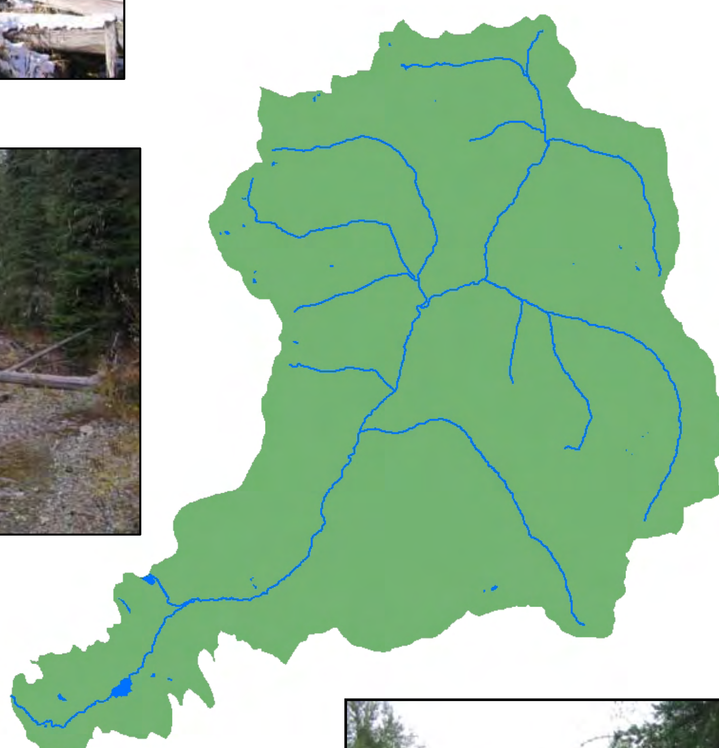
Grave Creek Watershed Water Quality and Habitat Restoration Plan and Sediment Total Maximum Daily Loads

Montana Department of Environmental Quality



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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
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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.

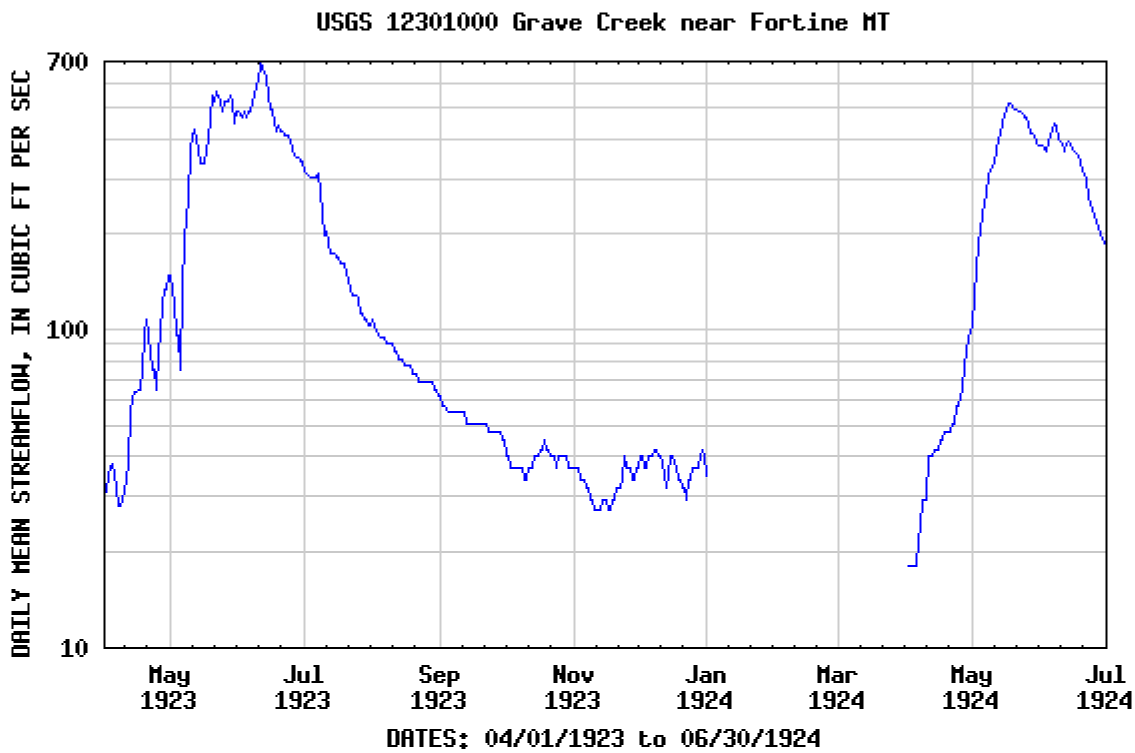

Figure 2-1: Grave Creek Hydrograph for April 1, 1923 through June 30, 1924 (Data Missing from January through April 1, 1924).

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).

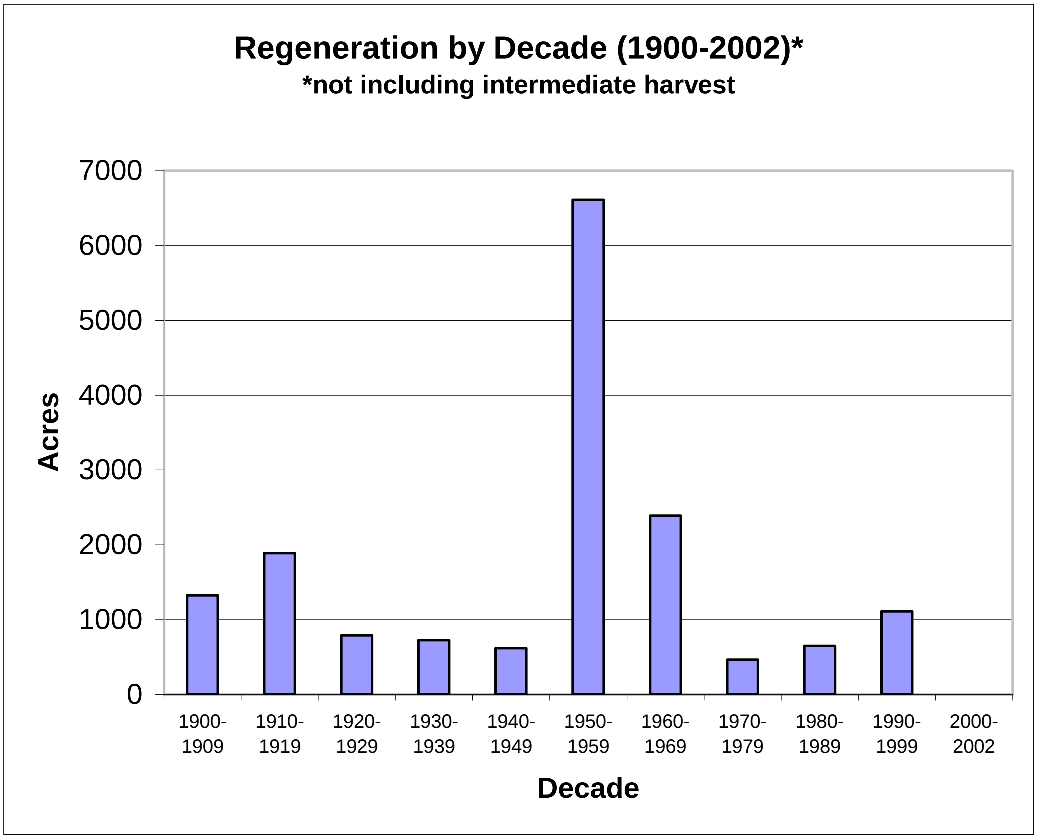

Figure 2-2: Acres of Regenerating Disturbance by Decade Over the 20th Century. The peak in the 1950s and 1960s is from spruce beetle logging; the higher figure from the 1990s is almost entirely attributable to the 1988 fire in Blue Sky drainage (1,040 acres burned). (Only US Forest Service ownership 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 25th to the 75th 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 ($\leq$ 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.

Stream	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass-Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
	(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.

Stream	Calculated Load (for inventoried segments)				Predicted Load (extrapolation to uninventoried segments)				Total Load from Mass-Wasting Sites					
	Surface		Toe		Surface		Toe		Surface		Toe		Total	
	(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

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PHOTOS

List of Photos

Photo 1: Clarence Creek – Riparian Harvest

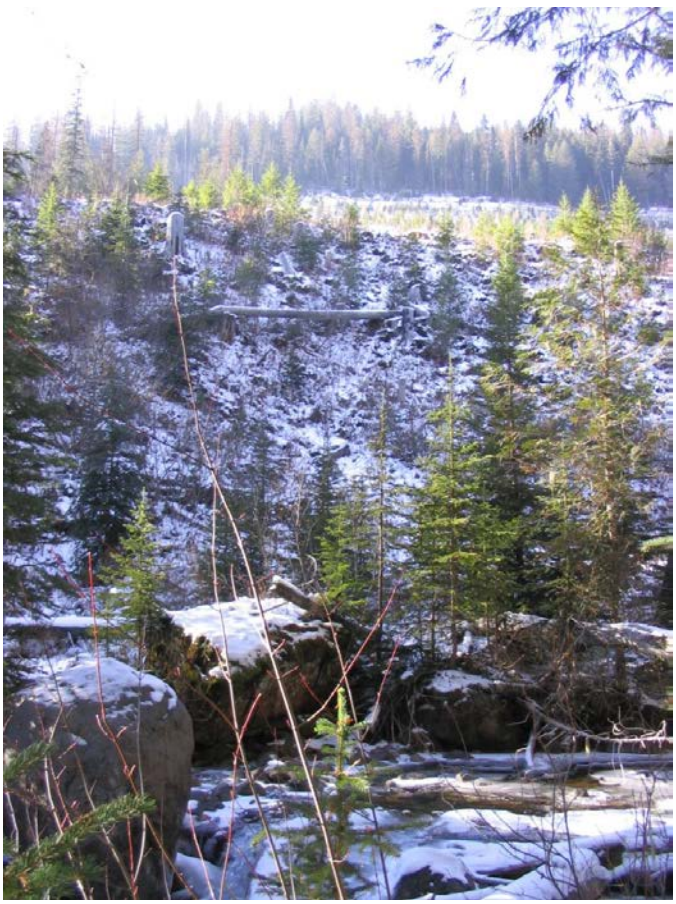


Photo 2: Stahl Creek - Riparian Harvest with No Buffer

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

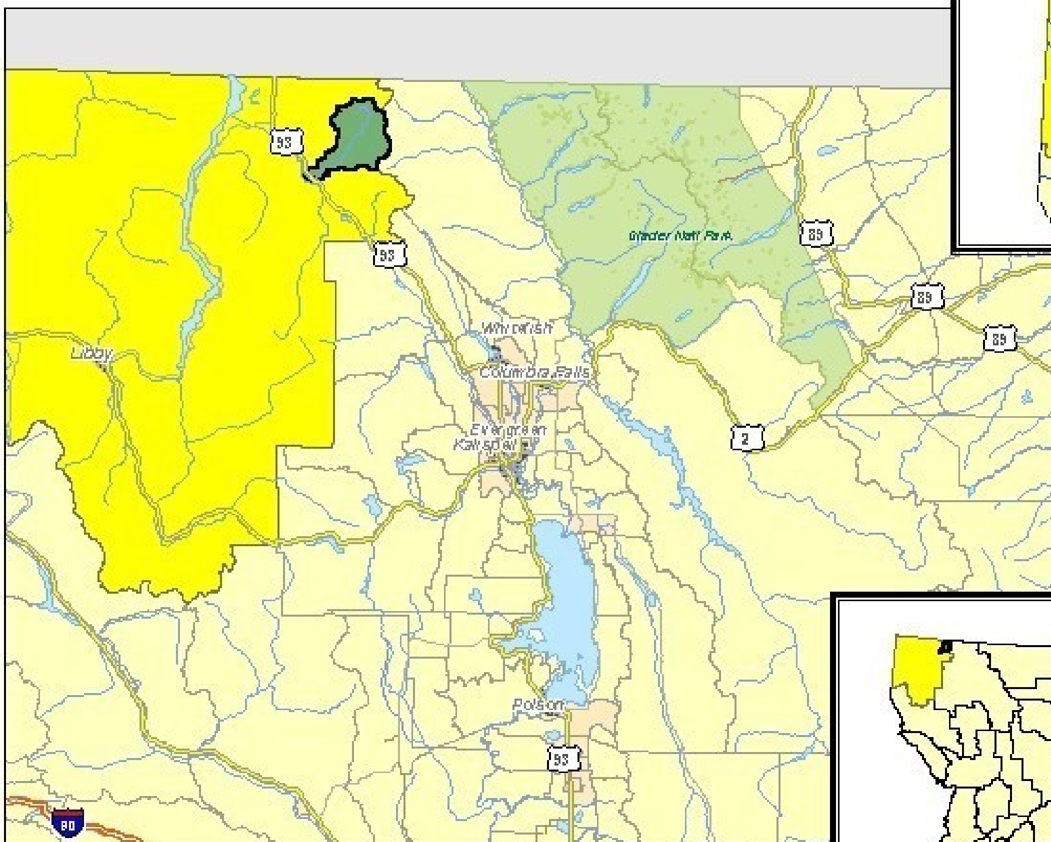
Photo 19: Main Stem Lower Below Canyon – Terrace Erosion

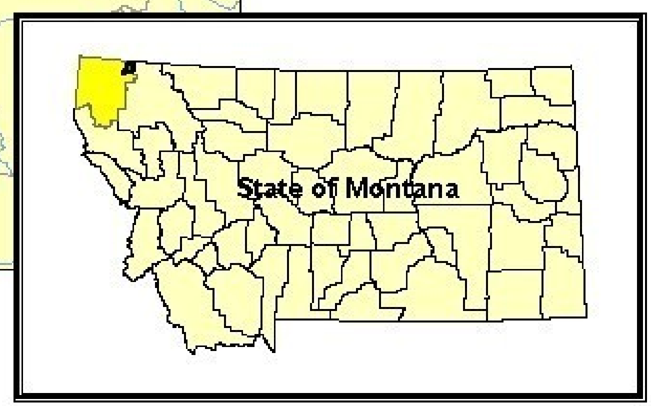
Photo 20: Main Stem Lower - Bank Armoring

