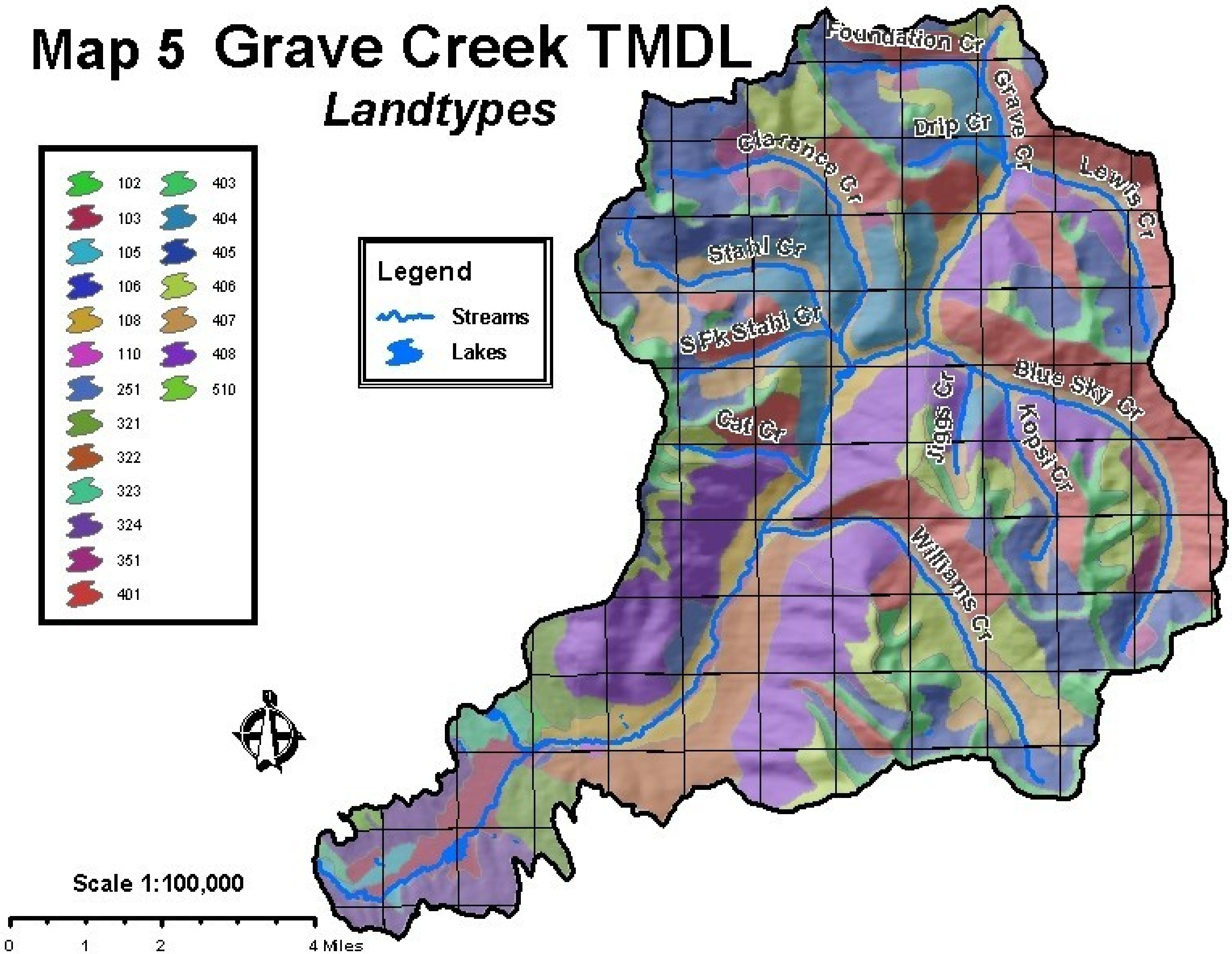


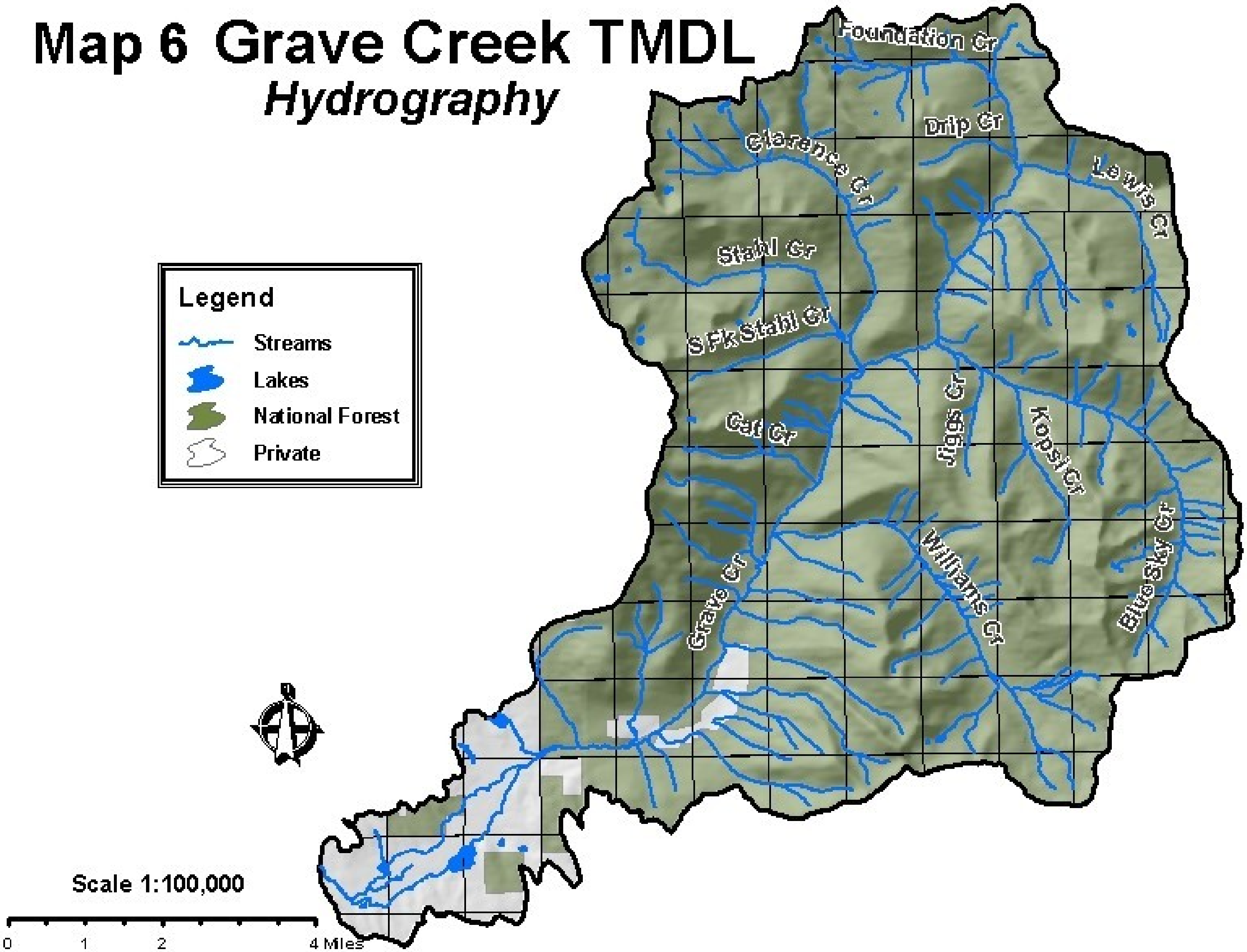
Map 3 Grave Creek TMDL

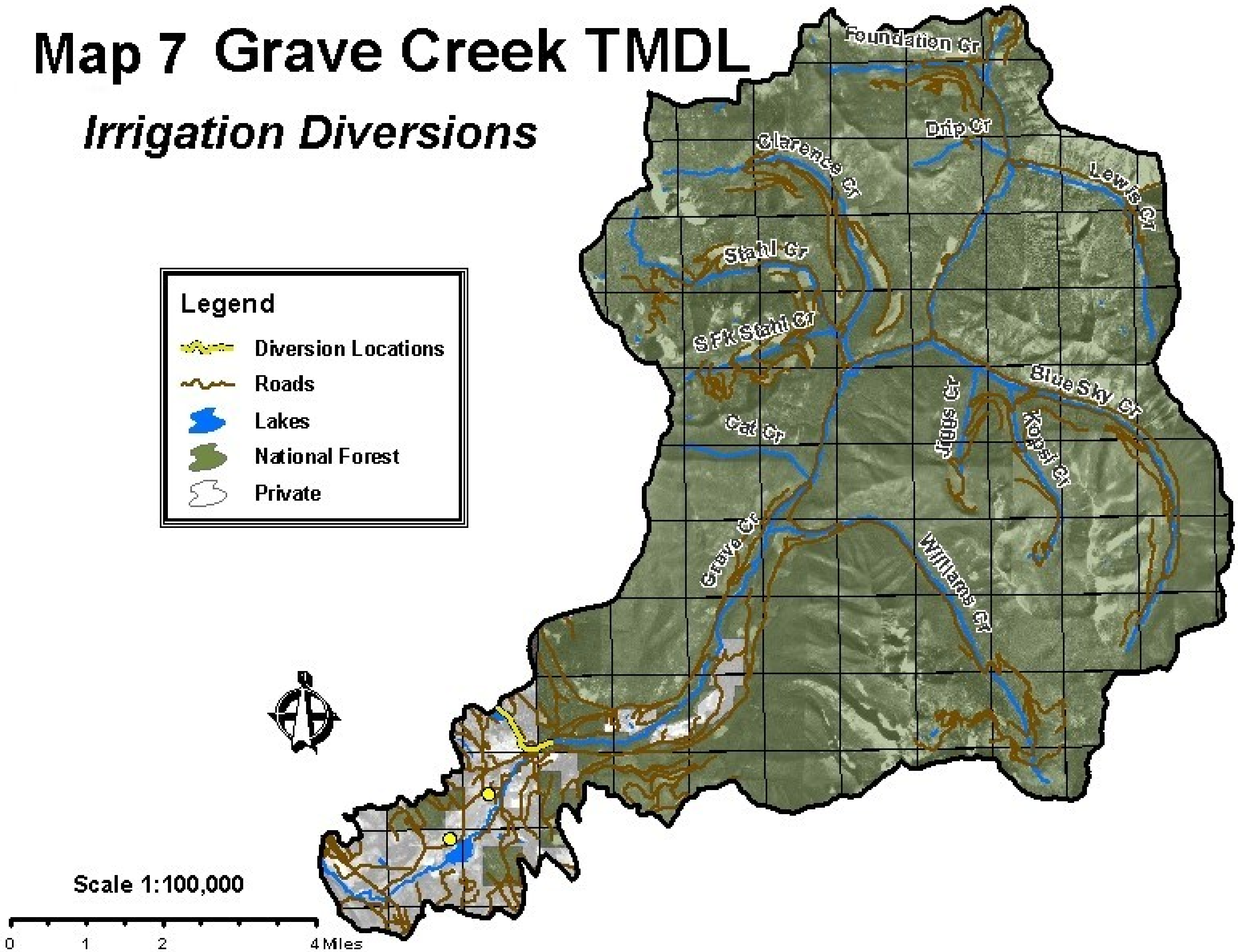
2000 Census
Population Density

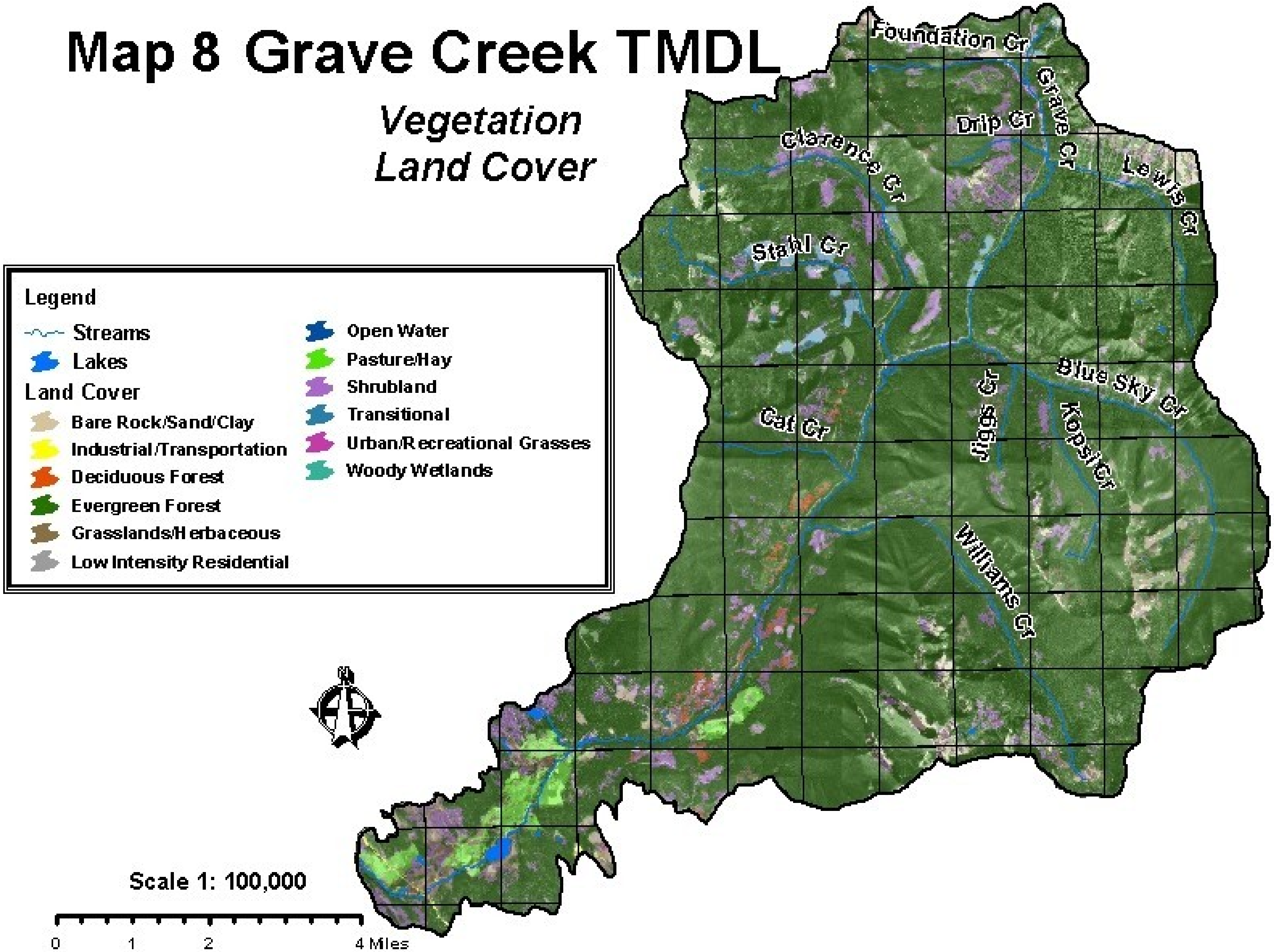


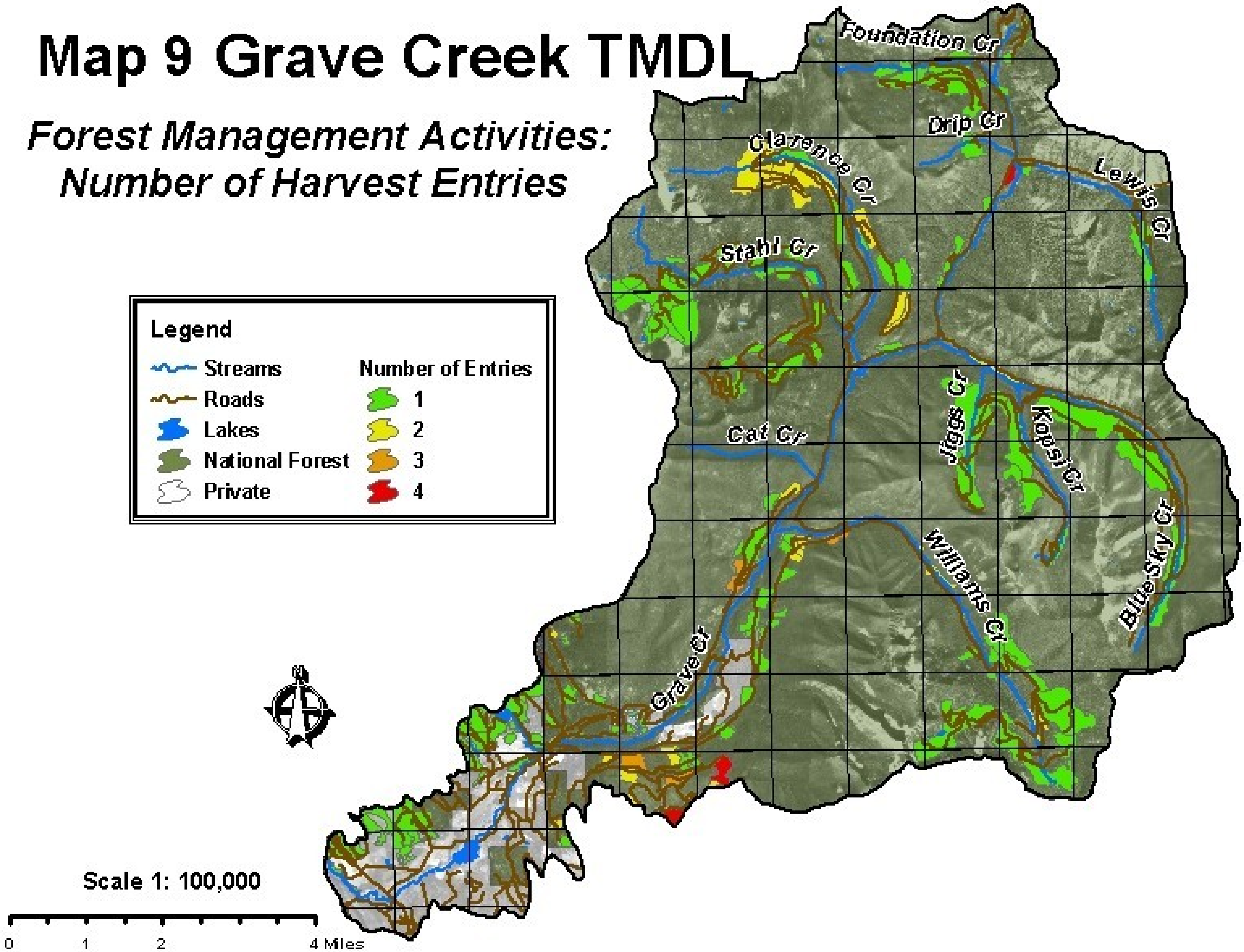

Map 4 Grave Creek TMDL
Topography
Elevation
Slope