Photo 21: Fish Passage Barrier on Foundation Creek

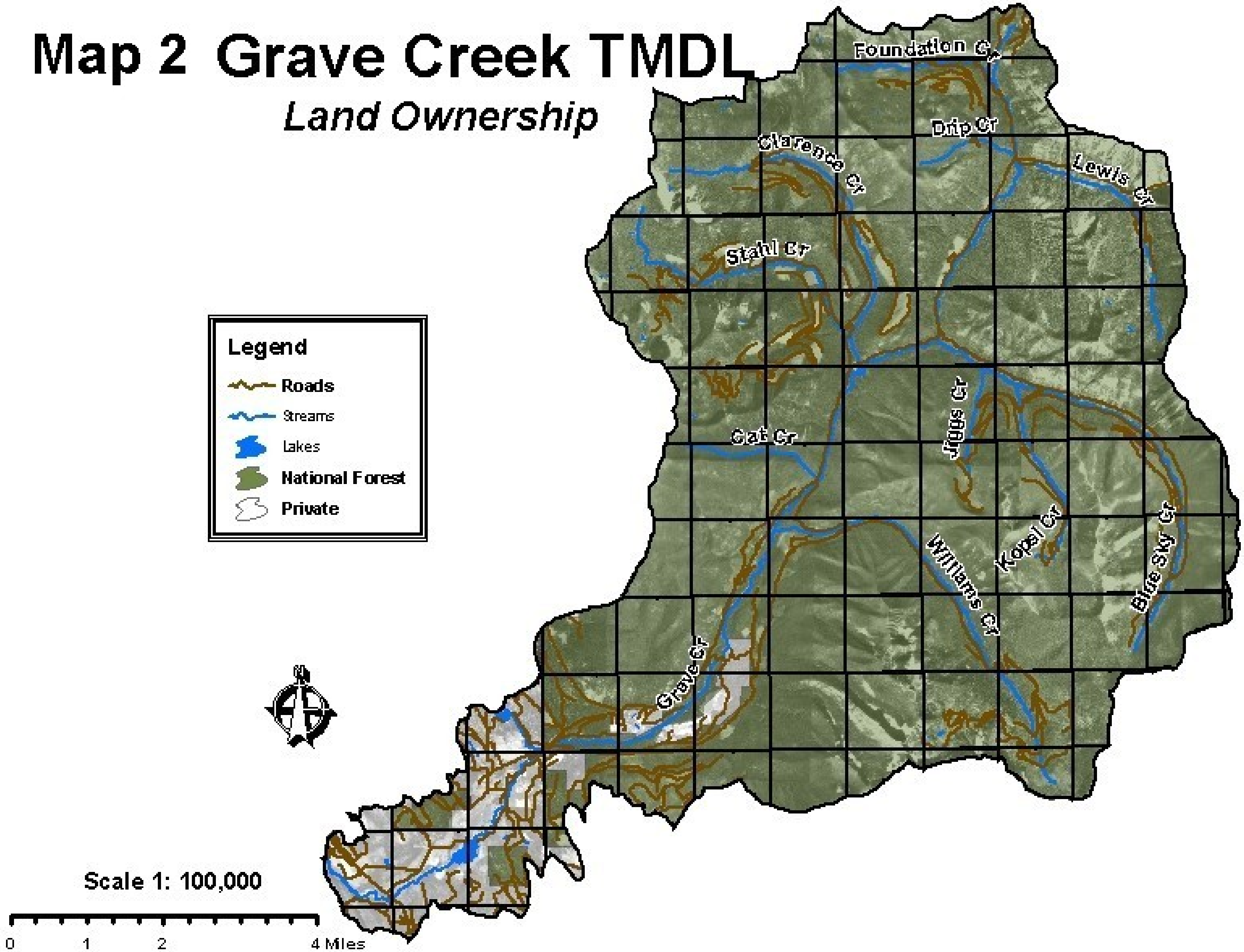
MAPS

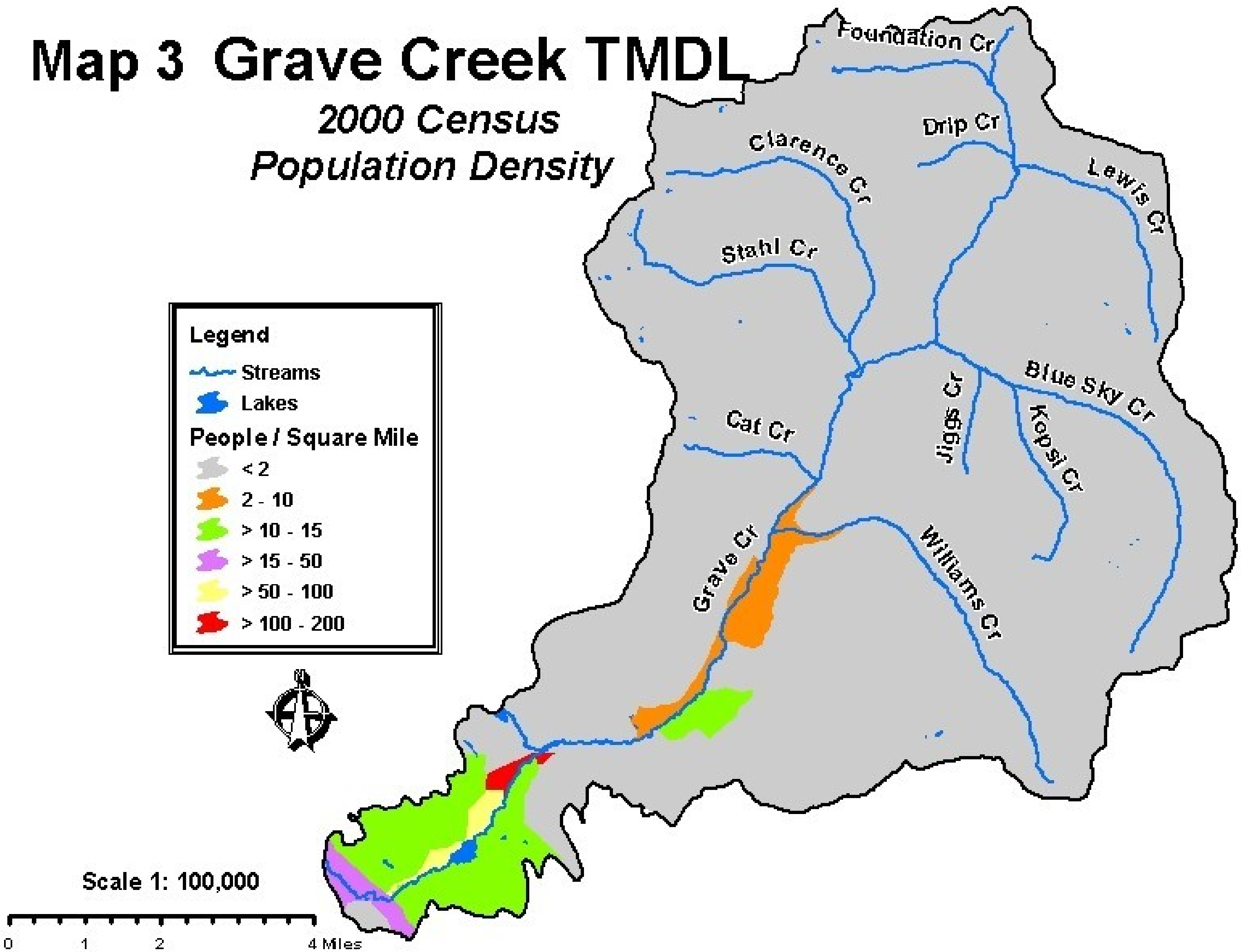
Map 1
Grave Creek TMDL
Vicinity Map

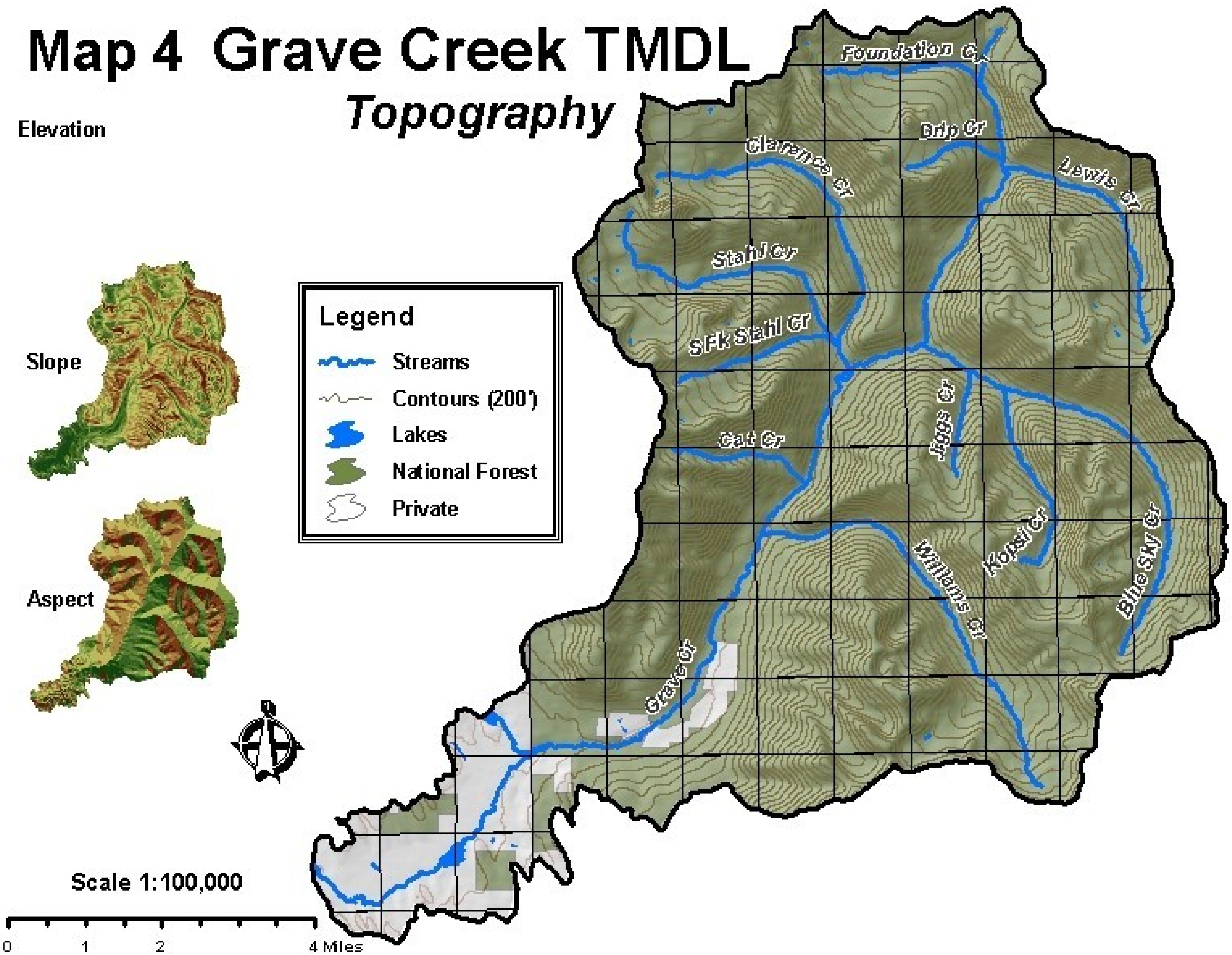


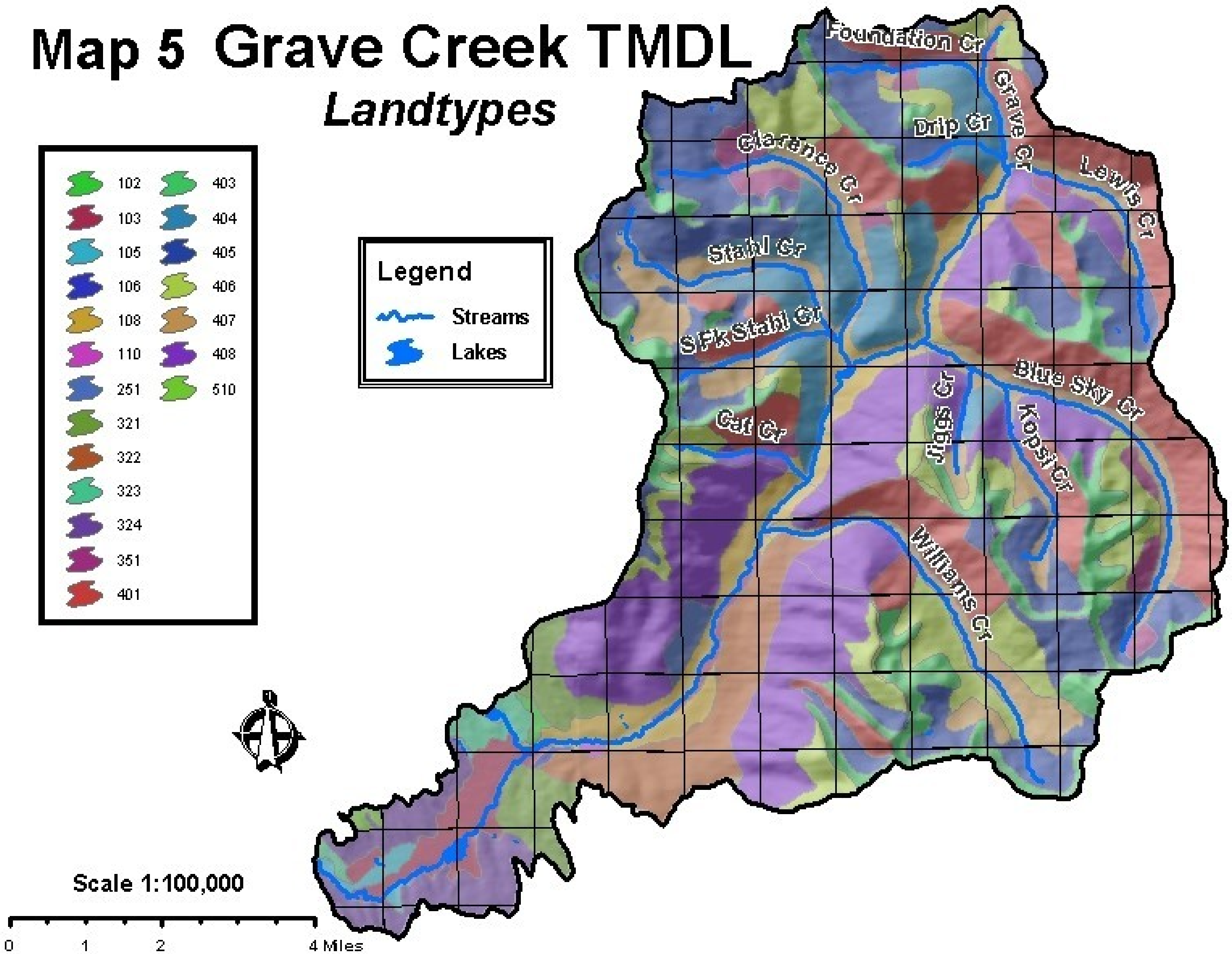


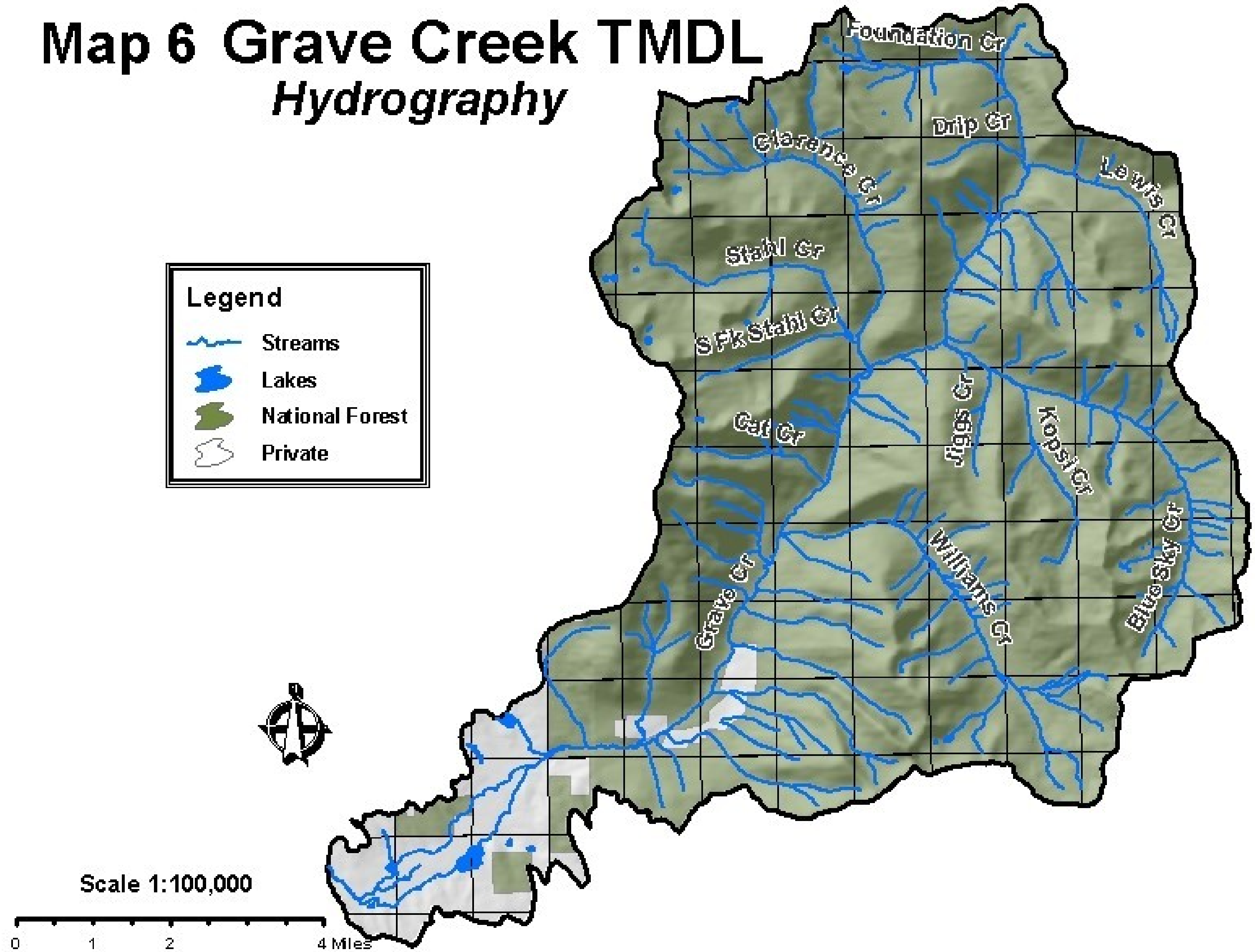
Adapted from ArcGIS USA Thematic Maps, ESRI.

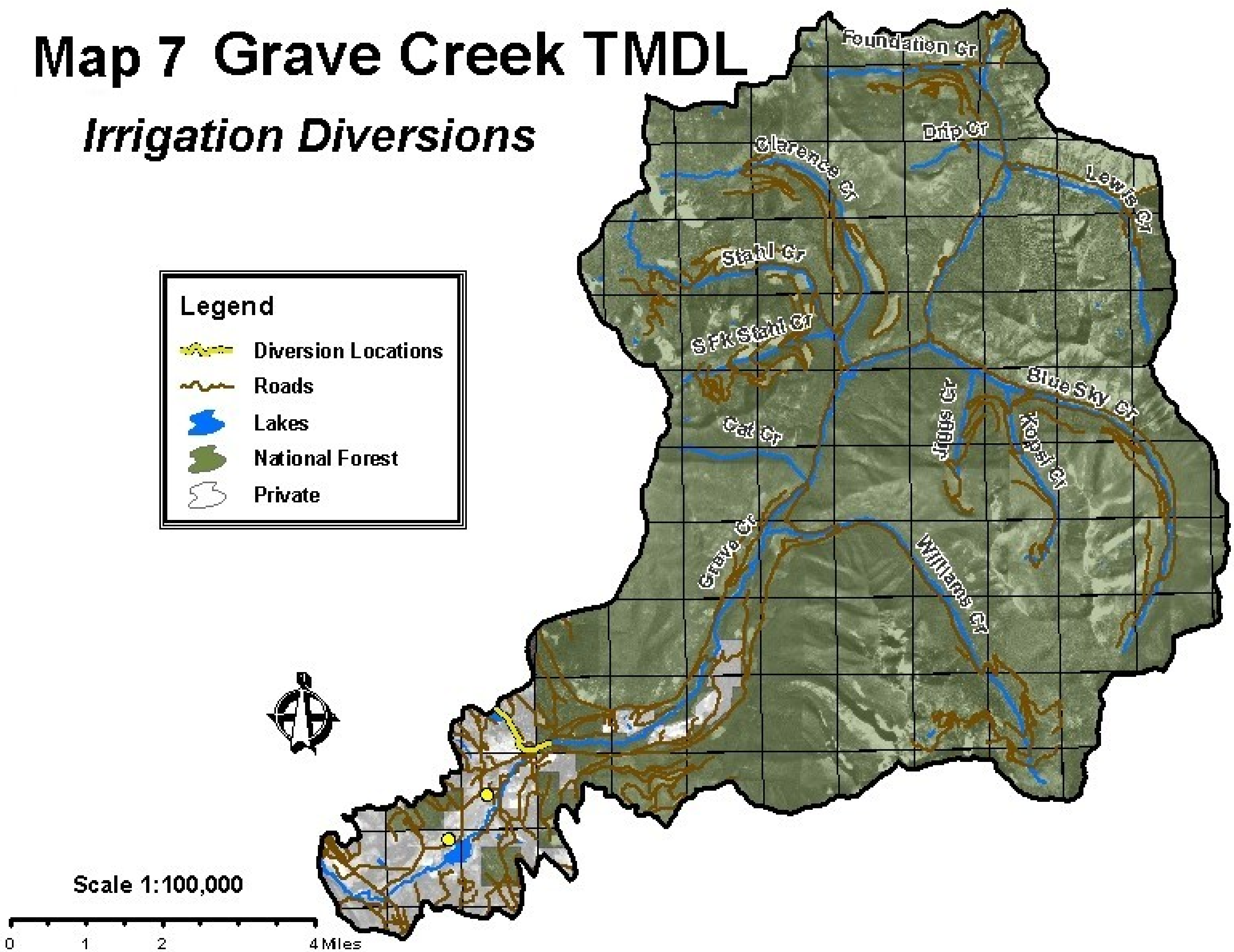

Map 2 Grave Creek TMDL
Land Ownership
Legend
Roads
Streams
Lakes
National Forest
Private
Scale 1: 100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
Cat Cr
Jiggs Cr
Williams Cr
Kopal Cr
Blue Sky Cr
Grave Cr


Map 3 Grave Creek TMDL
2000 Census
Population Density
Legend
Streams
Lakes
People / Square Mile
< 2
2 - 10
> 10 - 15
> 15 - 50
> 50 - 100
> 100 - 200
Scale 1: 100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
Blue Sky Cr
Jiggs Cr
Kopsi Cr
Cat Cr
Grave Cr
Williams Cr

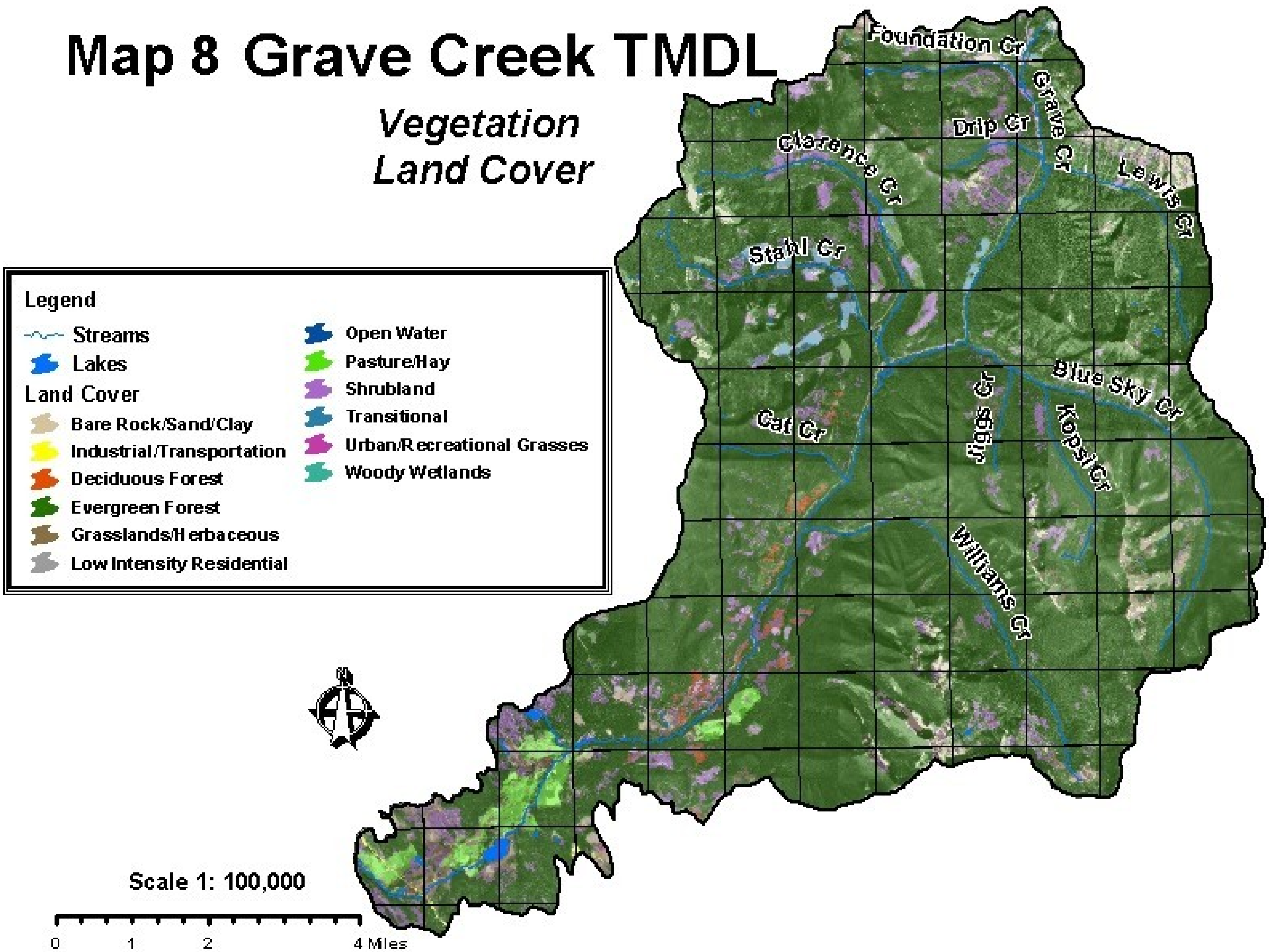

Map 4 Grave Creek TMDL
Topography
Elevation
Slope
Aspect
Legend
Streams
Contours (200')
Lakes
National Forest
Private
Scale 1:100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Williams Cr
Blue Sky Cr
Grave Cr


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
Scale 1:100,000
0
1
2
4 Miles
Foundation Cr
Grave Cr
Drip Cr
Clarance Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Blue Sky Cr
Jiggs Cr
Kopsi Cr
Cat Cr
Williams Cr


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
Blue Sky Cr
Grave Cr

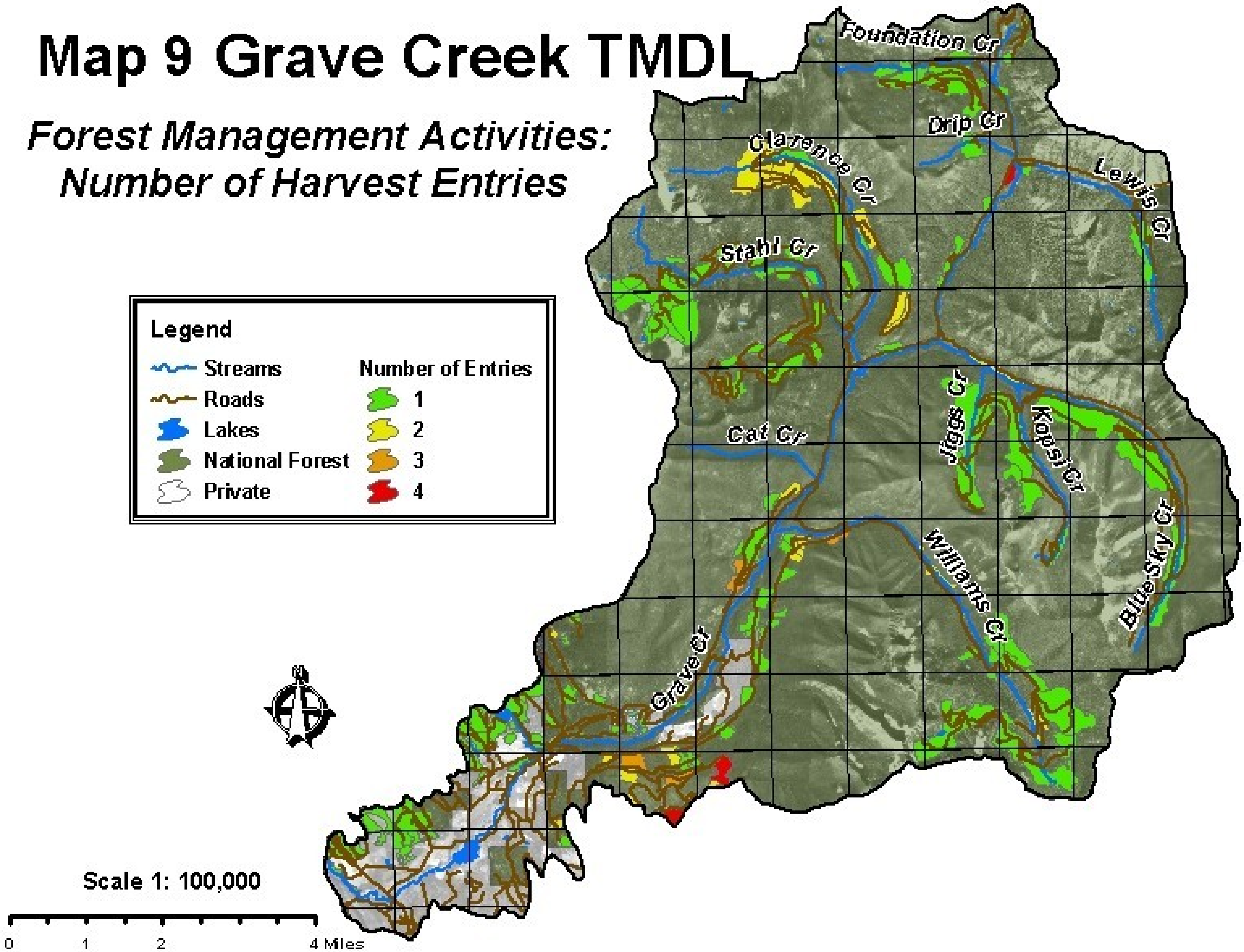


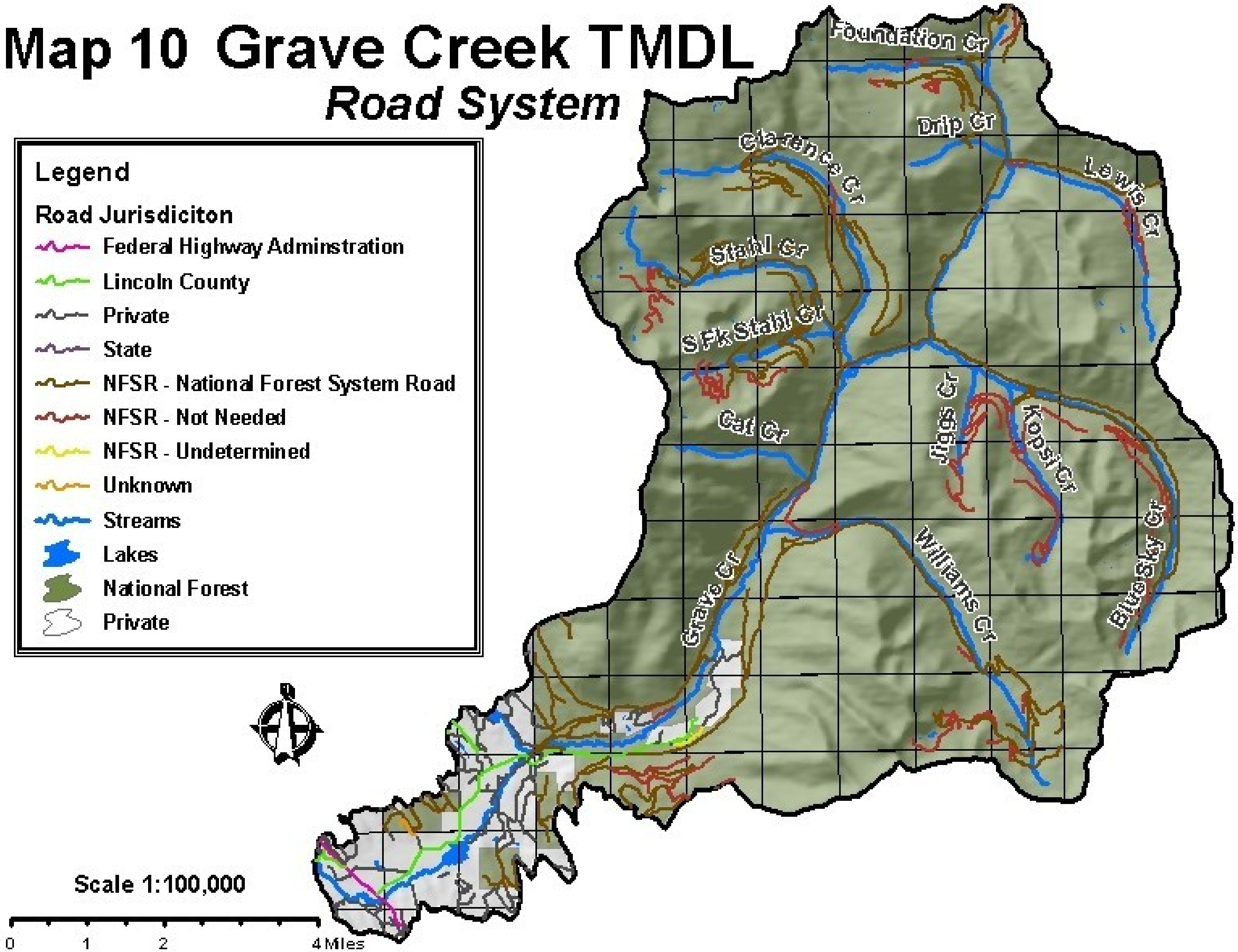
Map 7 Grave Creek TMDL
Irrigation Diversions
Legend
Diversion Locations
Roads
Lakes
National Forest
Private
Scale 1:100,000
0
1
2
4 Miles
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Blue Sky Cr
Cat Cr
Jims Cr
Kopsi Cr
Grave Cr
Williams Cr

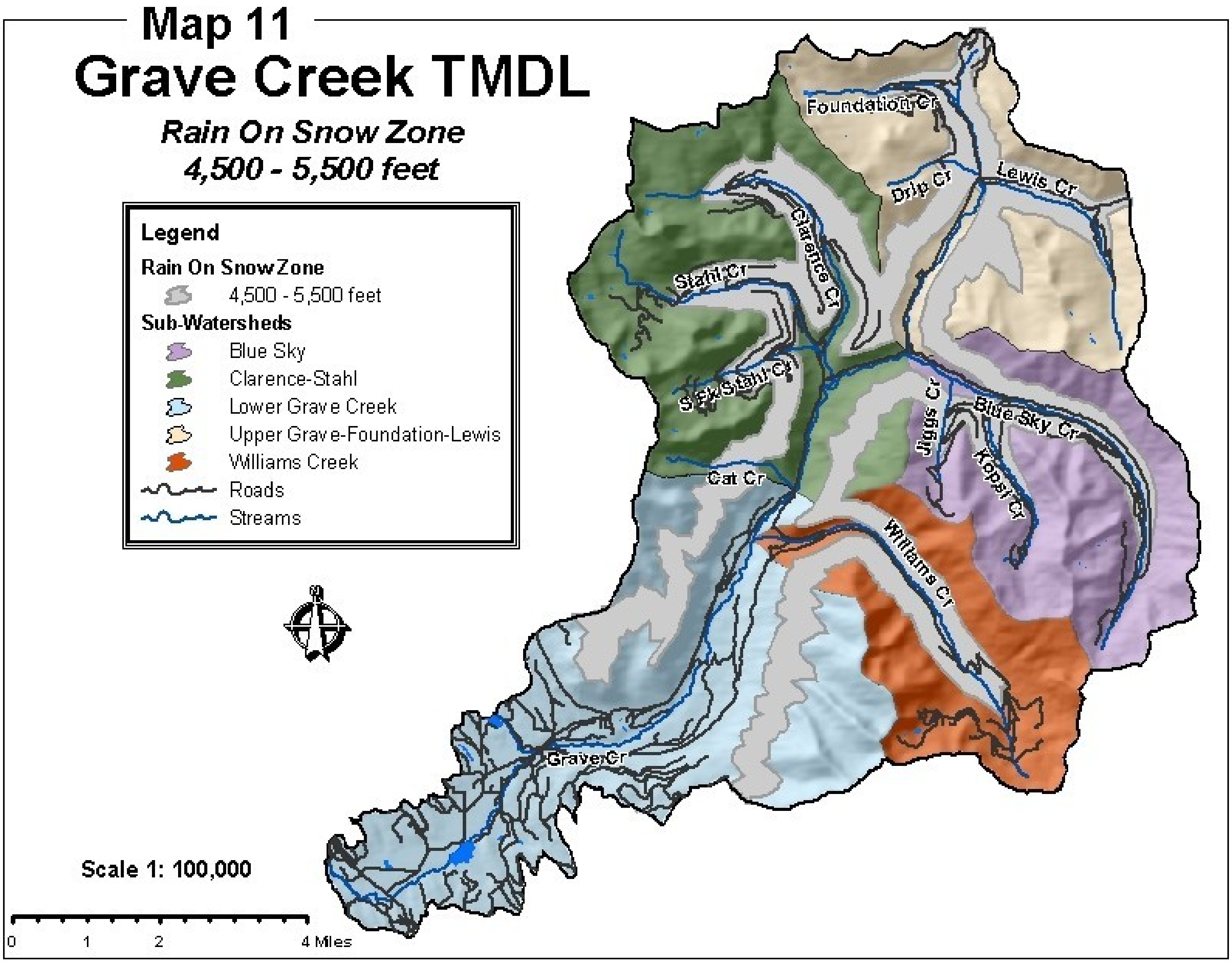

Map 8 Grave Creek TMDL
Vegetation
Land Cover
Legend
Streams
Lakes
Land Cover
Bare Rock/Sand/Clay
Industrial/Transportation
Deciduous Forest
Evergreen Forest
Grasslands/Herbaceous
Low Intensity Residential
Open Water
Pasture/Hay
Shrubland
Transitional
Urban/Recreational Grasses
Woody Wetlands
Foundation 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