Aspect
Legend
Streams
Contours (200')
Lakes
National Forest
Private
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Williams Cr
Blue Sky Cr
Grave Cr
Scale 1:100,000
0
1
2
4 Miles


Map 5 Grave Creek TMDL
Landtypes
102
103
105
106
108
110
251
321
322
323
324
351
401
403
404
405
406
407
408
510
Legend
Streams
Lakes
Foundation Cr
Grave Cr
Drip Cr
Clarance Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Blue Sky Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Williams Cr
Scale 1:100,000
0
1
2
4 Miles


Map 6 Grave Creek TMDL
Hydrography
Legend
Streams
Lakes
National Forest
Private
Scale 1:100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Williams Cr
Grave Cr
Blue Sky Cr

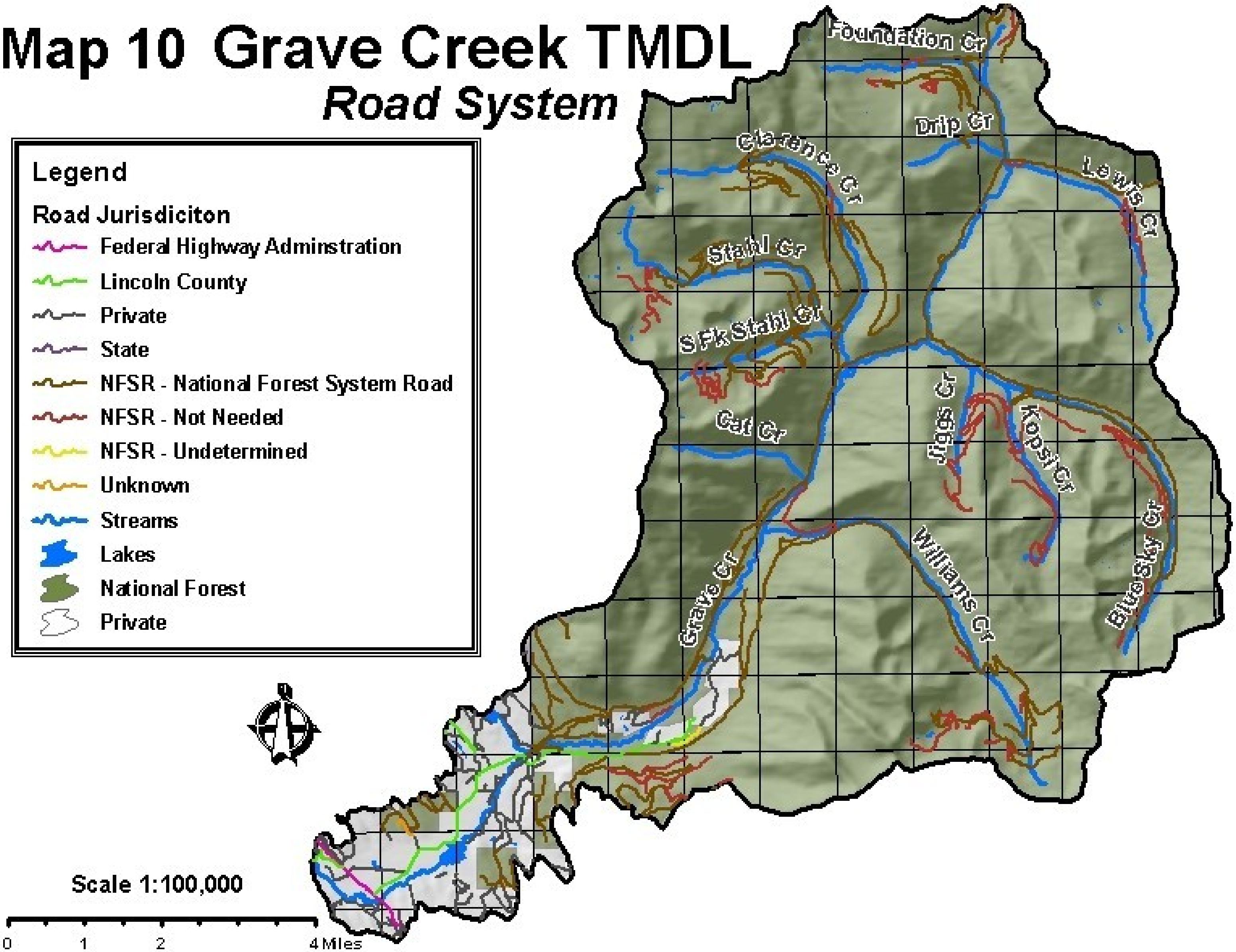

Map 7 Grave Creek TMDL
Irrigation Diversions
Legend
Diversion Locations
Roads
Lakes
National Forest
Private
Scale 1:100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Blue Sky Cr
Kopsi Cr
Cat Cr
Grave Cr
Williams Cr

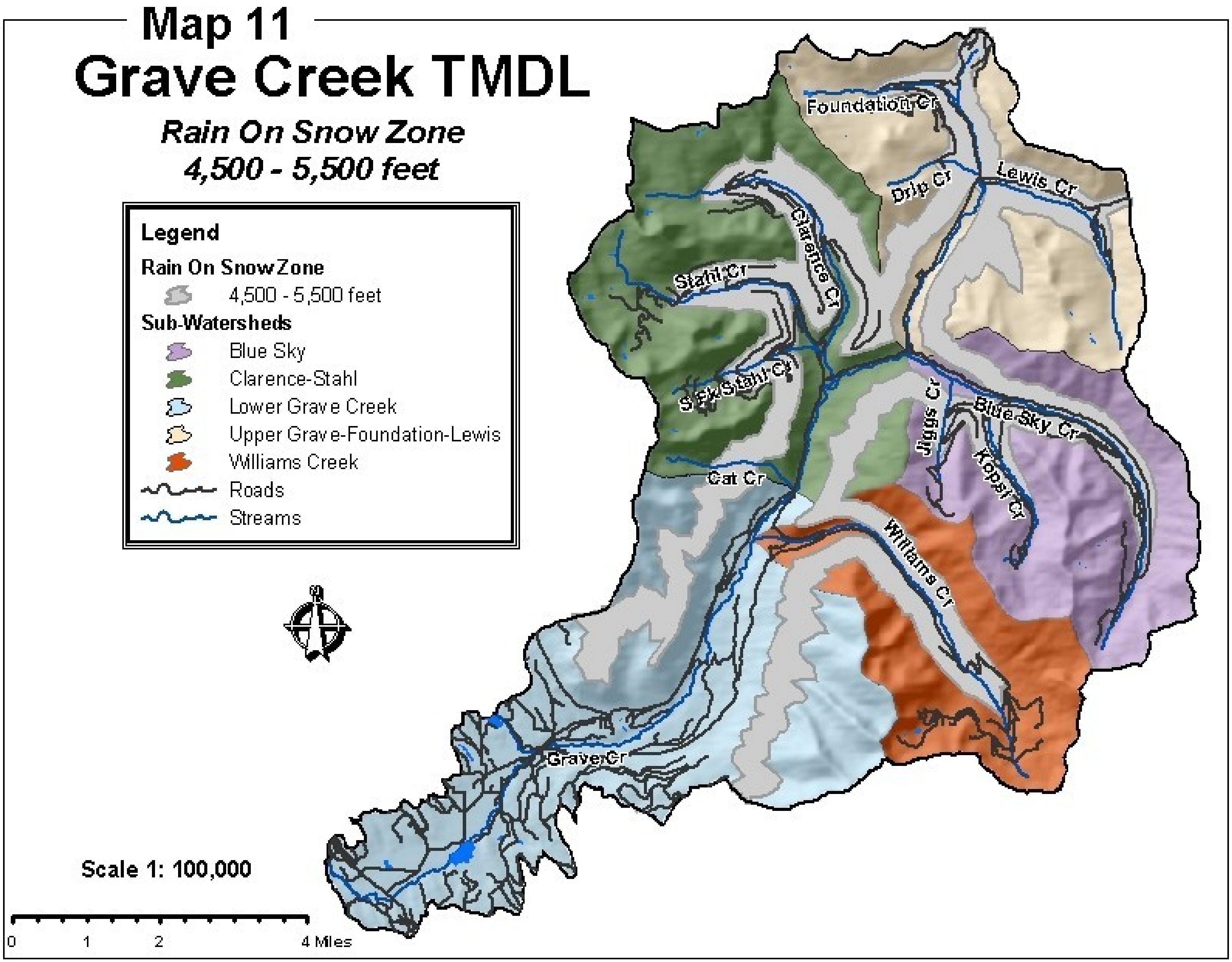

Map 8 Grave Creek TMDL
Vegetation
Land Cover
Legend
Streams
Lakes
Land Cover
Bare Rock/Sand/Clay
Industrial/Transportation
Deciduous Forest
Evergreen Forest
Grasslands/Herbaceous
Low Intensity Residential
Open Water
Pasture/Hay
Shrubland
Transitional
Urban/Recreational Grasses
Woody Wetlands
Foundation Cr
Grave Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
Blue Sky Cr
Jiggs Cr
Kopsi Cr
Cat Cr
Williams Cr
Scale 1: 100,000
0
1
2
4 Miles