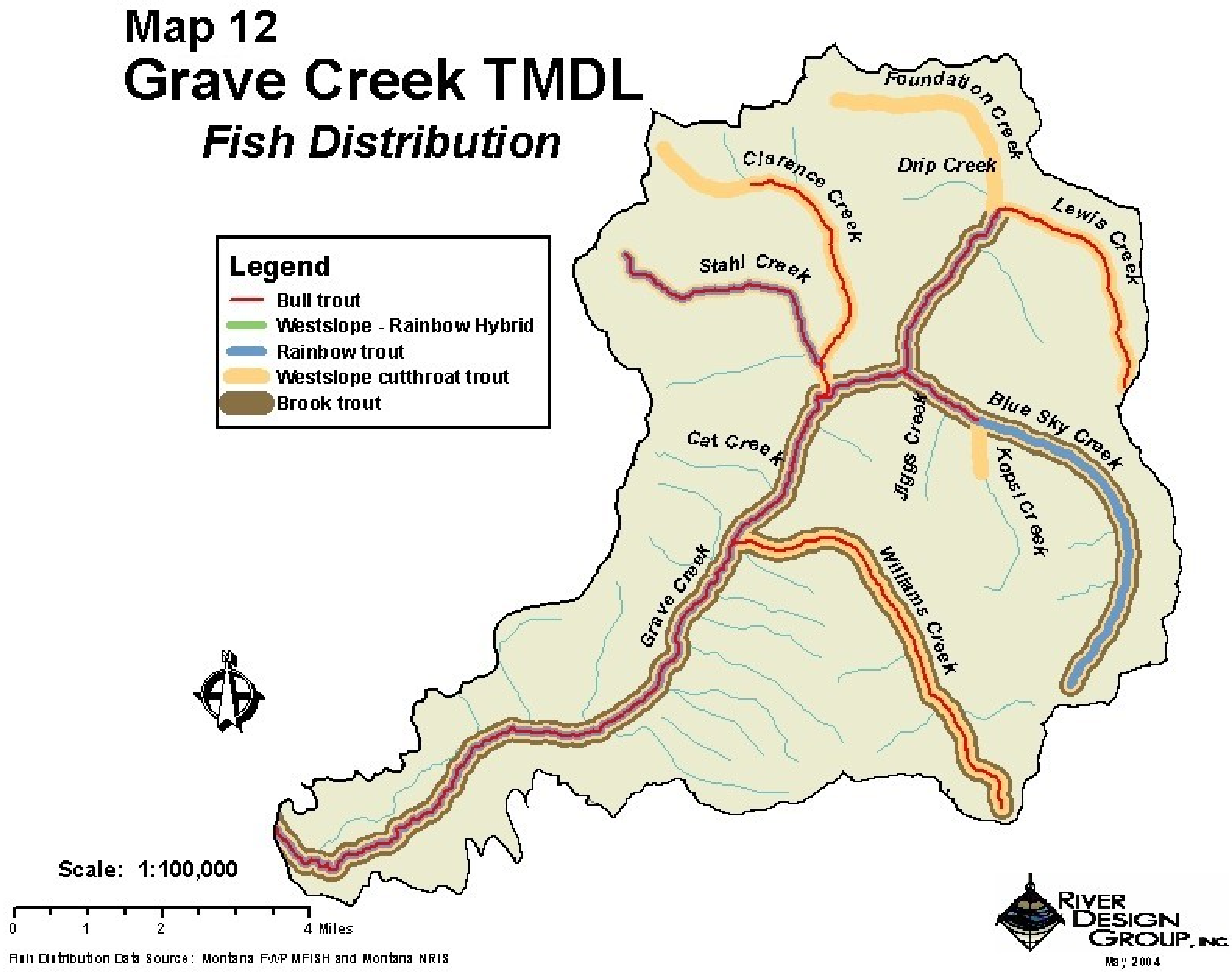
Forest Management Activities: Number of Harvest Entries

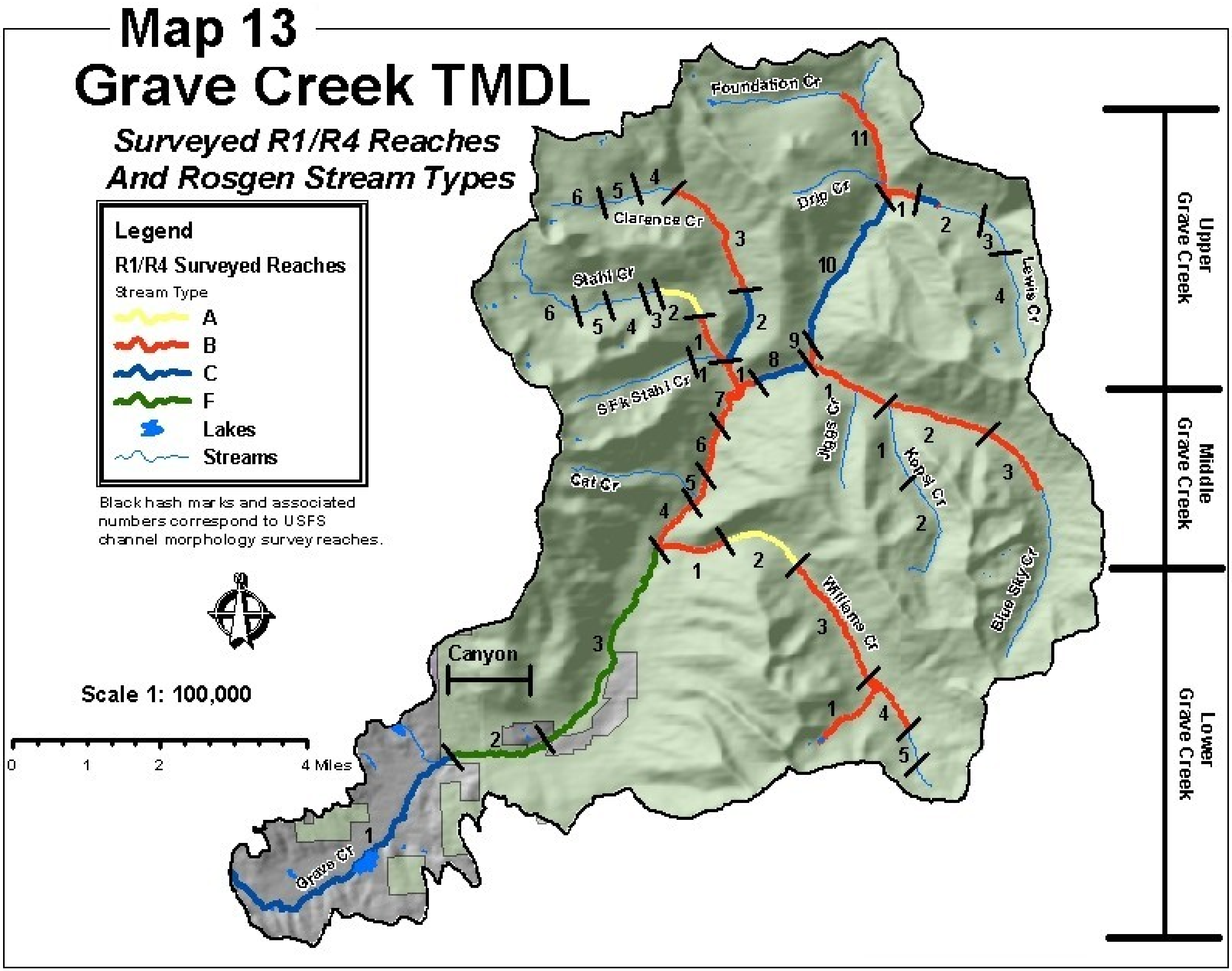



Map 10 Grave Creek TMDL
Road System
Legend
Road Jurisdiciton
Federal Highway Adminstration
Lincoln County
Private
State
NFSR - National Forest System Road
NFSR - Not Needed
NFSR - Undetermined
Unknown
Streams
Lakes
National Forest
Private
Foundation Cr
Drip Cr
Clarence Cr
Lewis Cr
Stahl Cr
S Fk Stahl Cr
Cat Cr
Jiggs Cr
Kopsi Cr
Blue Sky Cr
Williams Cr
Grave Cr
Scale 1:100,000
0
1
2
4 Miles

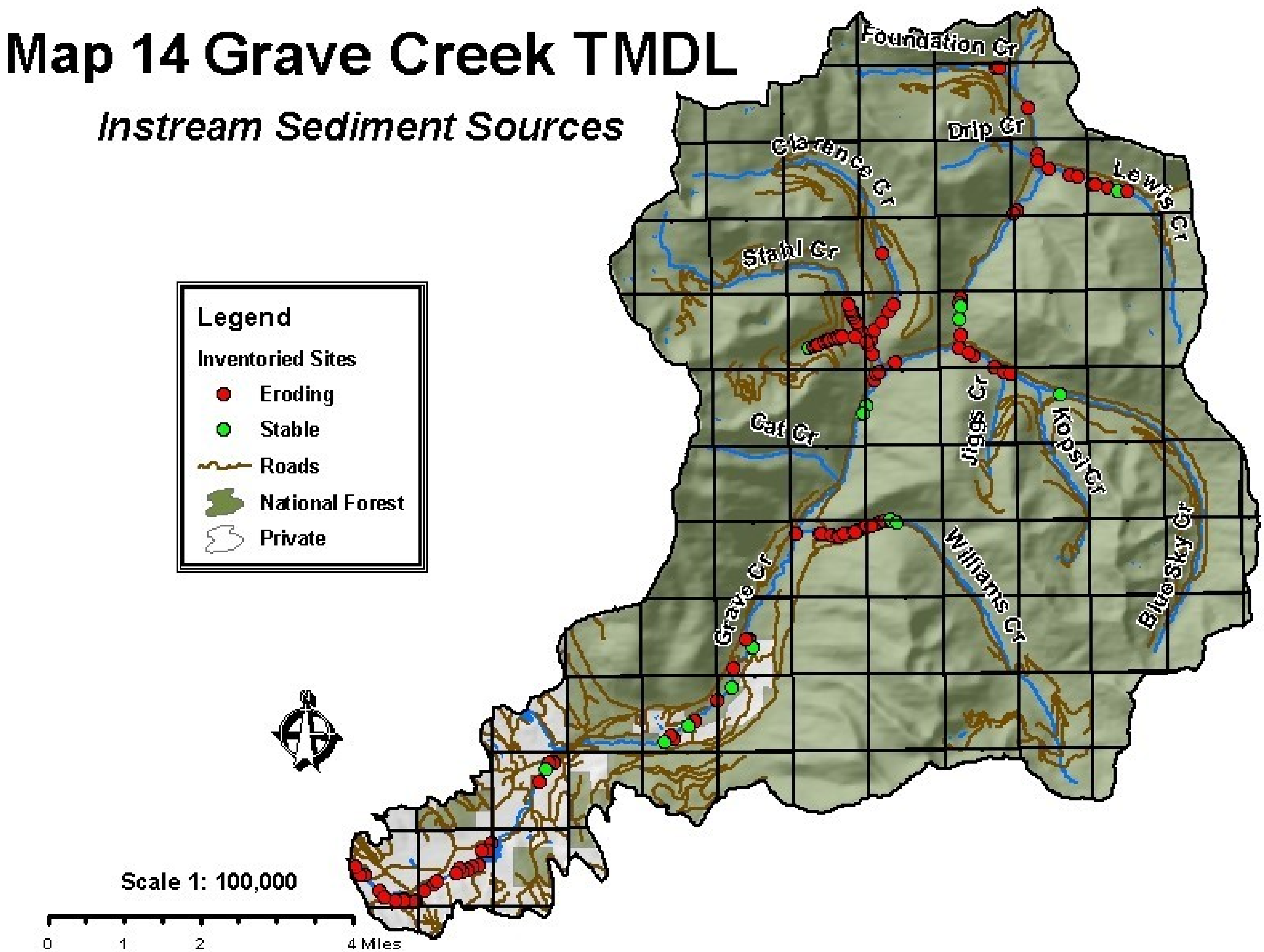


Map 11
Grave Creek TMDL
Rain On Snow Zone
4,500 - 5,500 feet
Legend
Rain On Snow Zone
4,500 - 5,500 feet
Sub-Watersheds
Blue Sky
Clarence-Stahl
Lower Grave Creek
Upper Grave-Foundation-Lewis
Williams Creek
Roads
Streams
Foundation Cr
Drip Cr
Lewis Cr
Clarence Cr
Stahl Cr
S Fk Stahl Cr
Jiggs Cr
Blue Sky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

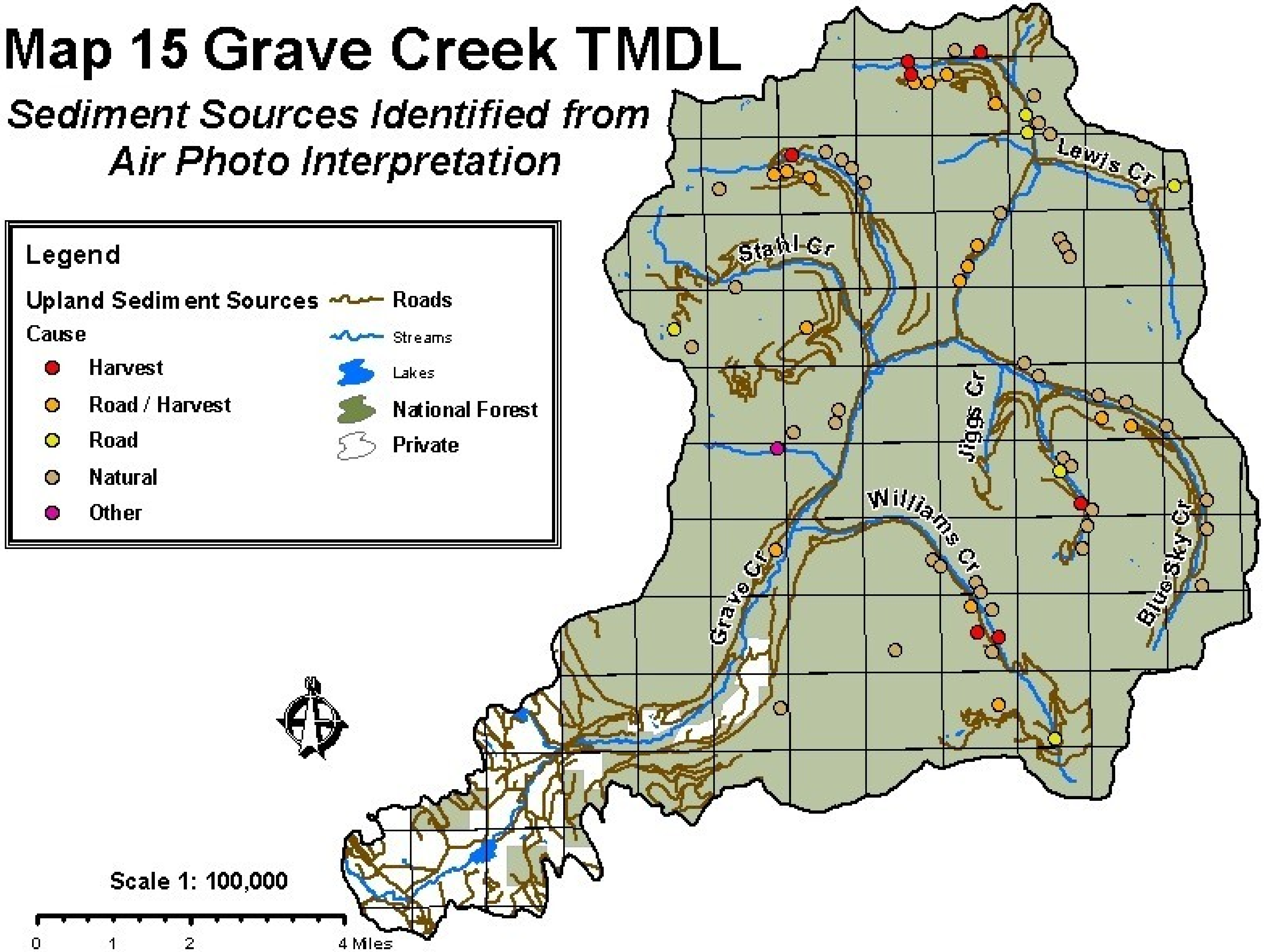


Map 13
Grave Creek TMDL
Surveyed R1/R4 Reaches
And Rosgen Stream Types
Legend
R1/R4 Surveyed Reaches
Stream Type
A
B
C
F
Lakes
Streams
Black hash marks and associated numbers correspond to USFS channel morphology survey reaches.
Scale 1: 100,000
0
1
2
4 Miles
Canyon
Foundation Cr
Clarence Cr
Stahl Cr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

Sediment Sources Identified from Air Photo Interpretation



APPENDIX A
HARVEST ANALYSIS SUMMARY

Spatial analyses were conducted to describe the harvest activity that has occurred during the twentieth century primarily on National Forest in the Grave Creek Watershed. Data used included the USFS TSMRS (Timber Stand Management Recording System) and a GIS layer of stand polygons, also provided by the Kootenai National Forest. A polygon layer of USFS Land Type Associations (USFS) and related Land Type Association (LTA) interpretations described in the Kootenai National Forest Soil Survey (USFS, 1995a) were also used in these analyses.

TSMRS records acres treated per stand but the location of these acres within a stand cannot be distinguished using these records. Similarly, using the TSMRS records to break down harvest activity by LTA is not possible without assuming treatment of the entire stand. Therefore, analyses reflect the assumption that total stand was harvested, which may result in an overestimate of area treated. Conversely, using the planar area as opposed to area based on slope length (what is recorded in TSMRS) results in an underestimate of stand area. Somewhat of a counterbalance is reached between these two limitations. Accuracy and completeness of TSMRS database is another limitation. Analyses were conducted acknowledging these assumptions and limitations.

Table A-1 provides a list of the TSMRS activity codes included in this analysis. Activity acreages only reflect single stand entries. Map 9 displays stands that were entered multiple times throughout the analysis time frame. The acreages presented in this appendix do not reflect repeat stands entries. Activities with accomplishment year 0 were not included. It is assumed accomplishment year 0 activities have not been completed and therefore could not have contributed to current stream conditions.

TSMRS acreages and GIS stand acreages were compared to test the degree of discrepancy between the two (Table A-2). The TSMRS columns (Table A-2) include the totals for acreage reported by USFS. The GIS columns include acreage totals for the stands harvested. The GIS-based harvest totals are in general lower than the TSMRS total; however, the relative trends are the same. The GIS-based values will be used to be consistent with additional spatial analyses. Results likely provide a relatively adequate representation of the distribution of timber harvest activity on National Forest.

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 as shown in Table A-2 and by watershed in Table A-3. This is in comparison to 27 miles^2 of riparian-linked stands (Table A-4). A riparian-linked stand is a stand that has at least a part of the stand within the 300-foot riparian buffer. Harvest activity may not have occurred in the portion of the stand that is within the riparian buffer. Spatial distribution of activities below the stand level (i.e. within a stand) cannot be determined using the TSMRS because the minimum mapping unit of the TSMRS database is the stand.

Tables A-1 through A-7 and Figures A-1 through A-3 provide a comprehensive summary of harvest statistics by year, watershed and LTA.

Table A-1: TSMRS Activity Codes Included in Harvest Analysis.	
TSMRS Activity Code	**TSMRS Activity Description**
4111	Clearcut – Patch
4113	Clearcut – Stand
4114	Clearcut - with Reserves
4131	Shelterwood Seed Cut
4132	Seed Tree Seed Cut
4146	Shelterwood Final Cut
4147	Seed Tree Final Cut
4148	Shelterwood Final Cut with Reserves
4149	Seed Tree Final Cut with Reserves
4152	Group Selection Cut
4211	Liberation Cutting
4220	Thinning
4230	Sanitation Salvage
4521*	Pre-commercial thinning
4987*	Fireline construction

* Not included in the ECA/Water Yield analysis described in Appendix C. ECA/Water Yield analysis in Appendix C also included 4250 (natural changes – Blue Sky/Kopsi fire) and 4270 (permanent land clearing).

Table A-2: Comparison of GIS-based (stand polygon) Area Summaries Versus TSMRS-based Harvest Summaries.				
	Area Harvested in Sub-Watershed (mi^2)	**Area Harvested in Riparian-Related Stands (mi^2)**	GIS	TSMRS
	GIS	TSMRS	1.8	2.1
Blue Sky	2.1	2.7	1.4	2.2
Clarence-Stahl	2.7	3.4	0.4	0.6
Lower Grave Creek	2.4	2.8	0.9	0.8
Upper Grave-Foundation-Lewis	1.0	1.0	0.8	1.0
Williams	1.6	1.9		
			5.3	6.7
Total	9.8	13.7		

Table A-3: Harvest Area Summary (miles²).						
	Total Area in Sub-Watershed	**Area Harvested**	**Area Harvested In Riparian-Related Stands**	**Area Harvested In Rain-on-Snow zone**		
Sub-watershed				Total	%North	%South
Blue Sky	12.5	**2.1**	**1.8**	1.2	97	3
Clarence-Stahl	17.9	**2.7**	**1.4**	1.4	50	50
Lower Grave Creek	21.8	**2.4**	**0.4**	0.0	0	0
Upper Grave-Foundation-Lewis	13.6	**1.0**	**0.9**	0.4	68	32
Williams	9.45	**1.6**	**0.8**	0.3	39	61
Total	**75.3**	**9.8**	**5.3**	3.3	69	31

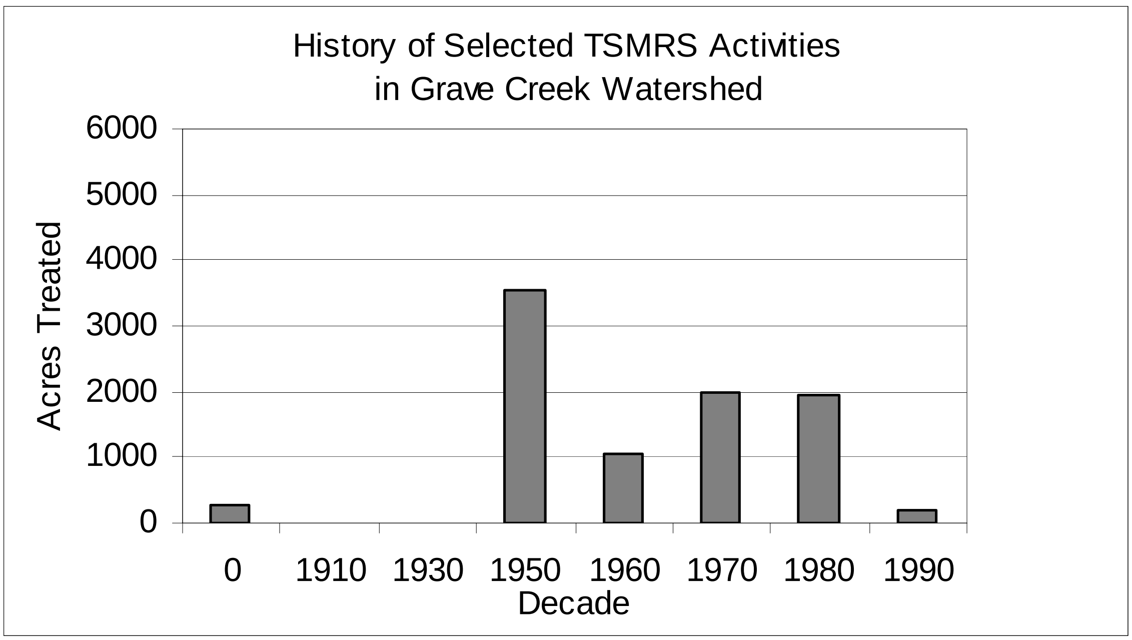


Figure A-1: History of Selected TSMRS Activities in Grave Creek Watershed.