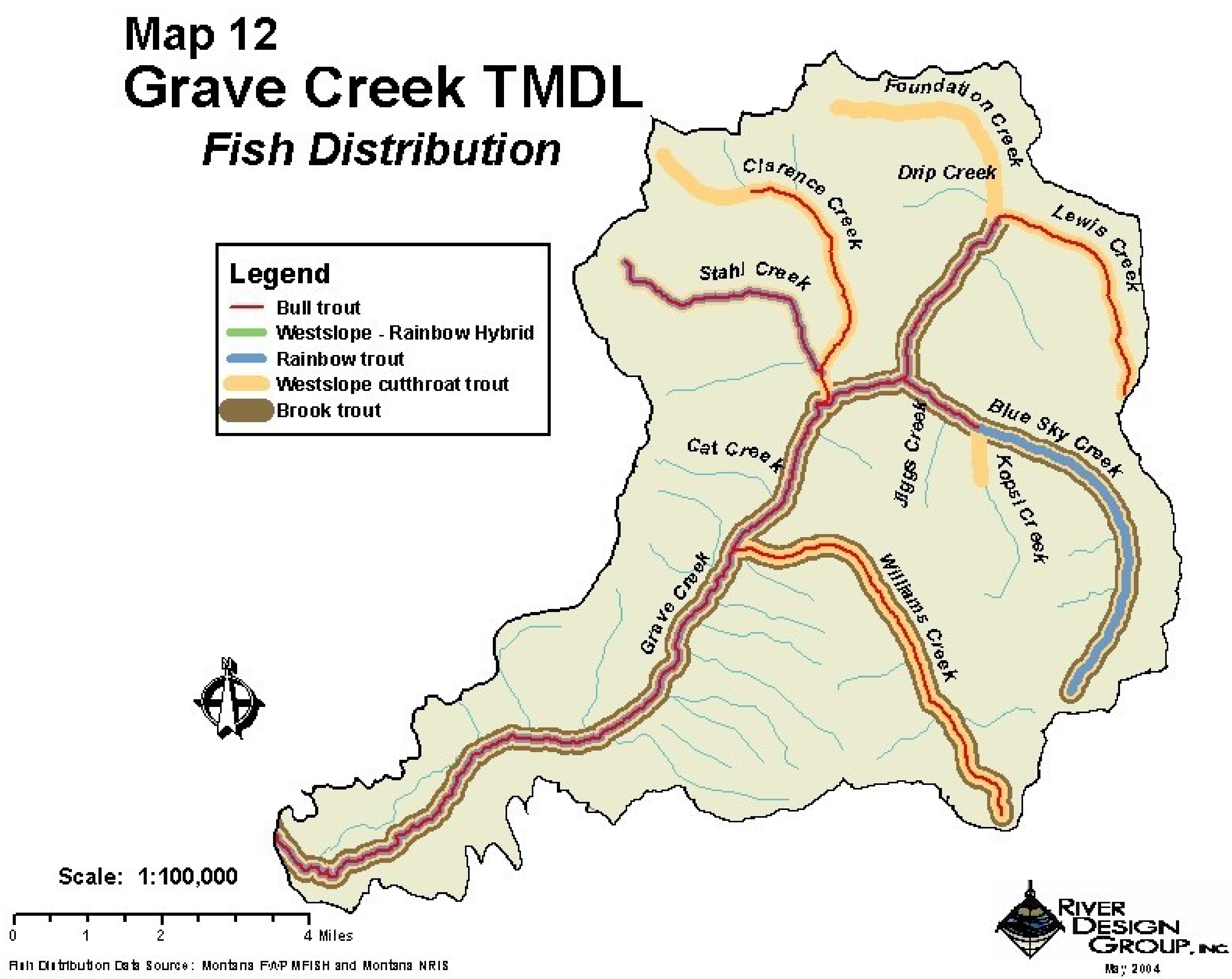

Map 9 Grave Creek TMDL
Forest Management Activities:
Number of Harvest Entries
Legend
Streams
Roads
Lakes
National Forest
Private
Number of Entries
1
2
3
4
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Williams Cr
Blue Sky Cr
Grave Cr
Scale 1: 100,000
0
1
2
4 Miles