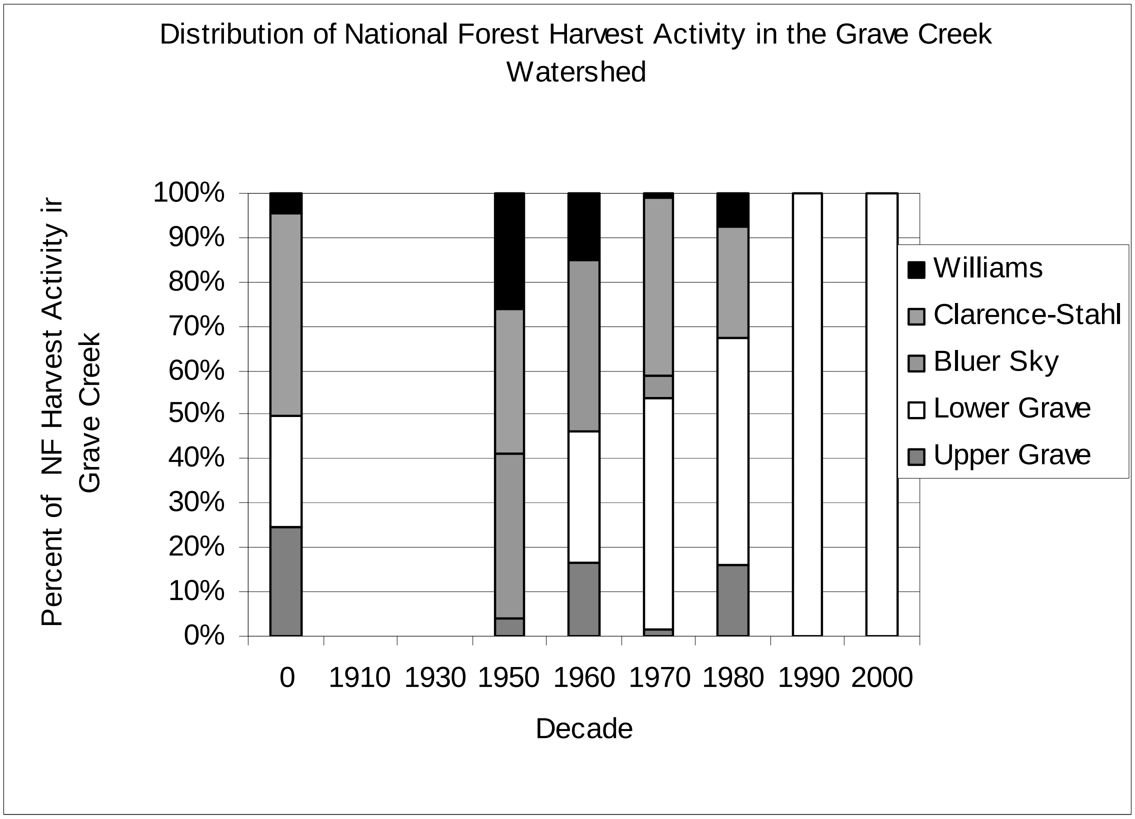


Figure A-2: Distribution of National Forest Harvest Activity in the Grave Creek Watershed.

Table A-4: Summary of Area within Riparian-linked Stands by Sub-Watershed.				
	Area within Riparian-linked Stands			
	Meters^2	**Acres**	**Miles^2**	**Percent**
Blue Sky	15328744	3788	5.92	22.0
Clarence-Stahl	19310475	4772	7.46	27.7
Lower Grave Creek	13412227	3314	5.18	19.2
Upper Grave-Foundation-Lewis	13130071	3244	5.07	18.8
Williams Creek	8652848	2138	3.34	12.4
Grave Creek Watershed	**69834364**	**17256**	**26.96**	100.0

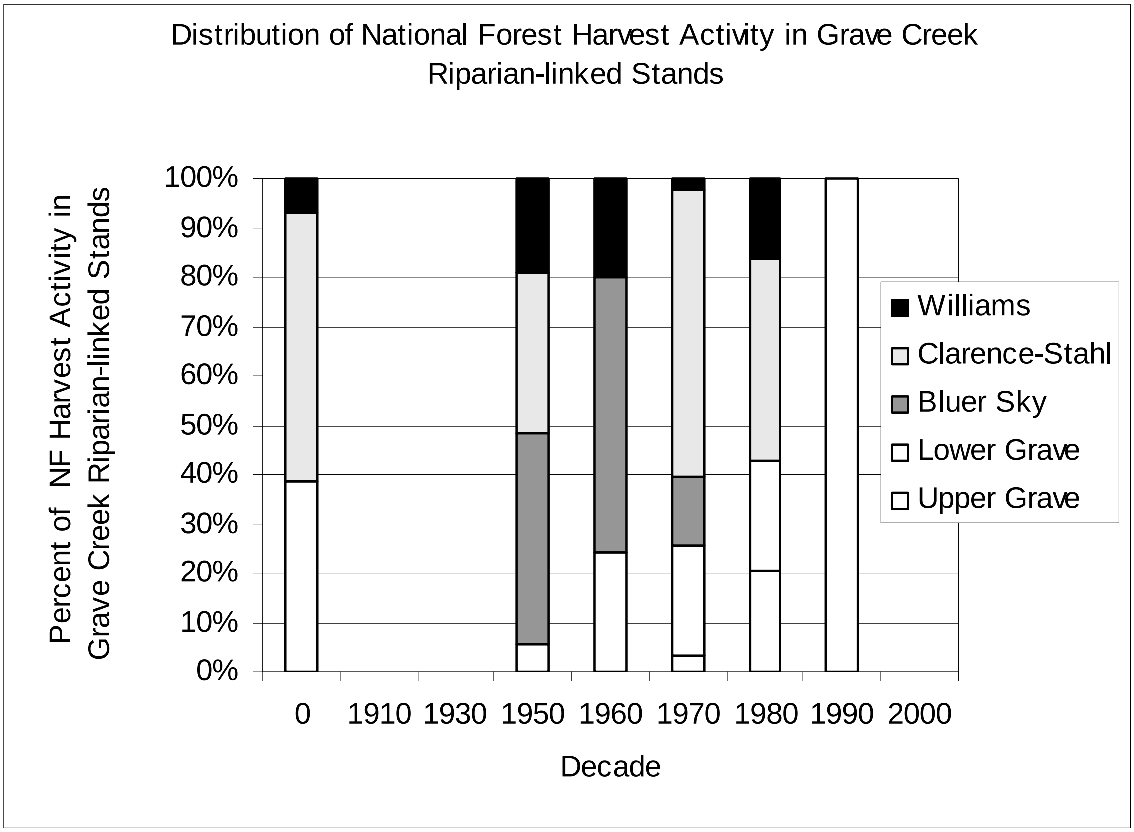


Figure A-3: Distribution of National Forest Harvest Activity in the Grave Creek Riparian-linked Stands.

Table A-5: Area Harvested at Least Once by Sub-Watershed.									
	Area Harvested			**Area Harvested in Riparian Related Stands**			**Area Harvested in ROS Zone**		
Sub-watershed	Miles^2	% Sub-Water-shed	%Water-shed	Miles^2	% Sub-Water-shed	%Water-shed	Miles^2	% Sub-Water-shed	%Water-shed
Blue Sky	**2.1**	**17.0**	**2.8**	**1.8**	**14.8**	**2.4**	**1.2**	**9.9**	**1.6**
Clarence-Stahl	**2.7**	**14.9**	**3.5**	**1.4**	**8.0**	**1.9**	**1.4**	**8.0**	**1.9**
Lower Grave Creek	**2.4**	**10.9**	**3.2**	**0.4**	**2.0**	**0.6**	**0.0**	**0.0**	**0.0**
Upper Grave-Foundation-Lewis	**1.0**	**7.3**	**1.3**	**0.9**	**6.3**	**1.1**	**0.4**	**3.0**	**0.5**
Williams Creek	**1.6**	**17.1**	**2.1**	**0.8**	**8.1**	**1.0**	**0.3**	**2.8**	**0.4**
Total	**9.8**		**13.0**	**5.3**		**7.1**	**3.3**		**4.4**

Table A-6: Area Harvested at Least Once by LTA by Sub-Watershed.										
Harvest Area by LTA by Sub-Watershed										
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Water-shed	%Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	389864	0.4	0.2	96	1.2	0.2	moderate	moderate	high	severe
401	3223	0.0	0.0	1	0.0	0.0	moderate	slight	high	severe
403	94985	0.1	0.0	23	0.3	0.0	moderate	slight	high	severe
404	395997	0.4	0.2	98	1.2	0.2	moderate	moderate	low	moderate
405	22799	0.0	0.0	6	0.1	0.0	moderate	slight	low	moderate
406	623607	0.6	0.2	154	1.9	0.3	moderate	slight	low	moderate
407	2015861	2.0	0.8	498	6.2	1.0	moderate	moderate	high	severe
408	1923845	1.9	0.7	475	6.0	1.0	moderate	slight	high	severe
	5470180	**5.5**	**2.1**	**1352**	**17.0**	**2.8**				
Clarence-Stahl										
108	47251	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	870667	0.9	0.3	215	1.9	0.4	moderate	moderate	high	severe
401	198159	0.2	0.1	49	0.4	0.1	moderate	slight	high	severe
403	10283	0.0	0.0	3	0.0	0.0	moderate	slight	high	severe
404	1875314	1.9	0.7	463	4.0	1.0	moderate	moderate	low	moderate
405	898312	0.9	0.3	222	1.9	0.5	moderate	slight	low	moderate
406	88666	0.1	0.0	22	0.2	0.0	moderate	slight	low	moderate
407	2913626	2.9	1.1	720	6.3	1.5	moderate	moderate	high	severe
408	1133	0.0	0.0	0	0.0	0.0	moderate	slight	high	severe
	6903412	**6.9**	**2.7**	**1706**	**14.9**	**3.5**				
Lower Grave Creek										
102	75521	0.1	0.0	19	0	0.0	moderate	severe	low	moderate
103	134544	0.1	0.1	33	0	0.1	moderate	severe	high	severe
105	156475	0.2	0.1	39	0	0.1	moderate	severe	low	moderate
108	945751	0.9	0.4	234	2	0.5	severe	severe	low	moderate
110	32599	0.0	0.0	8	0	0.0	moderate	severe	low	moderate
321	476874	0.5	0.2	118	1	0.2	moderate	moderate	low	moderate
322	2042682	2.0	0.8	505	4	1.0	moderate	severe	low	moderate
323	976375	1.0	0.4	241	2	0.5	severe	severe	low	moderate
324	1060842	1.1	0.4	262	2	0.5	moderate	moderate	low	moderate
408	90031	0.1	0.0	22	0	0.0	moderate	slight	high	severe
510	179712	0.2	0.1	44	0	0.1	severe	slight	moderate	severe
	6171406	**6.2**	**2.4**	**1525**	**10.9**	**3.2**				
Upper Grave-Foundation-Lewis										
108	306948	0.3	0.1	76	0.9	0.2	severe	severe	low	moderate
351	312877	0.3	0.1	77	0.9	0.2	moderate	moderate	high	severe
401	107250	0.1	0.0	27	0.3	0.1	moderate	slight	high	severe
404	849941	0.8	0.3	210	2.4	0.4	moderate	moderate	low	moderate
405	211722	0.2	0.1	52	0.6	0.1	moderate	slight	low	moderate
406	193902	0.2	0.1	48	0.5	0.1	moderate	slight	low	moderate

Table A-6: Area Harvested at Least Once by LTA by Sub-Watershed.										
Harvest Area by LTA by Sub-Watershed										
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Water-shed	%Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
407	515277	0.5	0.2	127	1.5	0.3	moderate	moderate	high	severe
408	72672	0.1	0.0	18	0.2	0.0	moderate	slight	high	severe
	2570588	**2.6**	**1.0**	**635**	**7.3**	**1.3**				
Williams										
108	99411	0.1	0.0	25	0.4	0.1	severe	severe	low	moderate
322	146471	0.1	0.1	36	0.6	0.1	moderate	severe	low	moderate
401	45382	0.0	0.0	11	0.2	0.0	moderate	slight	high	severe
403	114174	0.1	0.0	28	0.5	0.1	moderate	slight	high	severe
405	1255697	1.3	0.5	310	5.1	0.6	moderate	slight	low	moderate
406	678315	0.7	0.3	168	2.8	0.3	moderate	slight	low	moderate
407	1833424	1.8	0.7	453	7.5	0.9	moderate	moderate	high	severe
408	15747	0.0	0.0	4	0.1	0.0	moderate	slight	high	severe
	4188622	**4.2**	**1.6**	**1035**	**17.1**	**2.1**				
Grave Creek Watershed										
102	75521	0.1	0.0	19		0.0	moderate	severe	low	moderate
103	134544	0.1	0.1	33		0.1	moderate	severe	high	severe
105	156475	0.2	0.1	39		0.1	moderate	severe	low	moderate
108	1399361	1.4	0.5	346		0.7	severe	severe	low	moderate
110	32599	0.0	0.0	8		0.0	moderate	severe	low	moderate
321	476874	0.5	0.2	118		0.2	moderate	moderate	low	moderate
322	2189153	2.2	0.8	541		1.1	moderate	severe	low	moderate
323	976375	1.0	0.4	241		0.5	severe	severe	low	moderate
324	1060842	1.1	0.4	262		0.5	moderate	moderate	low	moderate
351	1573408	1.6	0.6	389		0.8	moderate	moderate	high	severe
401	354014	0.4	0.1	87		0.2	moderate	slight	high	severe
403	219442	0.2	0.1	54		0.1	moderate	slight	high	severe
404	3121252	3.1	1.2	771		1.6	moderate	moderate	low	moderate
405	2388530	2.4	0.9	590		1.2	moderate	slight	low	moderate
406	1584490	1.6	0.6	392		0.8	moderate	slight	low	moderate
407	7278188	7.3	2.8	1798		3.7	moderate	moderate	high	severe
408	2103428	2.1	0.8	520		1.1	moderate	slight	high	severe
510	179712	0.2	0.1	44		0.1	severe	slight	moderate	severe
	25304208	**25.3**	**9.8**	**6253**		**13.0**				

Table A-7: Area Harvested in Riparian-Linked Stands by LTA by Sub-Watershed.

		Harvest Area in Riparian Related Stands by LTA by Sub-Watershed								
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Water-shed	%Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	389864	0.4	0.2	96	1.2	0.2	moderate	moderate	high	severe
401	3223	0.0	0.0	1	0.0	0.0	moderate	slight	high	severe
403	91639	0.1	0.0	23	0.3	0.0	moderate	slight	high	severe
404	252381	0.3	0.1	62	0.8	0.1	moderate	moderate	low	moderate
405	22799	0.0	0.0	6	0.1	0.0	moderate	slight	low	moderate
406	417922	0.4	0.2	103	1.3	0.2	moderate	slight	low	moderate
407	1870951	1.9	0.7	462	5.8	1.0	moderate	moderate	high	severe
408	1724480	1.7	0.7	426	5.3	0.9	moderate	slight	high	severe
	4773259	**4.8**	**1.8**	**1179**	**14.8**	**2.4**				
Clarence-Stahl										
108	47251	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	870667	0.9	0.3	215	1.9	0.4	moderate	moderate	high	severe
401	198159	0.2	0.1	49	0.4	0.1	moderate	slight	high	severe
404	681455	0.7	0.3	168	1.5	0.3	moderate	moderate	low	moderate
405	432746	0.4	0.2	107	0.9	0.2	moderate	slight	low	moderate
406	5129	0.0	0.0	1	0.0	0.0	moderate	slight	low	moderate
407	1470539	1.5	0.6	363	3.2	0.8	moderate	moderate	high	severe
	3705947	**3.7**	**1.4**	**916**	**8.0**	**1.9**				
Lower Grave Creek										
102	22542	0.0	0.0	6	0	0.0	moderate	severe	low	moderate
103	101309	0.1	0.0	25	0	0.1	moderate	severe	high	severe
105	67869	0.1	0.0	17	0	0.0	moderate	severe	low	moderate
108	572661	0.6	0.2	142	1	0.3	severe	severe	low	moderate
323	331267	0.3	0.1	82	1	0.2	severe	severe	low	moderate
324	4818	0.0	0.0	1	0	0.0	moderate	moderate	low	moderate
408	24553	0.0	0.0	6	0	0.0	moderate	slight	high	severe
	1125019	**1.1**	**0.4**	**278**	**2.0**	**0.6**				
Upper Grave-Foundation-Lewis										
108	306948	0.3	0.1	76	0.9	0.2	severe	severe	low	moderate
351	312877	0.3	0.1	77	0.9	0.2	moderate	moderate	high	severe
401	107250	0.1	0.0	27	0.3	0.1	moderate	slight	high	severe
404	631908	0.6	0.2	156	1.8	0.3	moderate	moderate	low	moderate
405	198628	0.2	0.1	49	0.6	0.1	moderate	slight	low	moderate
406	91505	0.1	0.0	23	0.3	0.0	moderate	slight	low	moderate
407	508914	0.5	0.2	126	1.4	0.3	moderate	moderate	high	severe
408	72672	0.1	0.0	18	0.2	0.0	moderate	slight	high	severe
	2230700	**2.2**	**0.9**	**551**	**6.3**	**1.1**				
Williams										
108	99408	0.1	0.0	25	0.4	0.1	severe	severe	low	moderate

Table A-7: Area Harvested in Riparian-Linked Stands by LTA by Sub-Watershed.										
	Harvest Area in Riparian Related Stands by LTA by Sub-Watershed									
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Water-shed	%Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
322	100900	0.1	0.0	25	0.4	0.1	moderate	severe	low	moderate
401	45382	0.0	0.0	11	0.2	0.0	moderate	slight	high	severe
403	69387	0.1	0.0	17	0.3	0.0	moderate	slight	high	severe
405	664160	0.7	0.3	164	2.7	0.3	moderate	slight	low	moderate
406	300175	0.3	0.1	74	1.2	0.2	moderate	slight	low	moderate
407	693530	0.7	0.3	171	2.8	0.4	moderate	moderate	high	severe
408	15747	0.0	0.0	4	0.1	0.0	moderate	slight	high	severe
	1988689	**2.0**	**0.8**	**491**	**8.1**	**1.0**				
Grave Creek Watershed										
102	22542	0.0	0.0	6		0.0	moderate	severe	low	moderate
103	101309	0.1	0.0	25		0.1	moderate	severe	high	severe
105	67869	0.1	0.0	17		0.0	moderate	severe	low	moderate
108	1026268	1.0	0.4	254		0.5	severe	severe	low	moderate
322	100900	0.1	0.0	25		0.1	moderate	severe	low	moderate
323	331267	0.3	0.1	82		0.2	severe	severe	low	moderate
324	4818	0.0	0.0	1		0.0	moderate	moderate	low	moderate
351	1573408	1.6	0.6	389		0.8	moderate	moderate	high	severe
401	354014	0.4	0.1	87		0.2	moderate	slight	high	severe
403	161026	0.2	0.1	40		0.1	moderate	slight	high	severe
404	1565744	1.6	0.6	387		0.8	moderate	moderate	low	moderate
405	1318333	1.3	0.5	326		0.7	moderate	slight	low	moderate
406	814731	0.8	0.3	201		0.4	moderate	slight	low	moderate
407	4543933	4.5	1.8	1123		2.3	moderate	moderate	high	severe
408	1837453	1.8	0.7	454		0.9	moderate	slight	high	severe
	13823614	**13.8**	**5.3**	**3416**		**7.1**				

APPENDIX B
ROADS ANALYSIS SUMMARY

Based on the most current GIS data available (provided by the Kootenai National Forest) approximately 170 miles of roads exist in the Grave Creek Watershed today. “Jammer” roads and skid trails are not included as roads on the GIS layer (Map 10), and are therefore not included in the road length, density and other summary statistics values, thus providing an underestimate of total potential impacts from harvest roads and trails. Many of these skid trails and jammer roads will have revegetated since it has been more than one or two decades since most of the harvest occurred. These trails and jammer roads still have the potential to intercept and route flows, particularly if fire results in removal of some or all of the vegetation, thus creating a potential increased sediment loading impact from an otherwise natural event.

Tables B-1 and B-2 provide length and percentage summaries of the road distribution within the watershed. 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; and 52 miles (30%) are located in the rain-on-snow zone. The rain-on-snow zone is defined by the elevation band between 4500 and 5500 feet. All roads within the 300-foot riparian buffer would also be within the riparian related stands. Roads within the rain-on-snow zone can also fall within the riparian related stands as well as the 300-foot buffer. Table B-3 provides a summary of roads information within sensitive land type associations (LTAs 108 and 407). Tables B-4, B-5 and B-6 provide additional road summary information by watershed and LTAs. Appendix I provides additional analysis of road sediment loading. This analysis takes into account the fact that many roads have been closed and revegetated, thus reducing total erosion and potential sediment contribution to streams.

Table B-1: Road Length Summary (miles).

	Total Road Length (miles)	Road Density (miles/mile^2)	Length In Riparian-Related Stands (miles)	Length In 300' Riparian Buffer (miles)	Length In Rain-on-Snow zone (miles)		
Sub-watershed					Total	%North	%South
Blue Sky	**25.6**	2.1	**22.9**	**8.8**	16.8	79	21
Clarence-Stahl	**36.6**	2.0	**25.1**	**9.2**	19.7	50	50
Lower Grave Creek	**71.8**	3.3	**30.6**	**6.2**	0.0	0	0
Upper Grave-Foundation-Lewis	**19.4**	1.4	**15.7**	**6.7**	11.8	45	55
Williams	**16.6**	1.8	**10.2**	**4.1**	3.5	69	31
Total	**170.0**	2.3	**104.5**	**35.1**	51.8	59	41

Table B-2: Road Length Summary (Percent of Grave Creek Watershed).				
	% Total Road Length	% In Riparian-Related Stands	% In 300' Riparian Buffer	%Length In Rain-on-Snow zone
Sub-watershed				Total
Blue Sky	**15.1**	**13.5**	**5.2**	9.9
Clarence-Stahl	**21.5**	**14.8**	**5.4**	11.6
Lower Grave Creek	**42.2**	**18.0**	**3.7**	0.0
Upper Grave-Foundation-Lewis	**11.4**	**9.2**	**4.0**	22.8
Williams	**9.8**	**6.0**	**2.4**	2.0
Total	**100**	**61.5**	**20.6**	30.5

Table B-3: Miles of Road in LTA 108 and 407.									
Sub-watershed	Miles in LTA 108	%Sub-Water-shed	%Water-shed	Miles in LTA 407	%Sub-Water-shed	%Water-shed	Miles in LTA 108 & 407	%Sub-Water-shed	%Water-shed
Blue Sky	0.0	0.0	0.0	14.4	56.3	8.5	14.4	56.3	8.5
Clarence-Stahl	2.8	7.7	1.6	15.4	42.1	9.1	18.2	49.7	10.7
Lower Grave Creek	13.3	18.5	7.8	0	0.0	0.0	13.3	18.5	7.8
Upper Grave-Foundation-Lewis	3.6	18.6	2.1	5.2	26.8	3.1	8.8	45.4	5.2
Williams Creek	1.3	7.8	0.8	8.1	48.8	4.8	9.4	56.6	5.5
Total	21.1		12.4	43.1		25.4	64.2		37.8

Table B-4: Length of Road by LTA by Sub-Watershed.								
Road Length in LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky								
108	64	0.0	0.2	0.0	severe	severe	low	moderate
351	2734	1.7	6.6	1.0	moderate	moderate	high	severe
401	186	0.1	0.5	0.1	moderate	slight	high	severe
403	1087	0.7	2.6	0.4	moderate	slight	high	severe
404	3929	2.4	9.5	1.4	moderate	moderate	low	moderate
405	1672	1.0	4.1	0.6	moderate	slight	low	moderate
406	2527	1.6	6.1	0.9	moderate	slight	low	moderate
407	23104	14.4	56.0	8.4	moderate	moderate	high	severe
408	5930	3.7	14.4	2.2	moderate	slight	high	severe
	41235	**25.6**	**100.0**	**15.1**				
Clarence-Stahl								
108	4549	2.8	7.7	1.7	severe	severe	low	moderate
351	4841	3.0	8.2	1.8	moderate	moderate	high	severe
401	1782	1.1	3.0	0.7	moderate	slight	high	severe

Table B-4: Length of Road by LTA by Sub-Watershed.								
Road Length in LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
404	19382	12.0	32.9	7.1	moderate	moderate	low	moderate
405	2497	1.6	4.2	0.9	moderate	slight	low	moderate
406	1038	0.6	1.8	0.4	moderate	slight	low	moderate
407	24856	15.4	42.2	9.1	moderate	moderate	high	severe
	58944	**36.6**	**100.0**	**21.5**				
Lower Grave Creek								
102	1656	1.0	1.4	0.6	moderate	severe	low	moderate
103	15641	9.7	13.5	5.7	moderate	severe	high	severe
105	1162	0.7	1.0	0.4	moderate	severe	low	moderate
106	1144	0.7	1.0	0.4	moderate	severe	low	moderate
108	21397	13.3	18.5	7.8	severe	severe	low	moderate
110	501	0.3	0.4	0.2	moderate	severe	low	moderate
251	29	0.0	0.0	0.0	moderate	slight	high	severe
321	14509	9.0	12.6	5.3	moderate	moderate	low	moderate
322	25823	16.0	22.4	9.4	moderate	severe	low	moderate
323	9108	5.7	7.9	3.3	severe	severe	low	moderate
324	23993	14.9	20.8	8.8	moderate	moderate	low	moderate
408	564	0.4	0.5	0.2	moderate	slight	high	severe
	115526	**71.8**	**100.0**	**42.2**				
Upper Grave-Foundation-Lewis								
108	5779	3.6	18.5	2.1	severe	severe	low	moderate
351	2473	1.5	7.9	0.9	moderate	moderate	high	severe
401	1666	1.0	5.3	0.6	moderate	slight	high	severe
404	9751	6.1	31.3	3.6	moderate	moderate	low	moderate
405	576	0.4	1.8	0.2	moderate	slight	low	moderate
406	2497	1.6	8.0	0.9	moderate	slight	low	moderate
407	8444	5.2	27.1	3.1	moderate	moderate	high	severe
	31185	**19.4**	**100.0**	**11.4**				
Williams								
108	2107	1.3	7.9	0.8	severe	severe	low	moderate
322	1344	0.8	5.0	0.5	moderate	severe	low	moderate
401	752	0.5	2.8	0.3	moderate	slight	high	severe
403	17	0.0	0.1	0.0	moderate	slight	high	severe
405	6056	3.8	22.7	2.2	moderate	slight	low	moderate
406	2359	1.5	8.8	0.9	moderate	slight	low	moderate
407	12979	8.1	48.6	4.7	moderate	moderate	high	severe
408	1071	0.7	4.0	0.4	moderate	slight	high	severe
	26684	**16.6**	**100.0**	**9.8**				
Grave Creek Watershed								
102	1656	1.0		0.6	moderate	severe	low	moderate
103	15641	9.7		5.7	moderate	severe	high	severe
105	1162	0.7		0.4	moderate	severe	low	moderate

Table B-4: Length of Road by LTA by Sub-Watershed.								
Road Length in LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
106	1144	0.7		0.4	moderate	severe	low	moderate
108	33896	21.1		12.4	severe	severe	low	moderate
110	501	0.3		0.2	moderate	severe	low	moderate
251	29	0.0		0.0	moderate	slight	high	severe
321	14509	9.0		5.3	moderate	moderate	low	moderate
322	27167	16.9		9.9	moderate	severe	low	moderate
323	9108	5.7		3.3	severe	severe	low	moderate
324	23993	14.9		8.8	moderate	moderate	low	moderate
351	10048	6.2		3.7	moderate	moderate	high	severe
401	4386	2.7		1.6	moderate	slight	high	severe
403	1104	0.7		0.4	moderate	slight	high	severe
404	33061	20.5		12.1	moderate	moderate	low	moderate
405	10802	6.7		3.9	moderate	slight	low	moderate
406	8420	5.2		3.1	moderate	slight	low	moderate
407	69383	43.1		25.4	moderate	moderate	high	severe
408	7564	4.7		2.8	moderate	slight	high	severe
	273574	**170.0**		**100.0**				

Table B-5: Length of Road in Riparian-Related Stands by LTA by Sub-Watershed.								
Road Length in Riparian-Related Stands by LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky								
108	64	0.0	0.2	0.0	severe	severe	low	moderate
351	2040	1.3	4.9	0.7	moderate	moderate	high	severe
401	186	0.1	0.5	0.1	moderate	slight	high	severe
403	410	0.3	1.0	0.1	moderate	slight	high	severe
404	2411	1.5	5.8	0.9	moderate	moderate	low	moderate
405	1672	1.0	4.1	0.6	moderate	slight	low	moderate
406	2054	1.3	5.0	0.8	moderate	slight	low	moderate
407	22365	13.9	54.2	8.2	moderate	moderate	high	severe
408	5625	3.5	13.6	2.1	moderate	slight	high	severe
	36829	**22.9**	**89.3**	**13.5**				
Clarence-Stahl								
108	4549	2.8	7.7	1.7	severe	severe	low	moderate
351	4763	3.0	8.1	1.7	moderate	moderate	high	severe
401	1782	1.1	3.0	0.7	moderate	slight	high	severe
404	10099	6.3	17.1	3.7	moderate	moderate	low	moderate
405	1895	1.2	3.2	0.7	moderate	slight	low	moderate
406	98	0.1	0.2	0.0	moderate	slight	low	moderate

Table B-5: Length of Road in Riparian-Related Stands by LTA by Sub-Watershed.								
Road Length in Riparian-Related Stands by LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
407	17199	10.7	29.2	6.3	moderate	moderate	high	severe
	40386	**25.1**	**68.5**	**14.8**				
Lower Grave Creek								
102	135	0.1	0	0.0	moderate	severe	low	moderate
103	12511	7.8	11	4.6	moderate	severe	high	severe
105	616	0.4	1	0.2	moderate	severe	low	moderate
106	543	0.3	0	0.2	moderate	severe	low	moderate
108	16992	10.6	15	6.2	severe	severe	low	moderate
110	8	0.0	0	0.0	moderate	severe	low	moderate
251	29	0.0	0	0.0	moderate	slight	high	severe
321	3618	2.2	3	1.3	moderate	moderate	low	moderate
322	2461	1.5	2	0.9	moderate	severe	low	moderate
323	4737	2.9	4	1.7	severe	severe	low	moderate
324	7667	4.8	7	2.8	moderate	moderate	low	moderate
	49317	**30.6**	**42.7**	**18.0**				
Upper Grave-Foundation-Lewis								
108	5706	3.5	18.3	2.1	severe	severe	low	moderate
351	2422	1.5	7.8	0.9	moderate	moderate	high	severe
401	1570	1.0	5.0	0.6	moderate	slight	high	severe
404	6867	4.3	22.0	2.5	moderate	moderate	low	moderate
405	474	0.3	1.5	0.2	moderate	slight	low	moderate
406	1637	1.0	5.2	0.6	moderate	slight	low	moderate
407	6573	4.1	21.1	2.4	moderate	moderate	high	severe
	25248	**15.7**	**81.0**	**9.2**				
Williams								
108	1940.0366	1.2	7.3	0.7	severe	severe	low	moderate
322	943.9127	0.6	3.5	0.3	moderate	severe	low	moderate
401	751.5478	0.5	2.8	0.3	moderate	slight	high	severe
405	2899.7793	1.8	10.9	1.1	moderate	slight	low	moderate
406	2031.3657	1.3	7.6	0.7	moderate	slight	low	moderate
407	6721.7229	4.2	25.2	2.5	moderate	moderate	high	severe
408	1070.6976	0.7	4.0	0.4	moderate	slight	high	severe
	16359	**10.2**	**61.3**	**6.0**				
Grave Creek Watershed								
102	135	0.1		0.0	moderate	severe	low	moderate
103	12511	7.8		4.6	moderate	severe	high	severe
105	616	0.4		0.2	moderate	severe	low	moderate
106	543	0.3		0.2	moderate	severe	low	moderate
108	29251	18.2		10.7	severe	severe	low	moderate
110	8	0.0		0.0	moderate	severe	low	moderate
251	29	0.0		0.0	moderate	slight	high	severe
321	3618	2.2		1.3	moderate	moderate	low	moderate

Table B-5: Length of Road in Riparian-Related Stands by LTA by Sub-Watershed.								
Road Length in Riparian-Related Stands by LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
322	3405	2.1		1.2	moderate	severe	low	moderate
323	4737	2.9		1.7	severe	severe	low	moderate
324	7667	4.8		2.8	moderate	moderate	low	moderate
351	9224	5.7		3.4	moderate	moderate	high	severe
401	4290	2.7		1.6	moderate	slight	high	severe
403	410	0.3		0.1	moderate	slight	high	severe
404	19378	12.0		7.1	moderate	moderate	low	moderate
405	6941	4.3		2.5	moderate	slight	low	moderate
406	5821	3.6		2.1	moderate	slight	low	moderate
407	52859	32.8		19.3	moderate	moderate	high	severe
408	6696	4.2		2.4	moderate	slight	high	severe
	168139	**104.5**		**61.5**				

Table B-6: Road Length Within 300' Riparian Buffer by LTA by Sub-Watershed.								
Road Length in 300' Riparian Buffer by LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky								
401	161	0.1	0.4	0.1	moderate	slight	high	severe
404	313	0.2	0.8	0.1	moderate	moderate	low	moderate
405	229	0.1	0.6	0.1	moderate	slight	low	moderate
407	11754	7.3	28.5	4.3	moderate	moderate	high	severe
408	1677	1.0	4.1	0.6	moderate	slight	high	severe
	14133	**8.8**	**34.3**	**5.2**				
Clarence-Stahl								
108	3237	2.0	5.5	1.2	severe	severe	low	moderate
351	354	0.2	0.6	0.1	moderate	moderate	high	severe
401	214	0.1	0.4	0.1	moderate	slight	high	severe
404	2331	1.4	4.0	0.9	moderate	moderate	low	moderate
405	346	0.2	0.6	0.1	moderate	slight	low	moderate
407	8393	5.2	14.2	3.1	moderate	moderate	high	severe
	14874	**9.2**	**25.2**	**5.4**				
Lower Grave Creek								
102	8	0.0	0	0.0	moderate	severe	low	moderate
103	4433	2.8	4	1.6	moderate	severe	high	severe
105	35	0.0	0	0.0	moderate	severe	low	moderate
106	1	0.0	0	0.0	moderate	severe	low	moderate
108	4088	2.5	4	1.5	severe	severe	low	moderate
321	69	0.0	0	0.0	moderate	moderate	low	moderate
323	1154	0.7	1	0.4	severe	severe	low	moderate

Table B-6: Road Length Within 300' Riparian Buffer by LTA by Sub-Watershed.								
Road Length in 300' Riparian Buffer by LTA by Sub-Watershed								
Landtype	Meters	Miles	% Sub-Water-shed	% Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
324	204	0.1	0	0.1	moderate	moderate	low	moderate
	9993	**6.2**	**8.6**	**3.7**				
Upper Grave-Foundation-Lewis								
108	3561	2.2	11.4	1.3	severe	severe	low	moderate
351	1586	1.0	5.1	0.6	moderate	moderate	high	severe
401	532	0.3	1.7	0.2	moderate	slight	high	severe
404	3211	2.0	10.3	1.2	moderate	moderate	low	moderate
405	7	0.0	0.0	0.0	moderate	slight	low	moderate
407	1943	1.2	6.2	0.7	moderate	moderate	high	severe
	10840	**6.7**	**34.8**	**4.0**				
Williams								
108	1151	0.7	4.3	0.4	severe	severe	low	moderate
322	13	0.0	0.1	0.0	moderate	severe	low	moderate
401	752	0.5	2.8	0.3	moderate	slight	high	severe
405	533	0.3	2.0	0.2	moderate	slight	low	moderate
406	813	0.5	3.0	0.3	moderate	slight	low	moderate
407	2280	1.4	8.5	0.8	moderate	moderate	high	severe
408	1071	0.7	4.0	0.4	moderate	slight	high	severe
	6613	**4.1**	**24.8**	**2.4**				
Grave Creek Watershed								
102	8	0.0		0.0	moderate	severe	low	moderate
103	4433	2.8		1.6	moderate	severe	high	severe
105	35	0.0		0.0	moderate	severe	low	moderate
106	1	0.0		0.0	moderate	severe	low	moderate
108	12038	7.5		4.4	severe	severe	low	moderate
321	69	0.0		0.0	moderate	moderate	low	moderate
322	13	0.0		0.0	moderate	severe	low	moderate
323	1154	0.7		0.4	severe	severe	low	moderate
324	204	0.1		0.1	moderate	moderate	low	moderate
351	1939	1.2		0.7	moderate	moderate	high	severe
401	1658	1.0		0.6	moderate	slight	high	severe
404	5855	3.6		2.1	moderate	moderate	low	moderate
405	1115	0.7		0.4	moderate	slight	low	moderate
406	813	0.5		0.3	moderate	slight	low	moderate
407	24370	15.1		8.9	moderate	moderate	high	severe
408	2748	1.7		1.0	moderate	slight	high	severe
	56453	**35.1**		**20.6**				

APPENDIX C
RAIN-ON-SNOW, WATER YIELD, EQUIVALENT CLEARCUT ACREAGE AND PEAK FLOW INCREASES ANALYSIS SUMMARY

This section includes the results of spatial analysis conducted for the Grave Creek watershed to analyze timber harvest and road building activities that could potentially affect the hydrology and runoff regime of the watershed. Two sets of analyses are included: road and harvest activity within the rain on snow zone conducted by River Design Group (2003-2004), and water yield analysis conducted by the USFS (2004). The water yield analysis includes equivalent clearcut area (ECA) and peak flow increase (PFI) modeling.

Like roads, skid trails and jammer roads constructed in the rain-on-snow zone in the watershed (4,500 ft to 5,500 ft) can potentially modify the routing efficiency of managed sub-basins, shifting the timing of the peak flow to earlier in the snowmelt season, and increasing the magnitude of channel forming discharges. However, skid trails and jammer roads are not considered in these analyses because neither a map nor GIS layers of their extent and location have been compiled. These trails and jammer roads still have the potential to intercept and route flows, although the level of impact under normal conditions has been mitigated since many of these skid trails and jammer roads will have revegetated over time.

C.1 Rain on Snow Analysis

The rain-on-snow analysis is an extension of the harvest analysis and the road analyses provided in Appendix A and B, respectively. Summary statistics provided below were generated using the same input data and the same methods as those described in Appendix A and B. This rain-on-snow analysis includes summary statistics for road building and harvest activity within the rain-on-snow zone only. The rain-on-snow zone is defined as the area within the elevation band between 4500 and 5500 feet. This band was delineated using a 30m digital elevation model (USGS) provided by the Kootenai National Forest.

Table C-1: Area Harvested at Least Once within Rain-on-Snow Zone by Sub-Watershed.

Sub-watershed	Meters^2	KM^2	Miles^2	Acres	%Sub-Water-shed	% Water-shed	%North	%South
Blue Sky	3180772	3.2	1.2	786	9.9	1.6	97	3
Clarence-Stahl	3720606	3.7	1.4	919	8.0	1.9	50	50
Lower Grave Creek	0	0.0	0.0	0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	1052185	1.1	0.4	260	3.0	0.5	68	32
Williams Creek	690617	0.7	0.3	171	2.8	0.4	39	61
Total	**8644181**	**8.6**	**3.3**	**2136**		**4.4**	**69**	**31**

Table C-2: Harvest Area within Rain-on-Snow zone by LTA by Sub-Watershed.										
Landtype	Meters2	KM2	Miles2	Acres	% Sub-Watershed	% Grave Watershed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	180657	0.2	0.1	45	0.6	0.1	moderate	moderate	high	severe
404	357828	0.4	0.1	88	1.1	0.2	moderate	moderate	low	moderate
406	128528	0.1	0.0	32	0.4	0.1	moderate	slight	low	moderate
407	813882	0.8	0.3	201	2.5	0.4	moderate	moderate	high	severe
408	1699878	1.7	0.7	420	5.3	0.9	moderate	slight	high	severe
	3180773	**3.2**	**1.2**	**786**	**9.9**	**1.6**				
Clarence-Stahl										
351	618643	0.6	0.2	153	1.3	0.3	moderate	moderate	high	severe
401	135230	0.1	0.1	33	0.3	0.1	moderate	slight	high	severe
404	1746107	1.7	0.7	431	3.8	0.9	moderate	moderate	low	moderate
405	14497	0.0	0.0	4	0.0	0.0	moderate	slight	low	moderate
406	27486	0.0	0.0	7	0.1	0.0	moderate	slight	low	moderate
407	1177511	1.2	0.5	291	2.5	0.6	moderate	moderate	high	severe
408	1133	0.0	0.0	0	0.0	0.0	moderate	slight	high	severe
	3720606	**3.7**	**1.4**	**919**	**8.0**	**1.9**				
Lower Grave Creek										
Upper Grave-Foundation-Lewis										
108	47740	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	164775	0.2	0.1	41	0.5	0.1	moderate	moderate	high	severe
401	97177	0.1	0.0	24	0.3	0.0	moderate	slight	high	severe
404	374374	0.4	0.1	93	1.1	0.2	moderate	moderate	low	moderate
405	501	0.0	0.0	0	0.0	0.0	moderate	slight	low	moderate
406	37826	0.0	0.0	9	0.1	0.0	moderate	slight	low	moderate
407	283609	0.3	0.1	70	0.8	0.1	moderate	moderate	high	severe
408	46182	0.0	0.0	11	0.1	0.0	moderate	slight	high	severe
	1052185	**1.1**	**0.4**	**260**	**3.0**	**0.5**				
Williams										
401	18702	0.0	0.0	5	0.1	0.0	moderate	slight	high	severe
406	194648	0.2	0.1	48	0.8	0.1	moderate	slight	low	moderate
407	477267	0.5	0.2	118	1.9	0.2	moderate	moderate	high	severe
	690617	**0.7**	**0.3**	**171**	**2.8**	**0.4**				
Grave Creek Watershed										
108	47740	0.0	0.0	12		0.0	severe	severe	low	moderate
351	964075	1.0	0.4	238		0.5	moderate	moderate	high	severe
401	251109	0.3	0.1	62		0.1	moderate	slight	high	severe
404	2478309	2.5	1.0	612		1.3	moderate	moderate	low	moderate
405	14998	0.0	0.0	4		0.0	moderate	slight	low	moderate
406	388488	0.4	0.1	96		0.2	moderate	slight	low	moderate
407	2752269	2.8	1.1	680		1.4	moderate	moderate	high	severe
408	1747193	1.7	0.7	432		0.9	moderate	slight	high	severe
	8644181	**8.6**	**3.3**	**2136**		**4.4**				

Table C-3: Area of Riparian-Linked Stands Harvested at Least Once Within the 4500-5500' Elevation Band by Sub-Watershed.								
Sub-watershed	Meters^2	KM^2	Miles^2	Acres	%Sub-Water-shed	%Water-shed	%North	%South
Blue Sky	2851921	2.9	1.1	705	8.8	1.5	97	3
Clarence-Stahl	2347276	2.3	0.9	580	5.1	1.2	47	53
Lower Grave Creek	0	0.0	0.0	0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	886333	0.9	0.3	219	2.5	0.5	67	33
Williams Creek	651565	0.7	0.3	161	2.7	0.3	41	59
Total	**6737095**	**6.7**	**2.6**	**1665**		**3.5**	**70**	**30**

Table C-4: Harvest Area in Riparian Related Stands within Rain-on-Snow Zone by LTA by Sub-Watershed.										
Landtype	Meters2	KM2	Miles2	Acres	%Sub-Water-shed	%Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky										
351	180657	0.2	0.1	45	0.6	0.1	moderate	moderate	high	severe
404	214213	0.2	0.1	53	0.7	0.1	moderate	moderate	low	moderate
406	128528	0.1	0.0	32	0.4	0.1	moderate	slight	low	moderate
407	813882	0.8	0.3	201	2.5	0.4	moderate	moderate	high	severe
408	1514642	1.5	0.6	374	4.7	0.8	moderate	slight	high	severe
	2851921	**2.9**	**1.1**	**705**	**8.8**	**1.5**				
Clarence-Stahl										
351	618643	0.6	0.2	153	1.3	0.3	moderate	moderate	high	severe
401	135230	0.1	0.1	33	0.3	0.1	moderate	slight	high	severe
404	569993	0.6	0.2	141	1.2	0.3	moderate	moderate	low	moderate
405	14497	0.0	0.0	4	0.0	0.0	moderate	slight	low	moderate
406	5129	0.0	0.0	1	0.0	0.0	moderate	slight	low	moderate
407	1003784	1.0	0.4	248	2.2	0.5	moderate	moderate	high	severe
	2347276	**2.3**	**0.9**	**580**	**5.1**	**1.2**				
Lower Grave Creek										
Upper Grave-Foundation-Lewis										
108	47740	0.0	0.0	12	0.1	0.0	severe	severe	low	moderate
351	164775	0.2	0.1	41	0.5	0.1	moderate	moderate	high	severe
401	97177	0.1	0.0	24	0.3	0.0	moderate	slight	high	severe
404	246544	0.2	0.1	61	0.7	0.1	moderate	moderate	low	moderate
406	3807	0.0	0.0	1	0.0	0.0	moderate	slight	low	moderate
407	280108	0.3	0.1	69	0.8	0.1	moderate	moderate	high	severe
408	46182	0.0	0.0	11	0.1	0.0	moderate	slight	high	severe
	886333	**0.9**	**0.3**	**219**	**2.5**	**0.5**				
Williams										
401	18702	0.0	0.0	5	0.1	0.0	moderate	slight	high	severe
406	163173	0.2	0.1	40	0.7	0.1	moderate	slight	low	moderate

Table C-4: Harvest Area in Riparian Related Stands within Rain-on-Snow Zone by LTA by Sub-Watershed.										
Landtype	Meters2	KM2	Miles2	Acres	%Sub-Water-shed	%Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
407	469690	0.5	0.2	116	1.9	0.2	moderate	moderate	high	severe
	651565	**0.7**	**0.3**	**161**	**2.7**	**0.3**				
Grave Creek Watershed										
108	47740	0.0	0.0	12		0.0	severe	severe	low	moderate
351	964075	1.0	0.4	238		0.5	moderate	moderate	high	severe
401	251109	0.3	0.1	62		0.1	moderate	slight	high	severe
404	1030749	1.0	0.4	255		0.5	moderate	moderate	low	moderate
405	14497	0.0	0.0	4		0.0	moderate	slight	low	moderate
406	300638	0.3	0.1	74		0.2	moderate	slight	low	moderate
407	2567463	2.6	1.0	634		1.3	moderate	moderate	high	severe
408	1560824	1.6	0.6	386		0.8	moderate	slight	high	severe
	6737095	**6.7**	**2.6**	**1665**		**3.5**				

Table C-5: Road Length Within the 4500-5500' Elevation Band by Sub-Watershed.								
Sub-watershed	% Total Road Length in HUC 6.5 within ROS band	Meters	Feet	Miles	% Sub-Water-shed	% Water-shed	%North	%Sout h
Blue Sky	66	27122	88959	16.8	65.8	9.9	79	21
Clarence-Stahl	54	31701	103979	19.7	53.8	11.6	50	50
Lower Grave Creek	0	0	0	0.0	0.0	0.0	0	0
Upper Grave-Foundation-Lewis	61	19022	62392	11.8	61.0	22.8	45	55
Williams Creek	21	5578	18295	3.5	20.9	2.0	69	31
Total	**53**	**83422**	**273625**	**51.8**		**30.5**	**59**	**41**

Table C-6: Road Length in Rain-on-Snow band by LTA by Sub-Watershed.								
Landtype	Meters	Miles	% Sub-Water-shed	% Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
Blue Sky								
351	1639	1.0	4.0	0.6	moderate	moderate	high	severe
401	186	0.1	0.5	0.1	moderate	slight	high	severe
404	3473	2.2	8.4	1.3	moderate	moderate	low	moderate
406	1705	1.1	4.1	0.6	moderate	slight	low	moderate
407	14396	8.9	34.9	5.3	moderate	moderate	high	severe
408	5723	3.6	13.9	2.1	moderate	slight	high	severe
	27122	**16.9**	**65.8**	**9.9**				
Clarence-Stahl								
351	2441	1.5	4.1	0.9	moderate	moderate	high	severe
401	1225	0.8	2.1	0.4	moderate	slight	high	severe
404	15422	9.6	26.2	5.6	moderate	moderate	low	moderate

Table C-6: Road Length in Rain-on-Snow band by LTA by Sub-Watershed.								
Landtype	Meters	Miles	% Sub-Water-shed	% Grave Water-shed	Surface Erodibility	Subsurface Erodibility	Delivery Efficiency	Sediment Hazard
406	219	0.1	0.4	0.1	moderate	slight	low	moderate
407	12394	7.7	21.0	4.5	moderate	moderate	high	severe
	31701	**19.7**	**53.8**	**11.6**				
Lower Grave Creek								
Upper Grave-Foundation-Lewis								
108	886	0.6	2.8	1.1	severe	severe	low	moderate
351	1753	1.1	5.6	2.1	moderate	moderate	high	severe
401	1513	0.9	4.9	1.8	moderate	slight	high	severe
404	6770	4.2	21.7	8.1	moderate	moderate	low	moderate
406	1096	0.7	3.5	1.3	moderate	slight	low	moderate
407	7003	4.4	22.5	8.4	moderate	moderate	high	severe
	19022	**11.8**	**61.0**	**22.8**				
Williams								
401	364	0.2	1.4	0.1	moderate	slight	high	severe
406	1700	1.1	6.4	0.6	moderate	slight	low	moderate
407	3316	2.1	12.4	1.2	moderate	moderate	high	severe
408	197	0.1	0.7	0.1	moderate	slight	high	severe
	5578	**3.5**	**20.9**	**2.0**				
Grave Creek Watershed								
108	886	0.6		0.3	severe	severe	low	moderate
351	5833	3.6		2.1	moderate	moderate	high	severe
401	3289	2.0		1.2	moderate	slight	high	severe
404	25665	15.9		9.4	moderate	moderate	low	moderate
406	4720	2.9		1.7	moderate	slight	low	moderate
407	37109	23.1		13.6	moderate	moderate	high	severe
408	5920	3.7		2.2	moderate	slight	high	severe
	83422	**51.8**		**30.5**				

C.2. Water Yield, Equivalent Clearcut Acreage and Peak Flow Increases Analysis

The impact of increased water yield on sediment transport depends on both the sediment availability as well as the temporal distribution of the additional water on the flow hydrograph. Data derived from closely monitored, harvested watersheds characterized by spring snowmelt runoff have shown that the flow augmentation tends to be concentrated on the rising limb and peak of that spring snowmelt runoff event (Troendle et al., 2001).

An increase in stream flow during the snowmelt period can result in a significant increase in sediment transport capacity, as spring runoff conditions commonly constitute the channel forming discharge characterized by active sediment transport and channel adjustment (Andrews and Nankervis, 1995). In an analysis of sediment transport from Deadhorse Creek (Troendle and Olsen, 1994) it was concluded that documented increases in sediment production following timber harvest were derived from channel bank or bed scour due to increased duration of higher flows.

ECA, water yield, and peak flow increase estimates may also be used as a potential indicator of increased sediment production from other soil disturbing activities related to vegetation removal, for example skid trails. If sediment is conveyed to the stream network, the increased sediment transport capacity caused by an increase in peak flows will result in an increased delivery of sediment to Grave Creek. Alternatively, if sediment is not available for transport, increased transport energy will result in sediment sourcing downstream from the channel perimeter due to bank and bed scour (Troendle et al., 2001). Therefore, the most effective means of preventing increased water yield and associated sediment delivery is to increase or maintain vegetative cover.