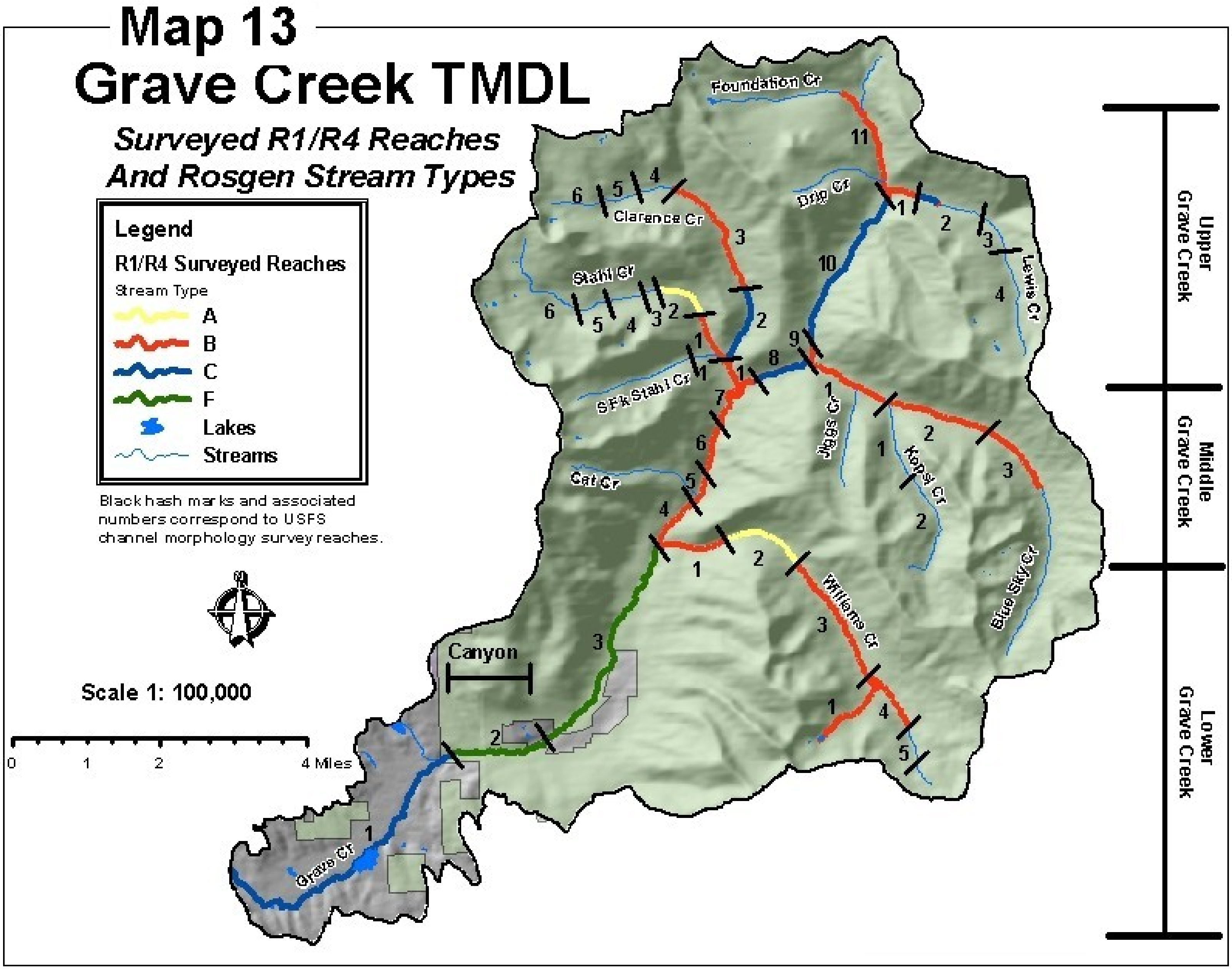
Map 10 Grave Creek TMDL

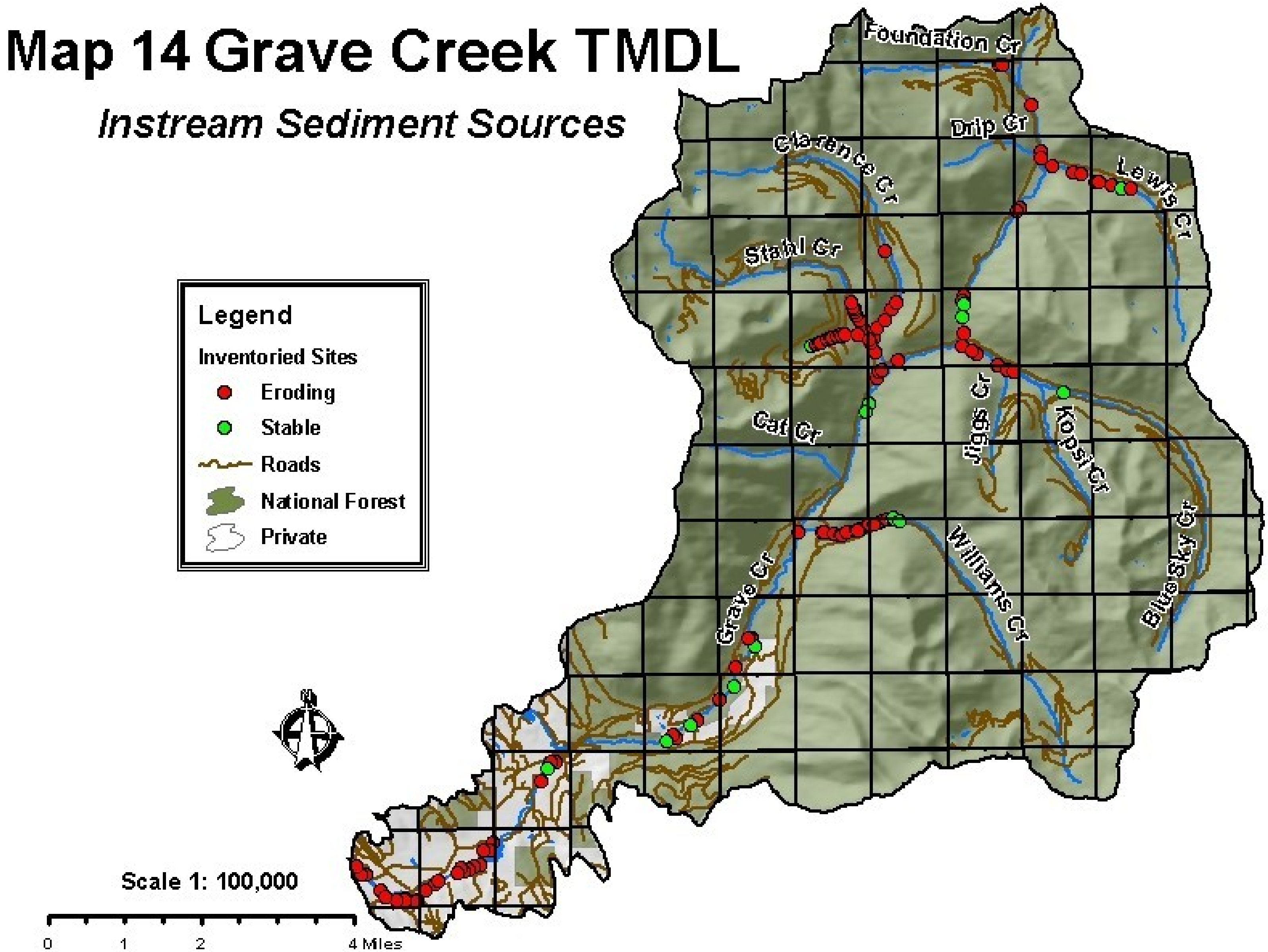
Road System

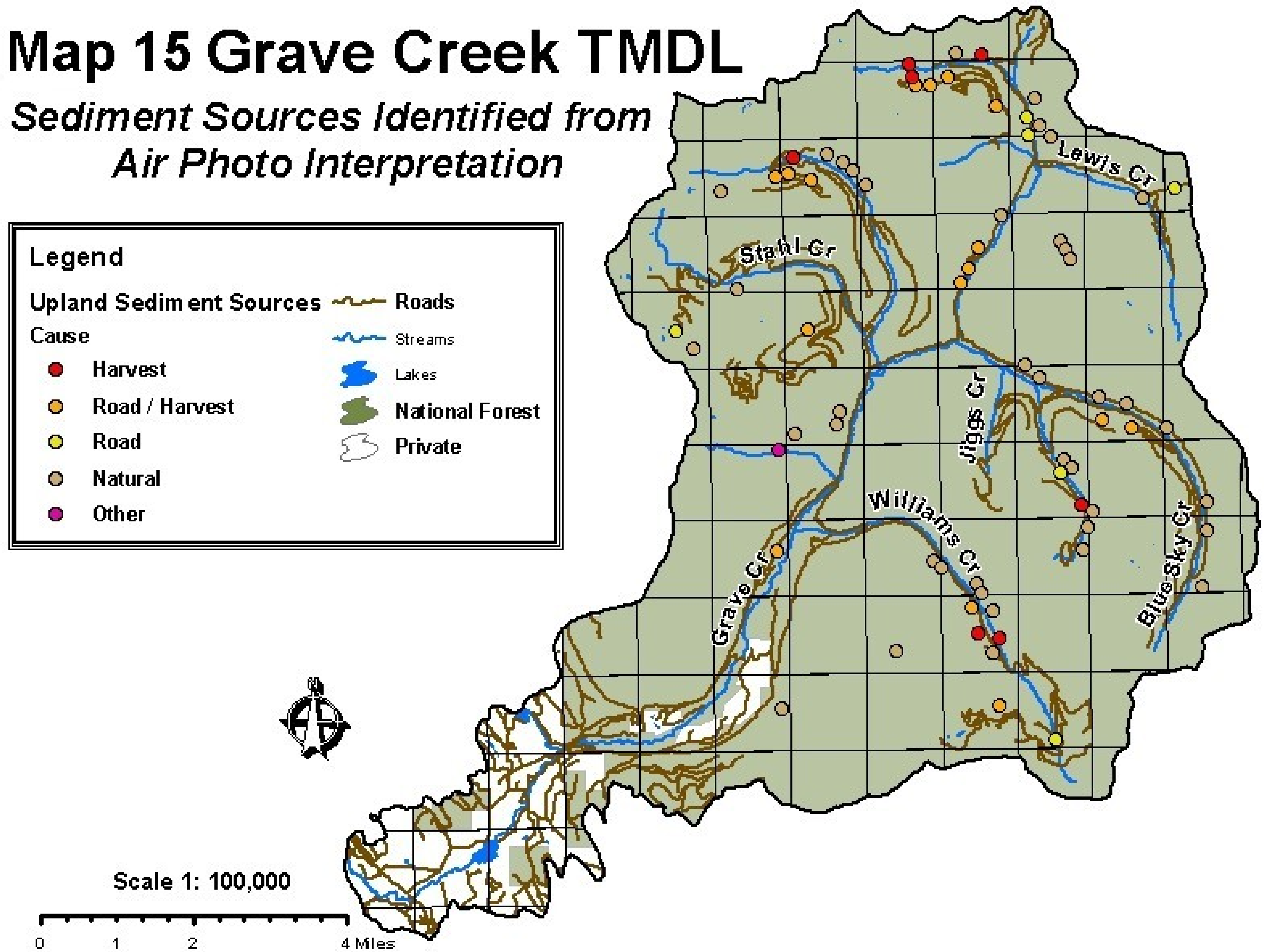



Map 11
Grave Creek TMDL
Rain On Snow Zone
4,500 - 5,500 feet
Legend
Rain On Snow Zone
4,500 - 5,500 feet
Sub-Watersheds
Blue Sky
Clarence-Stahl
Lower Grave Creek
Upper Grave-Foundation-Lewis
Williams Creek
Roads
Streams
Foundation Cr
Drip Cr
Lewis Cr
Clarence Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Blue Sky Cr
Kopsi Cr
Williams Cr
Grave Cr
Scale 1: 100,000
0
1
2
4 Miles


Map 12
Grave Creek TMDL
Fish Distribution
Legend
Bull trout
Westslope - Rainbow Hybrid
Rainbow trout
Westslope cutthroat trout
Brook trout
Foundation Creek
Clarence Creek
Drip Creek
Lewis Creek
Stahl Creek
Blue Sky Creek
Cat Creek
Jiggs Creek
Kopsi Creek
Williams Creek
Grave Creek
Scale: 1:100,000
0
1
2
4 Miles
Fish Distribution Data Source: Montana FWP MFISH and Montana NRIS
River Design Group, Inc.
May 2004


Map 13
Grave Creek TMDL
Surveyed R1/R4 Reaches
And Rosgen Stream Types
Legend
R1/R4 Surveyed Reaches
Stream Type
A
B
C
F
Lakes
Streams
Black hash marks and associated numbers correspond to USFS channel morphology survey reaches.
Scale 1: 100,000
0
1
2
4 Miles
Canyon
Foundation Cr
Clarence Cr
Drip Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Blue Sky Cr
Williams Cr
Grave Cr
Upper Grave Creek
Middle Grave Creek
Lower Grave Creek


Map 14 Grave Creek TMDL
Instream Sediment Sources
Legend
Inventoried Sites
Eroding
Stable
Roads
National Forest
Private
Scale 1: 100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Blue Sky Cr
Williams Cr
Grave Cr


Map 15 Grave Creek TMDL
Sediment Sources Identified from
Air Photo Interpretation
Legend
Upland Sediment Sources
Cause
Harvest
Road / Harvest
Road
Natural
Other
Roads
Streams
Lakes
National Forest
Private
Scale 1: 100,000
0
1
2
4 Miles
Lewis Cr
Stahl Cr
Jiggs Cr
Williams Cr
Blue Sky Cr
Grave Cr