Analysis of the effects of vegetation removal from road building and timber harvest on water yield included modeling of Equivalent Clearcut Areas (ECA) and associated projected Peak Flow Increases (PFI). This analysis was conducted by the USFS. The analysis included harvest activity recorded in the USFS TSMRS (Timber Stand Management Record System) as well as consideration of vegetation removed for roads and from the Kopsi Fire. The period of analysis was 1915 through 1998. Harvest and other activity on private land and National Forest harvest activity not recorded in TSMRS were not included. The TSMRS activity codes considered in this analysis are included in Table C-7.

Below is a summary of the parameters used by the USFS to run these analyses.

- Road ECAs are computed (4 acres per mile of road).
- HIR (historic roads) roads are included.
- Calculated PFI uses Forest Plan formula in Vol. II, Pp A 18-6, with maximum percent increase constants of .77 per road ECA and .45 per harvest ECA.
- WATSED PFI uses relationship between 217 %ECA and %PFI points (R^2 = .8971).

Table C-7: ECA Analysis Included the Following TSMRS Activity Codes.

TSMRS Activity Code	TSMRS Activity Description
4111	Clearcut – Patch
4113	Clearcut – Stand
4114	Clearcut - with Reserves
4131	Shelterwood Seed Cut
4132	Seed Tree Seed Cut
4146	Shelterwood Final Cut
4147	Seed Tree Final Cut
4148	Shelterwood Final Cut with Reserves
4149	Seed Tree Final Cut with Reserves
4152	Group Selection Cut
4211	Liberation Cutting

Table C-7: ECA Analysis Included the Following TSMRS Activity Codes.	
TSMRS Activity Code	TSMRS Activity Description
4220	Thinning
4230	Sanitation Salvage
4250*	Natural Changes (Blue Sky/Kopsi Fire)
4270*	Permanent Land Clearing

* Not included in the timber harvest analysis described in Appendix A. Timber harvest analysis in Appendix A also included 4521 (pre-commercial thinning) and 4987 (fire line construction).

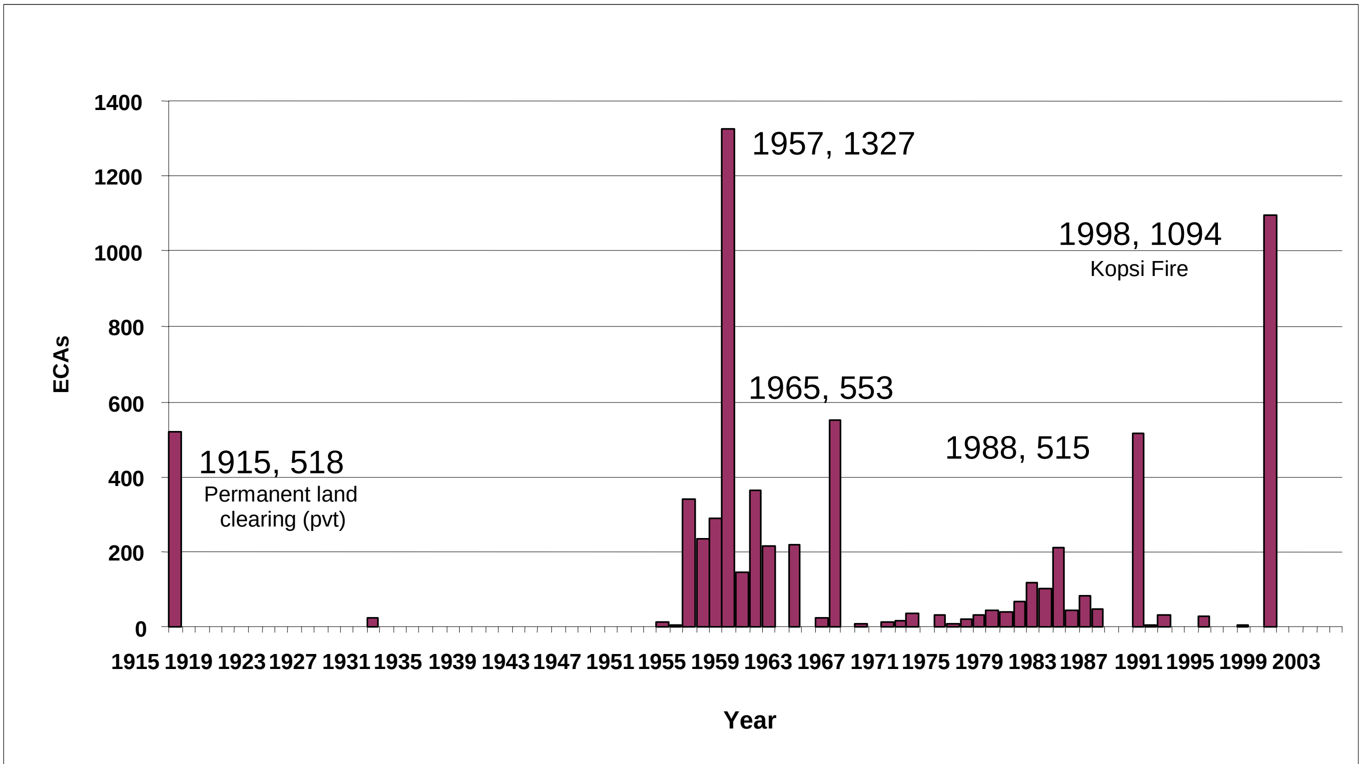


Figure C.3: Summary of ECA in Grave Creek Watershed.
Does not include timber harvest on privately owned land or land clearing on privately owned land after early twentieth-century development.

Figure C-3 provides a historical context for the equivalent clearcut acreage. Table C-8 summarizes the results of the equivalent clearcut area (ECA) and peak flow increase (PFI) analyses for tributary watersheds and all of the Grave Creek Watershed. The road modeling portion of the ECA is based on 2003 conditions. Watershed ECA from road and vegetation changes, either from historic harvest or the more recent Kopsi Fire, was modeled at 5 percent, with vegetation change constituting 72 percent of the cumulative ECA. Total watershed PFI was 2.5 percent. These existing PFI values linked to timber harvest activities in all watersheds are not considered very high and are likely not of significant concern. When the Kopsi Fire ECA results are removed, the harvest related PFI in the Blue Sky drainage would be within the range of the other watersheds (personal communication with Julie Gott, February 2005).

Historical values in all drainages and for the whole watershed would have been higher in the late 1950s through 1960s period based on the PFI calculation methodology and the Figure C.3 data. These elevated historical PFI values, in combination with a lack of BMPs during the 1950s and 1960s, including operations within the riparian areas, would likely have contributed to fine and coarse sediment loading based on the above discussions and references.

Table C-8. Equivalent Clearcut Area (ECA) and Peak Flow Increase (PFI) Results for the Grave Creek Watershed.

					Forest Plan Calculations			
	Road	Vegetation Change	Wtrsh	Percent	Roads	Vegetation Change	Total	WATSED
Watershed	ECAs	ECAs	Acres	ECA	PFI	PFI	PFI	PFI
Blue Sky	104	1326	7972	18%	1.0%	7.5%	8.5%	9.3%
Lewis	18	41	2458	2%	0.6%	0.8%	1.3%	1.9%
Foundation	29	76	1760	6%	1.3%	2.0%	3.2%	3.6%
Upper Grave	71	83	4507	3%	1.2%	0.8%	2.0%	2.4%
Clarence	63	175	4207	6%	1.2%	1.9%	3.0%	3.4%
Stahl	102	251	4351	8%	1.8%	2.6%	4.4%	4.6%
Upper Middle Grave	33	14	2925	2%	0.9%	0.2%	1.1%	1.5%
Williams	78	198	6048	5%	1.0%	1.5%	2.5%	2.9%
Lower Middle Grave	133	162	8571	3%	1.2%	0.9%	2.0%	2.4%
Lower Grave	285	309	5359	11%	4.1%	2.6%	6.7%	6.0%
Grave CE	916	2634	48158	7%	1.5%	2.5%	3.9%	4.3%

APPENDIX D
FISHERIES AND AQUATIC LIFE

D.1 Fisheries Overview

Grave Creek supports a largely native assemblage of fish comprised of ten species within four families (Table D-1). 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 catostomidae 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). Map 12 provides distribution data for several key fish species in the Grave Creek Watershed.

Classified as a bull trout core area (Montana Bull Trout Scientific Group, 1996b), Grave Creek is the major bull trout spawning tributary in Montana's portion of 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).

Table D-1: Native and Introduced Fish Species Sampled Inhabiting Grave Creek.
Native Species
Bull trout (*Salvelinus confluentus*)
Westslope cutthroat trout (*Oncorhynchus clarki lewisi*)
Largescale 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*)

D.2 Bull Trout

The Tobacco/Grave bull trout subpopulation (stock) is a part of the larger upper Kootenai River meta-population. The Tobacco/Grave population consists of both migratory and resident life forms. Both life forms are known to inhabit or reproduce in Grave Creek and the following tributaries: Lewis, Blue Sky, Clarence, Stahl, and Williams creeks. Both Stahl and Williams Creeks have in-stream falls that are fish passage barriers (USFS, 2000). Table D-2 includes species indicator classifications for the Tobacco/Grave bull trout subpopulation (stock).

Table D-2: Bull Trout Species Indicators for the Tobacco/Grave Subpopulation (USFS, 2000).	
Indicator Metric	Condition
Subpopulation Size	FAR
Growth and Survival	FAR
Life History Diversity and Connectivity	FAR
Persistence and Genetic Integrity	FAR

FAR = Functioning at Risk

D.2.1 Bull Trout Spawning Redd Results

MFWP maintains a spawning redd database for Grave Creek. The number of spawning redds in the watershed have significantly increased since 1995 (MFWP, unpublished data) (Table D-3). MFWP completed redd counts in the Grave Creek drainage (including Blue Sky, Clarence, Williams, and Lewis creeks) from 1983 through 1985, and then from 1993 through 2002. The annual redd count survey is completed from the Grave Creek confluence with the Tobacco River upstream to near the mouth of Lewis Creek (approximately 9 miles). Grave Creek becomes intermittent upstream of the Lewis Creek confluence. Most redds in Grave Creek were located upstream from the mouth of Clarence Creek to the confluence with Lewis Creek. Counts have been completed in Clarence Creek and Blue Sky Creek since 1996.

Bull trout have exhibited a positive trend in spawning abundance in Grave Creek since 1983 (Figure D-1; $r^2 = 0.73$; $p = 0.002$) (MFWP, unpublished data). Counts in Clarence Creek have been consistently increasing since 2001 relative to the rest of the Grave Creek Watershed. Blue Sky has exhibited a less consistent trend over the same period (MFWP, unpublished data). Redd count results indicated a significant increase in the number of bull trout spawning redds in Grave Creek over the 11-year period. The number of spawning bull trout in Grave Creek may be responding to the State of Montana's more restrictive bull trout fishing regulations that occurred in the 1990s; the removal of the Glen Lakes Irrigation District (GLID) diversion dam that was jointly executed by GLID and US Fish & Wildlife Service in 2000; or larger scale regional factors influencing Lake Koocanusa. From 1983 to 2000 (pre-dam removal period), an average of 55 redds were counted. From 2001 to 2003 (post-dam removal period), an average of 206 redds were counted in the survey areas.

Table D-3: Survey Year and Spawning Redd Count Results for Grave Creek and Two Primary Tributaries. MFWP, Unpublished Data.

Year Surveyed	Total	Main Stem Grave Creek	Clarence Creek	Blue Sky Creek	Miles Surveyed
1983	70				17
1984	35				17
1985	27				9
1986					
1987					

Table D-3: Survey Year and Spawning Redd Count Results for Grave Creek and Two Primary Tributaries. MFWP, Unpublished Data.					
Year Surveyed	Total	Main Stem Grave Creek	Clarence Creek	Blue Sky Creek	Miles Surveyed
1988					
1989					
1990					
1991	27				15
1992					
1993	36				17.1
1994	71				11.5
1995	15				9
1996	35	24	5	6	17
1997	49	42	6	1	9
1998	66	52	13	1	9
1999	134	85	39	10	9
2000	97	87	9	1	9
2001	173	131	29	13	9
2002	199	156	38	5	9
2003	245	173	52	20	9

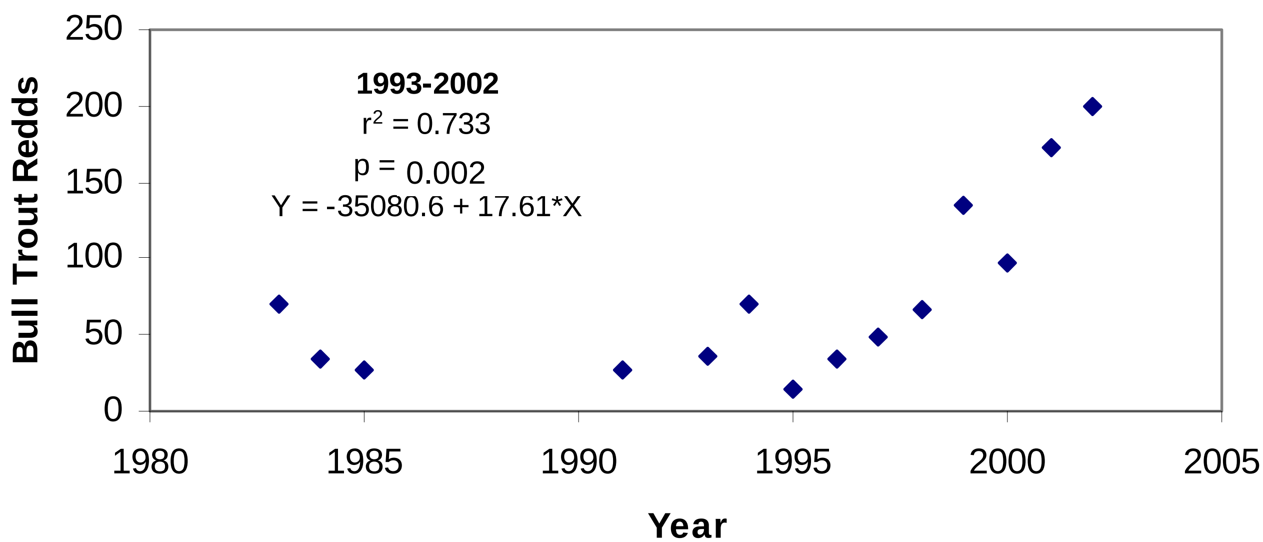


Figure D-1: Bull Trout Spawning Redd Counts in the Grave Creek Drainage Between 1983 and 2003.

Long-term monitoring of bull trout redd numbers can be an important and useful tool to assess bull trout population trends (Rieman and McIntyre, 1993). Based on annual redd counts in Grave Creek, and spring gill net catch rates in Koocanusa Reservoir, adult bull trout abundance within Koocanusa Reservoir has increased over the past 8 to 10 years. Based on spawning redd counts in Grave Creek and a ratio of 1.55 fish per redd (Baxter and Westover, 2000), approximately 380 spawning bull trout may have used Grave Creek in 2003. These data indicate that most of the criteria established by the USFWS

(2002) for the Lake Koocanusa core area are currently being met by the Grave Creek and Wigwam River bull trout spawning populations.

D.2.2 Juvenile Fish Population Estimates

Juvenile bull trout surveys have been completed in the Grave Creek Demonstration Restoration Project downstream of Clarence Creek, and in main stem Grave Creek near Blue Sky Creek. Juvenile bull trout were most abundant in the lower Grave Creek sampling section (upstream of Clarence Creek) in 2001; westslope cutthroat trout were the most abundant salmonid species sampled in 2000; and rainbow trout was the most abundant salmonid species observed in 2002 (MFWP, unpublished data).

Juvenile bull trout population estimates have been consistent over the period of record for the Grave Creek sampling reach near Blue Sky Creek (MFWP, unpublished data). Total juvenile bull trout estimates have ranged from 116 fish to 186 fish from 1997 to 2004 (Table D-4). Juvenile bull trout densities have increased slightly over the period of record although the trend is not significant (MFWP, unpublished data).

Table D-4: Juvenile Bull Trout Estimates for the Main Stem Grave Creek Sampling Reach Near Blue Sky Creek.

Year	Total Estimate	Area (m^2)	Density (#/m^2)
1997	158 (146 - 171)	1628	9.7 (9.0 - 10.5)
1998	186 (177 - 196)	1628	11.4 (10.9 - 12.0)
1999	139 (114 - 166)	1628	8.5 (7.0 - 10.2)
2000	160 (143 - 177)	1628	9.8 (8.8 - 10.9)
2001	165 (147 - 183)	1421	11.6 (10.3 - 12.9)
2002	116 (103 - 132)	1361	8.5 (7.6 - 9.7)
2003	156 (147 - 166)	999	15.6 (14.7 - 16.6)
2004	153 (149 - 159)	1148	13.3 (13.0 - 13.8)

MFWP maintained a screw trap in the GLID irrigation canal in 2002 and 2003 to detect fish entrainment by the ditch. The fish screen was designed to limit movement of fish 4 inches and larger into the ditch from Grave Creek. Entrainment of fish less than 4 inches in length was deemed acceptable during the design of the fish screen. Because the screw trap samples almost the entire width of the channel, the number of fish caught by the trap likely represents a high percentage of the individuals actually entrained by the canal. In 2002, 178 bull trout and 3 westslope cutthroat trout were captured in the screw trap and in 2003, 355 bull trout, 3 westslope cutthroat trout, and 4 mountain whitefish were captured in the screw trap and returned to main stem Grave Creek (Jim Dunnigan, MFWP, personal communication, 2004).

D.3 Westslope Cutthroat Trout

Juvenile westslope cutthroat trout (WCT) have been monitored in the main stem Grave Creek sampling reach near Blue Sky Creek. The monitoring period of record spans from

1997 to 2004. Juvenile WCT densities are approximately 1 order of magnitude lower than bull trout densities in the survey reach. Although WCT densities have increased slightly over the period of record, the trend is not significant (MFWP, unpublished data).

The juvenile bull trout and juvenile WCT data suggest that juvenile bull trout abundance is positively and significantly correlated ($r^2 = 0.668$, p-value = 0.013) to juvenile WCT densities in the survey reach (Figure D-2) (MFWP, unpublished data).

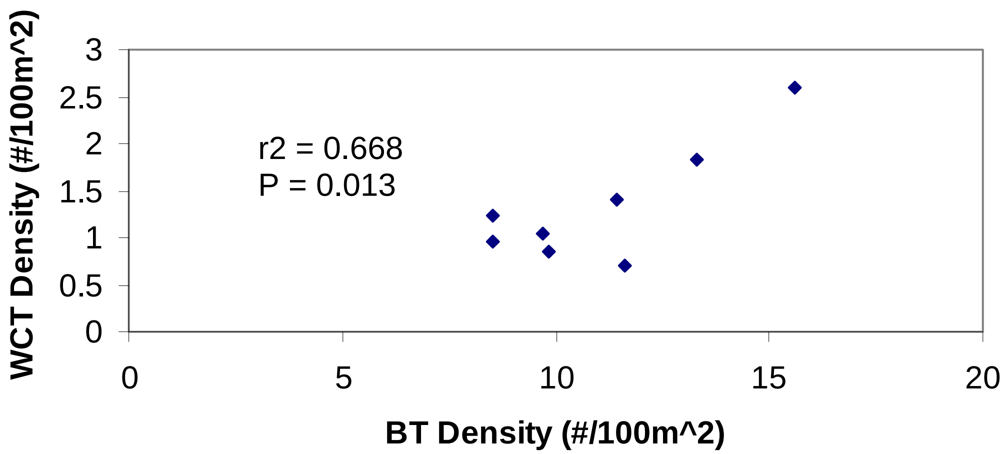


Figure D-2: Comparison of Juvenile Bull Trout and Westslope Cutthroat Trout Densities for the Main Stem Grave Creek Sampling Reach Near Blue Sky Creek.

D.4 Species of Special Concern

According to the Montana Natural Heritage Program (MNHP) the term "species of special concern" includes taxa that are rare, endemic, disjunct, declining, threatened or endangered throughout their range or in Montana, vulnerable to extirpation from Montana, or in need of further research. The term also encompasses species that have a special designation by organizations or land management agencies in Montana, including: Bureau of Land Management; U.S. Forest Service; and U.S. Fish and Wildlife Service. Taxa are evaluated and ranked by the MNHP on the basis of their global (range-wide) status, and their statewide status according to a standardized procedure used by all NHPs. These ranks are used to determine protection and data collection priorities, and are revised as new information becomes available. For each level of distribution, global and state, species are assigned a numeric rank ranging from 1 (critically imperiled, vulnerable to extinction) to 5 (demonstrably secure, though potentially rare in some portions of range). The numeric ranking signifies the species' relative endangerment and is based primarily on the number of occurrences of that species globally or within the state. However, other information such as date of collection, degree of habitat threat, geographic distribution patterns and population size and trends is considered when assigning a rank. The occurrences listed below are suggestions, not absolute criteria (MNHP, 2003). In the Grave Creek Watershed, westslope cutthroat trout is listed as a State of Montana species of special concern with a Global ranking of G4T3 (apparently secure, subspecific taxon). The westslope cutthroat trout State ranking is S2 (imperiled because of rarity, vulnerable to extinction throughout its range). Bull trout have a Global ranking of G3 (very rare and local throughout range) and a State ranking of S2 (imperiled because of rarity, vulnerable to extinction throughout range) (MNHP, 2003). Bull trout are also federally listed as threatened by the U.S. Fish & Wildlife Service, and were classified as a sensitive species by the U.S. Forest Service prior to the federally threatened designation (MNHP, 2003).

The U.S. Fish and Wildlife Service listed the Columbia River population of bull trout as a threatened species on June 10, 1998 (63 FR 31647), and have subsequently determined that the Kootenai River Recovery Unit forms part of the range within the Columbia River Population segment (USFWS, 2002). The USFWS recovery plan makes the distinction between primary and secondary core bull trout areas based mostly on size, connectedness, and complexity of the watershed and the degree of natural population isolation. The two primary core areas in the Kootenai River Recovery Unit include Lake Koocanusa and the Kootenai River/Kootenay Lake complex that begins downstream of Libby Dam to Kootenay Lake. The two secondary core areas are Bull Lake and Sophie Lake. The recovery plan has set four general recovery criteria.

1. Distribution criteria will be met when the total number of identified local populations (currently number 10 in the United States waters) has been maintained or increased and local populations remain broadly distributed in all four existing core areas.

2. Abundance criteria will be met when the primary Lake Koocanusa and Kootenai River/Kootenay Lake core areas are each documented to host at least five local populations (including British Columbia tributaries) with 100 adults in each and each of these primary core areas contains at least 1000 adult bull trout. The Grave Creek bull trout population counts toward one of the five local populations.

The abundance criteria for the Bull Lake and Sophie Lake secondary core areas will be met when each area supports at least one local population of bull trout containing 100 or more adult fish.

1. Trend criteria will be met when the overall bull trout population in the Kootenai River Recovery Unit is accepted, under contemporary standards of the time, as stable or increasing, based on at least 10 years of monitoring data.

2. Connectivity criteria will be met when dam operational issues are satisfactorily addressed at Libby Dam (as identified through U.S. Fish and Wildlife Service Biological Opinions) and when over half of the existing passage barriers identified as inhibiting bull trout migration on smaller streams within the Kootenai River Recovery Unit have been remedied.

Meeting the above fishery goals does not equate to meeting all of Montana State Water Quality Standards. Each individual waterbody and its habitat potential must be evaluated in the context of historical land uses and the application of appropriate management practices for existing land uses.

Four additional threatened wildlife species may occur within Grave Creek drainage (Table D-6). A healthy Grave Creek fishery could have a positive influence on one or more of these species.

Table D-6: Threatened Wildlife Species Potentially Inhabiting the Grave Creek Drainage.

Species	Global Ranking	State Ranking	USFWS Designation
Bald Eagle	G4	S3B, S3N	T
Canada Lynx	C5	S3	T
Gray Wolf	G4	S3	T
Grizzly Bear	G4T3T4	S3	T

D.5 Aquatic Macroinvertebrates

Aquatic macroinvertebrate surveys were completed during early September 2002 and late September 2003 on Grave Creek as part of a monitoring program before and after the demonstration project completed in the fall of 2002 downstream from Vukonich Bridge. Species Richness, Ephemeroptera, Plecoptera, and Tricoptera (EPT) richness, and the Montana Biotic index were computed for the collected samples. Based on standard MDEQ criteria, the results show good macroinvertebrate health in four riffles and one pool prior to restoration and good health in three riffles and one pool after restoration work. One post restoration riffle sample did not obtain an adequate population for analysis, possibly due to difficult sampling conditions (Jim Dunnigan, MFWP, personal communication, 2004). Overall, macroinvertebrate data is lacking throughout the watershed and is identified as a monitoring need in Section 9.0.

APPENDIX E
REGULATORY FRAMEWORK AND TMDL DEVELOPMENT

This appendix presents 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.

E.1 Grave Creek 303(d) List Status

E.1.1 Recent 303(d) Listing Information

The Montana 303(d) list, published every other year within Montana's Integrated Water Quality Report (MDEQ, 2004), identifies the mainstem of Grave Creek from Foundation Creek downstream to the confluence of Grave Creek and Fortine Creek as impaired. Table E-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 E-1 includes information from the 1996 303(d) list to ensure accountability for all previously identified causes of impairment. Note that the 2004 list incorporates and expands upon all impairment information within the 1996 list.

The impairment level is "partial support" of aquatic life and cold-water fish versus a more severe "non-support status". Note that "recreation" has been identified as a beneficial use not fully supported on the more recent 2004 list. This is due to flow alteration (dewatering) conditions within the channel of lower Grave Creek.

Table E-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

The Table E-1 "probable causes" for 2004 is unnecessarily long. These "probable causes" include several sub-causes (MDEQ, 2004). Both "fish habitat degradation" and "bank erosion" are sub-causes of the "other habitat alterations" cause category. Also, "dewatering" is a sub-cause of the "flow alterations" cause category. Therefore, the 2004 primary cause categories can be summarized as "other habitat alterations", "flow alterations" and "siltation".

TMDL development is required for all waterbody pollutant combinations where a pollutant has been identified within the "probable causes" column on the 303(d) list. There are not any pollutants, such as sediment, temperature, or nutrients, explicitly identified within the "probable causes" column in Table E-1. Because MDEQ does not currently use "sediment" as a "probable cause" in the 303(d) list, other terminology is used to indicate conditions where excess sediment loading may be linked to impairment. Thus the "siltation" listing for Grave Creek is linked to a sediment pollutant impairment condition, typically from excess concentrations of fine sediment less than 6.35 mm and/or 2 mm in size within riffles and/or potential spawning locations.

Furthermore, the "other habitat alterations" cause can sometimes be linked to other pollutant loading impacts such as nutrients, temperature, or an excess coarse or total (coarse plus fine) sediment load. An excess coarse or total sediment load to a channel can lead to pool filling and overall loss of desirable aquatic life habitat. This linkage between loss of aquatic habitat and excess coarse or total sediment loading appears to be a potential "other habitat alterations" linkage in many reaches of Grave Creek and its tributaries. This suggests a potential need to pursue TMDL development for both fine sediment as well as coarse or total sediment loading for Grave Creek in order to effectively address the existing listing causes. This approach is consistent with EPA TMDL guidance (EPA, 1999); and the "sediment" definition in Montana's Water Quality Standards (17.30.602.28), presented below in Table E-4. Note that any TMDL development is first preceded by a water quality impairment status update as discussed below in Section E.3.

The flow alteration cause falls under a category that does not require TMDL development (often referred to as "pollution"). Furthermore, some types of "other habitat alterations" may also be linked to non-pollutant type impairments where TMDL development is not required. An example of this would be fish passage blockage. Nevertheless, these "pollution" conditions represent probable impairments to cold-water fish and aquatic life and are addressed within this document.

E.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 as discussed above in Section E.1.1. Below is a summary of information used for making the impairment determinations for the major cause categories described above.

E.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). In one watershed analysis report (Bohn, 1998), it is stated:

> "A comparison of data between historic and existing conditions, reference and non-reference data, and reference conditions from data compiled from other sources (e.g., regional conservation strategies, literature) suggests that present fish habitat conditions in Grave Creek are generally in fair to poor condition. For example, many of the reaches lacked sufficient in-channel large woody debris. This, in turn, affected the number and quality of pool habitats. Accelerated peak flows from upslope vegetation removal and large amounts of small bed material made scour depths sufficient in some areas to effectively wash out redds during spring runoff. However, 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.
>
> The cause of degraded conditions on public lands stem from U.S. Forest Service management activities in the watershed beginning in the early 1950's and extending through the 1980's. Early spruce harvesting occurred along riparian areas, removing large diameter trees for sawlogs thereby reducing the number of large trees needed for recruitment. Early harvesting also increased the routing efficiency of the watershed by constructing an extensive skid trail network in and around first order tributaries. Factors contributing to degraded conditions on private land include converting riparian communities to pasture, urban development along the riparian corridor, and channel realignment."

The Bohn report goes on to further identify significant impacts from roads and large clearcuts within the watershed, particularly those used for the above referenced harvest activities. As part of the analysis of historical channel conditions, the report states: "this analysis revealed that over time, the condition of the channels have degraded as a result of upstream timber harvest, road failures, in-stream wood removal, and increased peakflows. Virtually every reach in the watershed has adjusted somewhat to the effects of these actions. For example, the average riffle width in lower Grave Creek went from 60 ft (18m) in 1947 to over 130 ft (40m) in 1992. During the 45 years of photographic record, the sinuosity went from 1.23 (1947) to 1.08 (1992). The widening and straightening of this reach has resulted in extreme bank erosion rates, pool filling, in-channel bar formation, and a decrease in low water depths. This response is typical throughout the basin. However the sensitivity of each reach varies by geomorphic unit."

In another report (Marotz and Fraley, 1986), reference is made to the apparent acceleration of bank erosion from grazing and forage production. It was concluded that livestock grazing, irrigation withdrawals, timber harvest and associated road building were sources of impairment. In a stream fishery data report (MFWP, 1985), road construction, logging and stock trampling were identified as factors limiting the fishery.

Another form of habitat alteration referred to in several reports (USFS, 1999a; Bohn, 1998; MFWP, 1985) is fish passage obstruction due to an irrigation diversion dam that was located in lower part of Grave Creek. A new irrigation diversion structure has been built and fish passage is no longer considered an impairment at this location.

E.1.2.2 Flow alteration

Flow losses due to irrigation diversions are of concern for cold-water fish, aquatic life, and recreation uses as identified within the MDEQ SCD/BUD files. Marotz and Fraley (1986) noted that the “water appropriations listed for Grave Creek total 80.8 cfs ...... if all water users exercise their rights to the fullest extent, the stream would be dewatered during most of the water year. It is unknown, however, what number of claims is valid or presently in use. A minimum discharge of 70 cfs is recommended for the low flow period from July 16 to March 31.” The 70 cfs data was derived from a wetted perimeter-discharge relationship for five riffle transects on Grave Creek. To ensure an average depth of 0.5 feet for successful passage of spawning migrants, the authors suggest maintaining the 70 cfs flow during periods when such passage is needed. Furthermore, the MFWP Dewatered Stream List (1991) shows Grave Creek as being chronically dewatered from Glen Lake diversion dam to Fortine Creek. Flow for September 1986 was at 43 cfs (Marotz and Fraley, 1986). Similar low flow conditions were observed in lower Grave Creek by MDEQ assessment personnel during summer, 2003.

In addition to the water quality standards presented below, it is important to note that when dealing with flow alteration conditions the TMDL development section of Montana State Law (75-5-705) states “nothing in this part may be construed to divest, impair, or diminish any water right recognized pursuant to Title 85.”

E.1.3 Water Quality Restoration Planning and TMDL Development Requirements

This water quality restoration plan identifies water quality goals and objectives to address the above-noted impairment causes at a minimum. Where excess pollutant loading is involved, TMDL development is incorporated into the water quality goals and objectives as part of the problem solving approach for excess pollutant loading conditions. Table E-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 E -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, as discussed below in Section E.3.

Table E-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)

E.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 provides a summary of the applicable water quality standards for sediment and other conditions limiting cold-water fish as identified in Table E-2.

E.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. There are a variety of “uses” of state waters including: growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana Water Quality Act (WQA) directs the Board of Environmental Review (BER, i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (Administrative Rules of Montana (ARM) 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed based classification system with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications have multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply, however the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or non-point source activities or pollutant discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water’s classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions can only occur if the water was originally misclassified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

Descriptions of Montana’s surface water classifications and designated beneficial uses are presented in Table E-3. All waterbodies within the Grave Creek TPA 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]).

Table E-3: Montana Surface Water Classifications and Designated Beneficial Uses.

Classification	Designated Uses
A-CLOSED CLASSIFICATION:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1 CLASSIFICATION:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.

Table E-3: Montana Surface Water Classifications and Designated Beneficial Uses.	
Classification	Designated Uses
B-1 CLASSIFICATION:	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.
B-2 CLASSIFICATION:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3 CLASSIFICATION:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1 CLASSIFICATION:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2 CLASSIFICATION:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I CLASSIFICATION:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

E.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.

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular WQB-7 (MDEQ, 2004a). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., life long) exposures as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies including a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be “non-significant” or an authorization to degrade must be granted by the Department. However under no circumstance may standards be exceeded. It is important to note that, waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term “Narrative Standards” commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface water quality standards. The General Prohibitions are also called the “free from” standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi and algae.

The standards applicable to sediment, which is the only pollutant identified on the 303(d) list for the Grave Creek Planning Area, are summarized below. In addition to the below sediment standards, the beneficial use support standard (17.30.623[1]) for a B-1 Stream, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include impacts from dewatering/flow alterations or impacts from habitat modifications not linked directly to excess sediment concentrations.

Sediment

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in Table E-4. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels 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-4).

Table E-4: Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.623(2)(d)	The maximum allowable increase above naturally occurring turbidity is: five nephelometric turbidity units except as permitted in 75-5-318, MCA.
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will.
17.30.637(1)(a)	Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
17.30.602(17)	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.
17.30.602(21)	"Reasonable land, soil, and water conservation practices" means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.
17.30.602.(28)	"Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation or biological activity.

It should be noted that reasonable land, soil, and water conservation practices are not always accomplished by using best management practices (BMPs) (MDEQ, 1999). BMPs are land management practices that provide a degree of protection for water quality, but they may not be sufficient to achieve compliance with water quality standards and protect beneficial uses. Therefore, 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.

Temperature

Although no temperature impairment has been identified in Grave Creek, fishery impacts from elevated temperatures are a possibility in the lower part of Grave Creek given the habitat alterations and dewatering conditions. Montana's temperature standards address a maximum allowable increase above "naturally occurring" temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana's temperature standards address the maximum allowable rate at which temperature changes (i.e., above or below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as B-1 the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67º Fahrenheit) is 1° (F) and the rate of change cannot exceed 2°F per hour. If the natural occurring temperature is greater than 67º F, the maximum allowable increase is 0.5º F (ARM 17.30.623(e)).

E.2.3 Reference Conditions

E.2.3.1 Reference Conditions as Defined Within Appendix A 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 historic land use activities.

MDEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as sediment) that have specific narrative standards. All classes of waters are subject to the provision that there can be no increase above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids sufficient to create a nuisance or render the water harmful, detrimental or injurious. These levels depend on site-specific factors, so the reference conditions approach is used.

Also, Montana water quality standards do not contain specific provisions addressing nutrients (nitrogen and phosphorous), or detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when nutrients, flow or habitat modifications are present.

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 condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry or hydrogeomorphology due to human activity. Therefore, 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. MDEQ realizes that presettlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar season and/or hydrologic conditions for both waters. For example, the TSS of a stream at base flow during the summer should not be compared to the TSS of reference condition that would occur during a runoff event in the spring. In addition, a comparison should not be made to the lowest or highest TSS values of a reference site, which represent the outer boundaries of reference conditions.

The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc. that were conducted on similar waterbodies that are least impaired.
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

MDEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there are no regional data. MDEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

E.2.3.2 Development of Reference Conditions for the Grave Creek Watershed

E.2.3.2.1 Stream Potential Given Historic Land Uses

As discussed above, the reference condition reflects a waterbody's greatest potential for water quality given historic land use 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. This "potential" terminology is consistent with the use of the term "capability," and both terms are used interchangeably in this document. It is anticipated that MDEQ will change to the use of this "stream capability" terminology instead of "stream potential given historic land use activities."

For many streams such as those in the upper portions of the Grave Creek Watershed, recovery from historic land use activities that led to elevated sediment loading and removal of riparian vegetation is possible, even though full recovery may take decades. This recovery then represents the greatest potential because existing and future forest activities, including timber harvest, can still be pursued in a way that will allow recovery via the application of BMPs and all reasonable land, soil and water conservation practices.

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. This is supported by the Bohn (1998) analysis showing significant negative departure in fish habitat indicators between 1947 and 1992, by the potential for improvements in riparian protection along lower Grave Creek, and by the success of physical restoration projects discussed in Section 8.0.

E.2.3.2.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution, whereas water resources data tend to have a non-normal distribution (Hensel and Hirsch, 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on a non-normal distributions are far less influenced by such observations.

Figure E-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative water quality standards or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (EPA, 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing MDEQ guidance development for interpreting narrative water quality standards where it is determined that there is “good” confidence in the quality of the reference sites and resulting information (MDEQ, 2004e). If it is determined that there is only a “fair” confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is “very high” confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be “fair” to “good” quality. This is primarily due to a the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set.

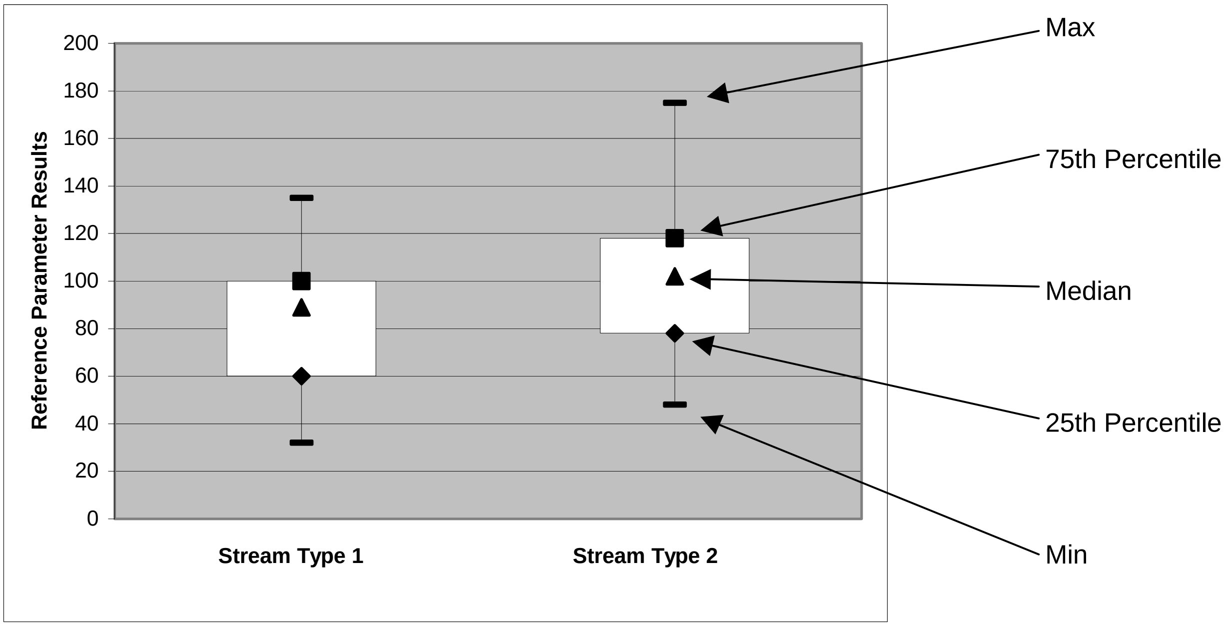


Figure E-1: Boxplot Example for Reference Data.

The above 25^{th} – 75^{th} percentile statistical approach has several considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25% of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream's potential may prevent it from achieving the reference range as part of an adaptive management plan.
3. About 25% of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25^{th} to 75^{th} percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. Obtaining reference data that represents a naturally occurring condition, as defined above in Table E-4, can be difficult, particularly for larger waterbodies with multiple land uses within the drainage. This is because all reasonable land, soil and water conservation practices may not be in place in many larger water bodies across the region. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as riparian harvest, where reasonable land, soil and water conservation practices were not applied.
5. A stream should not be considered impaired unless there is a relationship between the parameter of concern and the beneficial use such that not meeting the reference range is likely to cause harm or other negative impacts to the beneficial use as described by the water quality standards in Table E-4. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, cold water fish or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. Figure E-2 shows example

relationship between a parameter of concern and a beneficial use (aquatic life in this example). Relationships that show an impact to the beneficial use can be used to justify impairment based on the above statistical approach.

As identified in (2) and (3) above, there are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed. 1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range. 2) A stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The implications of making either of these errors can be used to modify the above approach, although the approach used will need to be protective of water quality to be consistent with MDEQ guidance and water quality standards (MDEQ, 2004e). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations. This adaptive management is further defined in later sections of this document.

Where the data does suggest a normal distribution, or reference data is presented in a way that precludes use of non-normal statistics, then the above approach can be modified to include the mean plus or minus one standard deviation to provide a similar reference range with all of the same considerations defined above.

In some cases, there is very limited reference information and applying a statistical approach like above is not possible. Under these conditions the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development as defined in Section E.2.3.1.

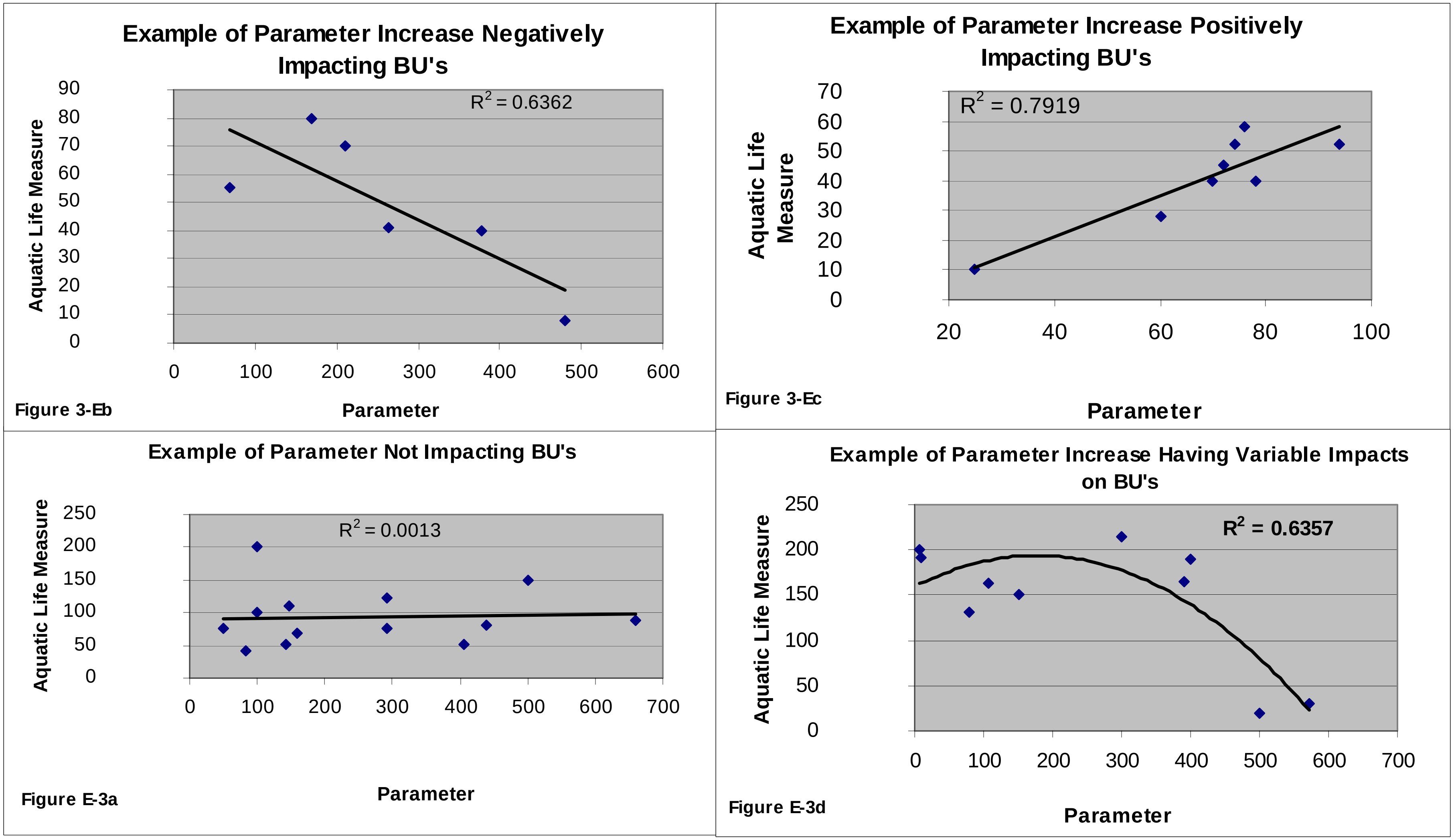


Figure E-2: Examples of Various Ways Which a Given Parameter Can Influence Aquatic Life or Other Beneficial Uses.

E.3 Application of Water Quality Standards and Reference Conditions

The water quality standards and reference condition approach is used in this and other water quality restoration plans to develop an updated water quality impairment status. This includes the steps defined below. Figure E-3 is a flow chart of this process.

1) Present water quality data for the Grave Creek Watershed. This includes looking at water quality data from both Grave Creek and significant tributaries to provide a better overall understanding of watershed health and to help identify potential reference conditions within the watershed. Focus is on physical water quality parameters that provide the best linkages between sediment and/or habitat alterations and the potentially impacted beneficial uses of cold-water fish and associated aquatic life. These parameters include stream channel and fish habitat conditions such as pool frequency, width to depth ratio, and percent fine sediment in spawning areas. This information is presented in Section 4.0.
2) Develop water quality reference values for the Grave Creek Watershed using the guidance presented above. These reference values will tend to focus on the parameters that provide the best indicator of beneficial use support for the sediment and habitat alterations of concern. The development of water quality reference values is presented in Section 5.1.
3) Use the reference values to define beneficial use support conditions that must be met to satisfy water quality standards. Where there is a link to excess sediment loading impacts, beneficial use support conditions are presented as "targets" consistent with TMDL development terminology. The development of these beneficial use support conditions is presented in Section 5.2.
4) Compare the existing water quality data from waterbodies in the Grave Creek Watershed to targets and use support objectives. This comparison, referred to as a departure analysis, is used for making final water quality impairment determinations. Section 5.3 presents this comparison and Section 5.4 provides the updated water quality impairment status.

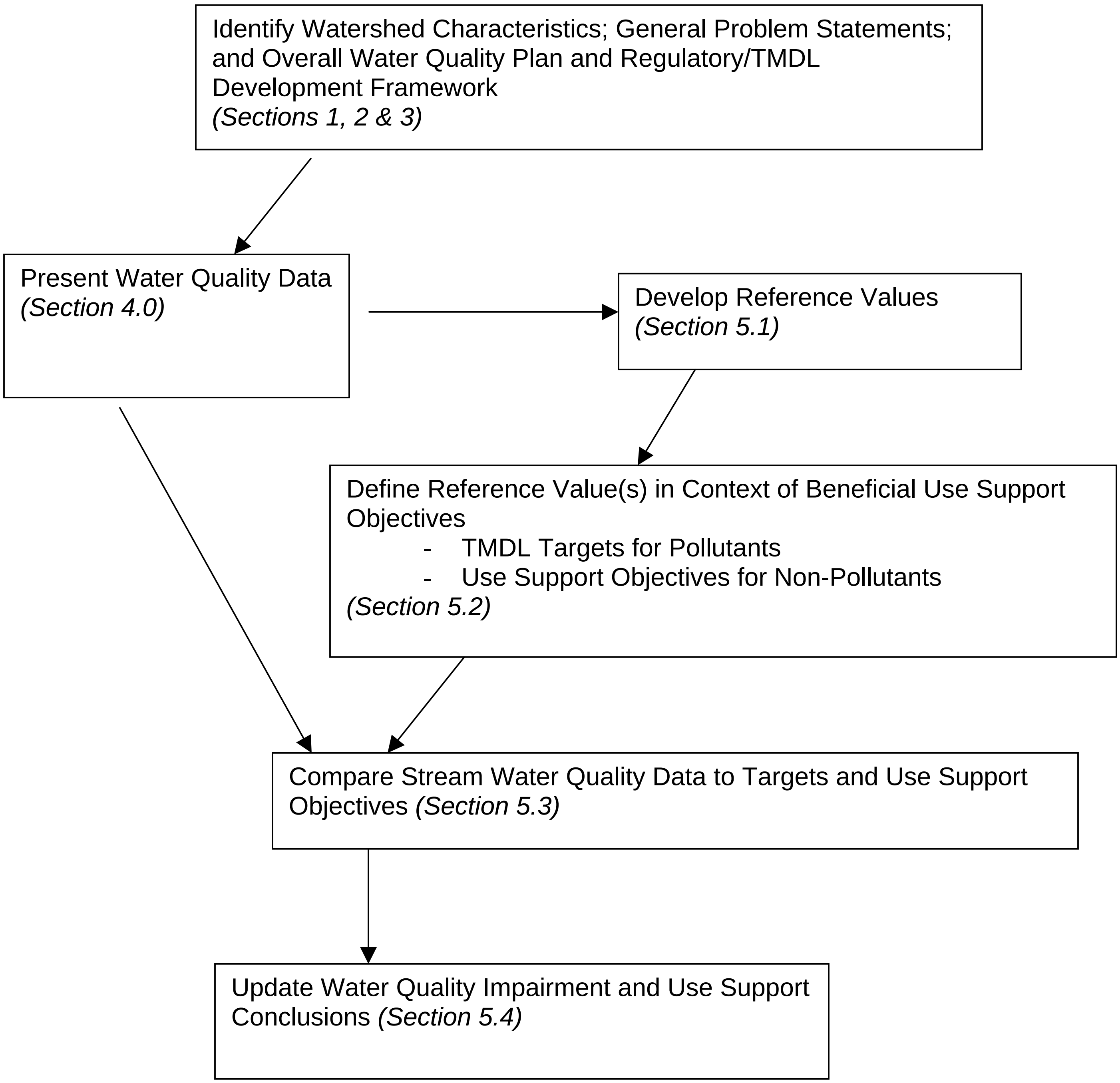


Figure E-3: Water Quality Restoration Planning Process for the Grave Creek Watershed – Initial Steps Through Updated Water Quality Impairment Status.

E.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 described below. Figure E-4 is a flow chart of this process.

1. Perform a detailed assessment to characterize the types, magnitudes, and locations of sources contributing to impairment conditions. This includes a sediment loading analysis for the Grave Creek Watershed. The detailed assessment is presented within 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. For sediment (or any pollutant), this includes developing one or more TMDLs and presenting the restoration objectives in the form of load allocations that would lead to conditions where TMDL targets are satisfied. Non-TMDL restoration objectives are developed to address actions that would lead to conditions where use support objectives are satisfied. Restoration objectives and TMDLs are developed in Section 7.0.
3. Identify strategies for implementing this water quality plan. Also identify monitoring strategies to help track specific implementation activities, measure overall progress toward meeting beneficial use support objectives, and address uncertainties and monitoring gaps identified as part of this planning effort. Implementation strategies are identified in Section 8.0, and a monitoring strategy is developed in Section 9.0. The implementation and monitoring strategies are a key component of adaptive management.

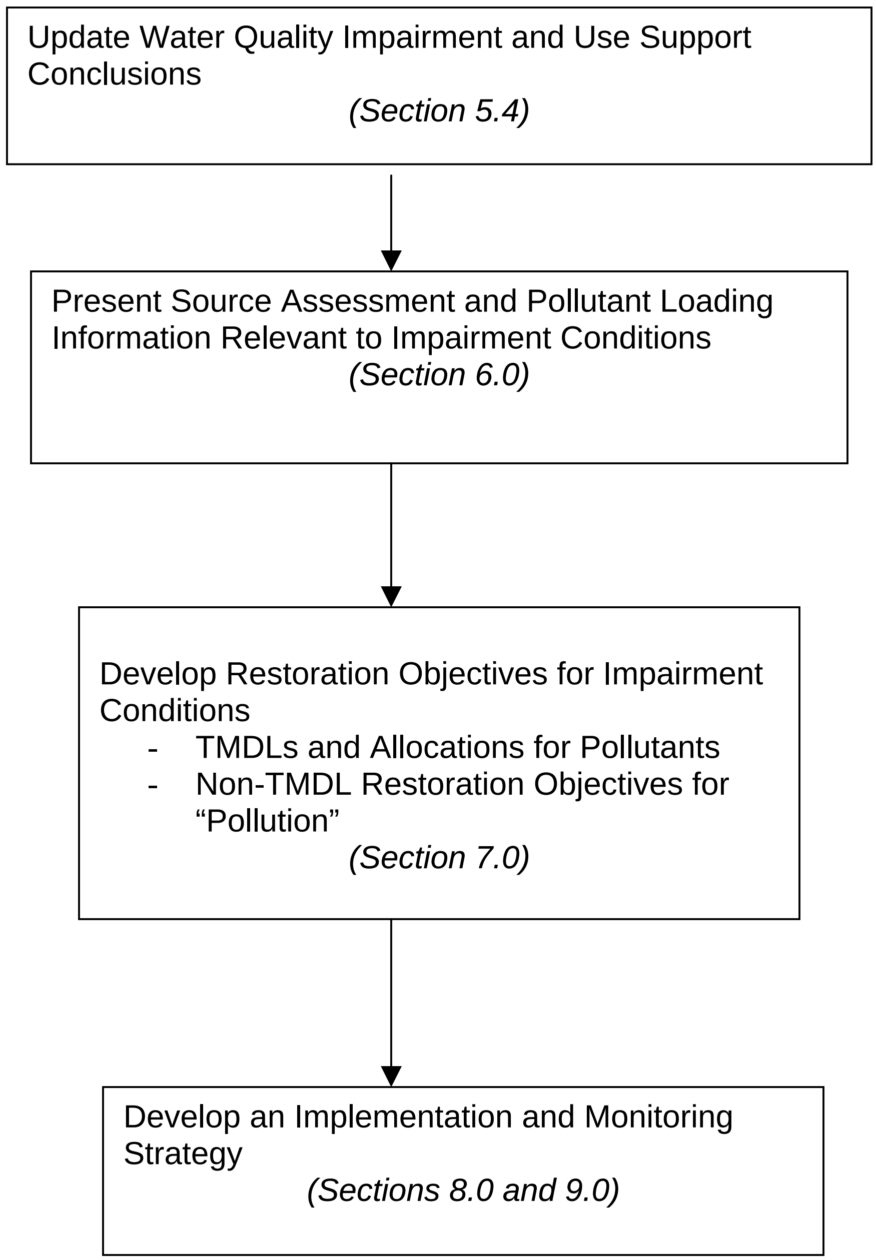


Figure E-4: Water Quality Restoration Plan and TMDL Development Process for Grave Creek Watershed - After Making Updated Impairment Status Determinations Through Final Plan Sections.

APPENDIX F
SUMMARY OF DATA COLLECTION AND ASSESSMENT METHODOLOGIES

This appendix summarizes the types of data collection and assessment tools used to develop the Grave Creek Water Quality and Habitat Restoration Plan. The plan is based on review of existing data and assessments as well as new data collection and analyses. Several sources of existing information were reviewed including existing watershed assessments, and fish habitat and population data. New information collected included channel morphology data, sediment source inventory, and remote and field-based vegetation surveys. New analyses of relevant spatial information using GIS modeling were conducted. The spatial analyses results were used to evaluate the role of land use activities on the existing stream conditions and impairment status.

Other appendices include detailed methods descriptions for specific analyses including sediment source assessments (road sediment sources (Appendix I) and in-stream sediment sources (Appendix J)), and land use assessments (timber harvest (Appendix A), road building (Appendix B), water yield/ECA/rain-on-snow zone (Appendix C)).

F.1. Existing Data and Watershed Assessments

In 1999 MDEQ reviewed existing data related to water quality and fish habitat in the Grave Creek Watershed. The existing information reviewed included fish habitat, channel morphology, and upland assessments completed, primarily by MFWP and USFS.

F.1.1 MDEQ-led Existing Data Review and Coarse Screen Analysis

Water quality chemistry data were determined to be limited for the focus stream. To verify this, the Environmental Protection Agency's STORET database was accessed to evaluate collected water chemistry data. The lack of water quality chemistry data has no bearing on the physical parameter analysis linked to sediment and habitat impairments.

Documents in MDEQ's reference library include USFS stream habitat assessments, MFWP fish population estimates and reports, and limited USGS gaging station discharge data. Of particular importance were MDEQ's SCD/BUD data sheets[1], which summarize the agency's rationale for placing streams on the 2000 303(d) list. The existing data were determined by MDEQ to be adequate for making beneficial use determinations for all uses but drinking water, due to the absence of water chemistry data. Appendix E provides a summary of the beneficial use impairment justifications.

1 Available: http://nris.state.mt.us/scripts/esrimap.dll?name=tmdl&Inst=10120&Null=9910205&Cmd=Main2.

As part of the data inventory process, resource specialists from state and federal agencies (MFWP, USFS, and USFWS) were consulted for their professional opinions on the condition of Grave Creek. Agencies were also asked to provide any additional data or reports not previously considered in MDEQ reviews.

F.1.2 USFS Watershed-scale Assessments

The USFS has completed numerous resource investigations in the Grave Creek Watershed. In 1995, the USFS commissioned sediment source investigations in primary tributaries to Grave Creek. The surveys identified major sources and recommended treatments to mitigate sediment delivery to primary tributaries. Bryce Bohn, former Fortine District Hydrologist with the USFS, conducted a study of Grave Creek with primary emphasis on the application of watershed scale analyses to identify and remedy causes and source of water quality degradation (Bohn and Kershner, 2002). The report provided generalized recommendations aimed at improving native fish habitat, reducing sediment sources, re-establishing proper channel form and function, and improving fish passage and habitat conditions in select locations in the watershed. The study also provided geomorphic unit descriptions for major stream segments and rated their sensitivity to varying levels of physical inputs including large woody debris, sediment, and increased peak flows.

The USFS completed a baseline evaluation of the Tobacco/Grave bull trout subpopulation in 2000. The baseline assessment covered the Lower Clark Fork Fifth Code HUC, including individual evaluations for each subordinate sixth code HUC. The sub-population of bull trout within the Tobacco/Grave sixth code HUC received one set of evaluations. Each set of evaluations included 19 habitat indicators to determine the level of habitat integrity.

In September 2002, the USFS completed the Grave Creek Watershed Ecosystem Analysis at the Watershed Scale (EAWS). This effort estimated direct, indirect, and cumulative effects of management activities that have occurred in the watershed. The document also identified the purpose and need for management recommendations for implementation of the Forest Land and Resource Management Plan (Forest Plan), current policy, and other applicable state and federal regulations (USFS, 2002).

F.2. Fish Habitat Assessment

During summer 2001, the USFS completed fish habitat condition surveys (USFS, 2001) using the R1/R4 fish habitat inventory method (Overton et al., 1997). Field surveys were completed for the entire main stem and primary tributaries including Williams Creek, Blue Sky Creek, Lewis Creek, Clarence Creek, and Stahl Creek.

R1/R4 data collection includes stratification of all inventoried stream reaches by Rosgen channel type (Level I A, B, C, D, E F or G) and by channel units' type (fast-riffle or step; or slow-pool). For each channel unit, measurements include width, depth (average and maximum), length, percent pool tailout surface fines, and number LWD pieces. From this information, measures of pool frequency and LWD concentration and other measures were calculated for each reach. An Access database was created to query and analyze the habitat data by stream, reach type and by channel unit type.

R1/R4 data characterize the wetted channel conditions during the time of the survey; therefore, some R1/R4 results are biased by water levels at the time of the survey (e.g. width or depth). Comparison of R1/R4 data among surveys or even the same channel reach under different surface water conditions can provide considerably different information. Some R1/R4 measures, such as LWD values, pool counts, and residual pool measures would not be expected to result in this type of variation since the information is not linked to current water levels and stream width measures.

F.2.1 Pool Frequency

Pool frequency methodology for Grave Creek assessment work and reference stream assessment work is presented in this section.

F.2.1.1 Grave Creek

Pool frequency for each stream, reach and channel type was calculated by tallying the total number of pools. For each stratification, the pool count was then divided by the total length in miles to get a value of pools per mile for that stream, reach, and/or channel type.

According to the modified R1/R4 protocol used by the Kootenai National Forest, pools are slow water habitat units associated with channel bed scour or where the stream course has been damned by wood or rock. To ensure correct delineation between channel units (e.g. riffle versus pools), surveys are conducted at base flows. Surveying at base flow also ensures more accurate measurements for calculating residual pool volume. R1/R4 also counts pocket pools, which are defined as any pool in fast water habitats (e.g. riffles) that are 10 to 30% of the wetted channel width, however, pocket pools were not included in the TMDL analysis.

F.2.1.2 Reference Streams

Several sources were used to develop pool reference values. These include: 1) data from the Swan Lake Watershed used for TMDL development (MDEQ, 2004d), 2) unpublished reference data provided by the Libby Ranger District of the KNF, 3) unpublished reference data provided by the Rexford Ranger District of the KNF, 4) reference data from the Lolo National Forest (USFS, 1998), and 5) an internal reference reach for lower Grave Creek. Methods varied between studies although the various methods can result in similar values, particularly for the 2^{nd} and 3^{rd} order streams and smaller 4^{th} order streams. For the Swan River data, features with slack water and a deepened thalweg were counted as pools. Pools in the Libby Ranger District data were areas with slack water at least one-third the bankfull width with a scour feature and a hydraulic control. Pools in the Rexford Ranger District reference data (and also the

Grave Creek existing condition data) include slow water habitat features with a channel bed scour or a damming obstruction (such as wood or a large boulder). The Lolo reference data counted slow water areas as pools using the Lolo National Forest Basin Wide Method (Kramer et al., 1993).

Caution should be used when comparing pool frequency values from data sets, or when planning pool assessment activities. Pool frequency data from longitudinal profiles are likely to be lower than pool frequencies from R1/R4 surveys due to differing survey methods and pool identification criteria. This is because there may be significant pocket pools in areas outside the thalweg where the longitudinal profile is typically measured.

F.2.2 LWD Frequency

LWD frequency methodology for Grave Creek assessment work and reference stream assessment work is presented in this section.

F.2.2.1 Grave Creek

Table F-1 describes the large woody debris counting method used by the Rexford Ranger District of the Kootenai National Forest for determining LWD concentrations in Grave Creek.

Table F-1: R1/R4 Large Woody Debris Count Criteria.		
LWD Category	Criteria	
LWD Singles	> 3 m long OR > 2/3 bankfull width AND 0.1 m diameter AND within active bankfull width	Number of qualifying pieces
LWD Aggregates	2 or more pieces entangled within active channel	Number of qualifying aggregates
LWD Rootwads	rootwads providing cover for fish OR affecting hydraulics of stream at bankfull flows in future	Number of qualifying rootwads

F.2.2.2 Reference Streams

The same streams used for pool frequency reference development were used for LWD frequency reference development. As with pools, methods for determining pieces of LWD generally varied from study to study. The LWD method in the Swan TMDL development effort is similar to the method used in the Grave Creek Watershed R1/R4 surveys to establish existing condition. The Swan data are primarily from streams with minor impacts that may not represent the ideal reference condition, although all data is from stream reaches representing satisfactory conditions from a beneficial use support perspective for LWD and pool values.

The Libby Ranger District and Lolo/Flathead data are from streams with no or minimal human impacts using methods which both tend to result in lower LWD counts than the method used for Grave Creek Watershed, with greater potential discrepancy as bankfull width increases. LWD in the Libby data set includes both live and dead material inside the bankfull channel that is larger than 6" in diameter, longer than the bankfull width, and in contact with the channel or suspended above it. LWD in the Lolo data set included the "acting" LWD defined as stable wood within the channel according to the LNF Basin Wide Methodology (Kramer et al., 1993).

The Rexford Ranger District collected LWD data from 81 reaches using the same method as used for Grave Creek. Of those 81 reaches, twenty met INFISH RMOs and received either a good or fair Pfankuch rating. These twenty reaches were therefore considered as reference reaches. Lower LWD reference values in the Rexford data are attributed to the 1910 fires in that area and, as a result, a lag in LWD recruitment compared to the other reference data sets. In recent years, a notable increase in LWD recruitment has occurred, possibly representing a recovery in this lag (Pat Price, personal communication, 2004)

F.2.3 Percent Fines in spawning areas

Evaluation of percent fines in spawning areas provides an indicator of spawning habitat conditions. A high percentage of inter-gravel fines in spawning areas are detrimental to fry development. Percent surface fines in pool tail outs were measured using the 49-point grid toss method for each pool surveyed in the USFS-led R1R4 fish habitat survey (2001). These surface fines results were then used as an indicator of the total substrate fines down to the depth where impacts can occur to fry. Most data from reference streams were based on this same methodology, although some reference data were based on a viewing bucket modification to the grid toss.

F.3 McNeil Core Substrate Percent Fines Sampling

Percent fines in surface and sub-surface channel bed material was measured using the McNeil core sampling methods (Weaver and Fraley, 1993). McNeil core data was collected by MFWP on upper Grave Creek upstream of Clarence Creek. Reference data is based on this same methodology.

F.4 Fish population and Other Biological Indicators

MFWP efforts in Grave Creek have focused primarily on pre and post restoration effectiveness monitoring of fish populations as well as bull trout redd estimates from the period 1983 through present. Macroinvertebrates were collected in September 2002 and September 2003 in the lower reach of Grave Creek for the Restoration Project work

(Appendix D). Taxa and metrics were computed and analyzed by EcoAnalysts, Inc. and MDEQ.

Recent reports including Mitigation for the Construction and Operation of Libby Dam Annual Report 2001-2002 (MFWP, 2003a) were provided to KRN during the Phase 1 coarse screen assessment. The reports summarized the status of bull trout in the Kootenai River Drainage and provided preliminary effectiveness monitoring results from two restoration projects completed in the lower Grave Creek Watershed on private land.

Additional data and methodology regarding fry and juvenile bull trout entrapment in the GLID conveyance canal is presented in Appendix D. Appendix D also includes other fish population data provided by MFWP and presented in Appendix D.

F.5. Channel Morphology and Stability

During summer 2003, the USFS (USFS, 2003) completed channel morphology surveys to characterize stream channel dimensions, channel stability, and composite riffle-pool substrate particle distribution. Similar morphology assessments were also conducted by WCI (2000) in both C (reference) and D (degraded) reaches of lower Grave Creek.

Pebble counts and cross sections are positioned at a location along the reach that is representative of conditions throughout the reach. They represent one sample along the length of a stream reach. Pfankuch channel stability assessments are conducted for the length of the reach or a representative length of the reach.

F.5.1 Channel Cross-Section Dimensions

During summer 2003, the USFS completed channel morphology surveys using the Rosgen methodology (Rosgen, 1996), which focuses on bankfull dimensions. Field surveys were completed at representative cross sections throughout the entire main stem above private land, and primary tributaries including Williams Creek, Blue Sky Creek, Lewis Creek, Clarence Creek, and Stahl Creek. WCI conducted similar surveys on representative reaches of lower Grave Creek on private land. Bankfull indicators were used to determine bankfull channel width. Mean depth was calculated from the plotted cross section (or cross section area divided by bankfull width). Entrenchment, sinuosity and slope were also measured in order to determine a Rosgen Level 3 stream type for each location. The results were used to calculate width to depth ratios based on bankfull width and mean bankfull depth.

F.5.2 Pfankuch Channel Stability Rating

The Pfankuch channel stability method is a semi-quantitative field analysis technique used to rate the relative stability of a channel based on a number of parameters including vegetation condition, channel morphology, and bank material composition among other variables. The USFS included Pfankuch ratings for each reach.

F.5.3 Substrate Distribution

Wolman pebble counts were used to determine channel substrate particle size distribution. Both USFS and consultant-led channel morphology surveys used the Wolman pebble count for all surveyed cross-sections. Pebble counts sampling represented particles from both riffles and pools. The number of individual particles sampled from each feature corresponded to the relative percent of riffle versus pool with in each reach. For example, in a reach consisting of 60 percent riffle and 40 percent pool, a count of 100 particles included 60 from riffles and 40 from pools. The resulting particle size distribution is thus a composite. A cumulative percent finer-than graph was generated for each cross-section pebble count.

F.5.4 Percent Surface Fines

From Wolman pebble counts discussed above, cumulative percent finer-than graphs were used to interpolate percent fines less than 6.35mm and less than 2mm

F.5.5 Plan Form Geometry

Multi-temporal air photo sets were used to evaluate changes in plan form geometry of lower Grave Creek. In particular changes in channel length, radius of curvature, sinuosity and meander wavelength were noted.

F.6 Sediment Source Assessment

Following compilation and review of all pertinent and available data and information, a coarse screen analysis was conducted to develop the framework for the source assessment phase of restoration planning. The coarse screen analysis included development of a color balanced, image mosaic of the entire watershed used to conduct preliminary stream reach delineations. A hazard rating map was developed based on degree of channel departure over time (with reference to the 1954 photo series), concentration of past timber harvest and road construction activities, and visible sediment sources. All potential upland and in-stream sediment sources visible and within 300 ft of perennial and intermittent drainages in the watershed were mapped and measured for field validation during this phase of source assessment.

Supplemental field data were collected by RDG during the fall and winter 2003. Data collection was streamlined to ensure inventories of conditions noted on the 303(d) list for the main stem Grave Creek. The objectives of the field assessment were to fill data gaps to the extent practical, identify sources of sediment loading and habitat alterations, and collect data used in the development of numeric and performance targets for TMDLs and other restoration goals.

F.6.1 Upland Sediment Sources

Sediment sources were identified during air photo interpretation. 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 was assigned.

Most of the sources within 150' of the riparian area overlapped with in-stream sources (all mass wasting sites) identified during the in-stream inventory of sediment sources. Sediment loading from these specific riparian area sources is accounted for in the In-stream Sediment Source Analysis (Appendix J).

The remaining sites identified via aerial assessment were located at mid and upper slope and were determined to be beyond the sediment contributing distance to the stream network. Therefore, sediment loads from these sources were not calculated.

F.6.2 In-stream Sediment Sources and Associated Riparian Vegetation

Detailed field sediment source surveys were completed on the main stem and primary tributaries. Results from the Coarse Screen Analysis indicated that sediment sources associated with roads, old logging units, bank erosion and natural sources such as debris slides and avalanche paths were the primary sources of sediment to the watershed.

F.6.2.1 Bank Erosion in Lower Watershed

Bank erosion was linked to apparent land management activities on or adjacent to the eroding bank in the lower watershed. As such, the field source assessments included inventorying and measuring the area of eroding surfaces (e.g. streambanks, terraces, moraines) contributing to the drainage network, and linking sources to one of several land use categories. A bank hazard erosion index (BEHI) rating was applied to each site based on several factors including the ratio of low bank height to bankfull stage, rooting depth ratio, bank angle, and percent surface protection (Rosgen, 1996). Bank erosion sources and eroding areas with the potential to contribute sediment to the stream network were quantified to generate a contributed load for each of the tributaries and main stem Grave Creek. Appendix J provides details and analysis results of the in-stream sediment source and associated riparian vegetation assessment.

F.6.2.2 Mass Wasting in the Middle and Upper Watershed

Mass wasting sites along the middle and upper main stem Grave Creek and several tributaries were identified and measured in the field. Two methods were used to model loading from these sites. First, surface erosion from mass wasting sites was evaluated using the WEPP model and treating the slope failure sites similar to road fill slopes. Second, 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 evaluated with a modified BEHI approach.

F.6.2.3 Riparian Vegetation Assessment

Modified Daubenmeyer vegetation plot surveys were conducted at each in-stream sediment source assessment sites. At each sediment source identified, a percent cover class was assigned to each vegetation class. Vegetation classes included overstory, understory and groundcover. Percent cover classes included absent, sparse, moderate, heavy and very heavy. Table F.2 presents percent cover and vegetation class criteria. Associated land use, ownership, and sediment source dimensions and stability rating were also collected.

Table F-2: Riparian Vegetation Class Survey Criteria.				
Vegetation Cover Density			Vegetation Cover Class	
Percent Cover Class	Percent Cover		Vegetation Class	Vegetation Class Criteria
Absent	0		Overstory	> 5 m high, large and small trees
Sparse	< 10		Understory	0.5 – 5 m high, shrubs, herbs, forbs
Moderate	10-40		Ground Cover	< 0.5 m shrubs, seedlings, herbs, forbs, grasses
Heavy	40-75			
Very heavy	> 75			

F.6.3 Road Sediment Source Modeling

The USFS conducted an analysis of sediment derived from forest roads using WEPP. The modeled delivery rates were extrapolated to all system roads in the watershed to estimate total sediment contribution from roads at the sub-watershed level. Appendix I provide details and analysis results of the road sediment source assessment.

F.7 Land Use Indicator Assessments

USFS TSMRS database records noting the activity year, type, and extent of harvest and road construction in the basin were queried and analyzed using GIS. Appendix A and B provide details and analysis results of the timber harvest and road building land use assessment.

Equivalent clearcut acres (ECA) and water yield and peak flow increase modeling results and analysis of vegetation removal in the rain-on-snow zone were evaluated to determine possible effects of land use activities on water yield. Appendix C provides details and analysis results of the water yield assessments.

APPENDIX G
STREAM CONDITIONS

This appendix addresses existing channel, floodplain, fish habitat and upland conditions along with a general discussion on human activities and potential linkages between these activities and existing conditions. The focus is on non-point sources of pollution, links with riparian vegetation condition and stream morphology, and the relation of riparian and stream morphology conditions to land use practices in the Grave Creek Watershed. Data assessment methods summarized in Appendix F provides the basis for the following discussion.

G.1 General Summary of Natural and Human Impacts Linked to Sediment Loading

Due to local geology and climate, streams of northwestern Montana have naturally evolved under an above average bed load availability and a high runoff regime with periodic rain-on-snow events. This has led to stream systems that are very dynamic in that they naturally adjust to facilitate the deviations in flow and sediment produced by natural processes in the watershed. Grave Creek has not only adjusted to periodic flood events, but also to timber harvest and road development in the headwaters as well as agriculture, grazing, riparian vegetation losses, and channel alterations along the downstream reaches. These underlying conditions can impact stream channel stability, the quantity and quality of available fish habitat, and the structure and composition of the riparian community, particularly in the lower portions of the drainage. A review of the historical aerial photograph series and existing data indicate that reaches of Grave Creek are currently functioning below their geomorphic and riparian health potentials (WCI, 2000). Biological function is also likely below potential because of the association of habitat with geomorphology and riparian health.

Sediment production and transport is a natural occurrence within watersheds. A significant challenge to the formulation of this TMDL was to partition the natural, background loads from human-induced loads and to then determine the extent even those loads associated with human activities can be controlled via BMPs and reasonable land, soil and water conservation practices. This is an important distinction in light of Montana’s water quality standards and the use of reference conditions. For example, some of the narrative standards are based on increases above “naturally occurring” concentrations of sediment that can negatively impact beneficial uses. The multiple lines of evidence to assess sources and potential for delivery of sediment (summarized in Section 6.0) provide the basis for discriminating among natural and human-related sources.

There are several potential natural sources of sediment in the Grave Creek Watershed. Erosion and ultimate delivery of sediment from hillslopes to streams is a potentially significant natural source, especially in areas of the watershed that are characterized by the rain-on-snow zone (elevations ranging from 3,500 ft to 5,500 ft), erodible soils, and low vegetation cover. Mass wasting is an extreme form of hillslope erosion that can contribute substantial sediment to streams. Mass wasting events are a relatively frequent phenomenon in the Grave Creek Watershed. Eighty-six out of 133 – 65%- sediment sources identified along streams in Grave Creek were described as mass wasting, some of which are linked to natural occurring avalanche chutes or slide areas (Photos 4 and 5). Additional upland mass wasting sites were also identified. Section 6.0 and Appendices H, I and J describe the source assessment and sediment loading analysis in more detail. Finally, stream bank erosion is to some extent, a natural occurrence within streams that contributes to the system's sediment load.

Human activities can accelerate natural erosion and sediment loading processes that contribute excess sediment to the stream system. Human activities within the Grave Creek Watershed that have increased sediment production and delivery include riparian vegetation removal, road building, improper bank stabilization, channelization, large woody debris removal from the channel, and surface water diversions. Land use practices that reduce riparian vegetation and/or cause channel encroachment can increase the rate and pattern of bank erosion (Photos 6 and 7) and can increase the extent of mass wasting in the watershed (Photos 8, 9 and 10). Channel changes, such as historical channel straightening or activities that prevent natural channel movements, also cause accelerated erosion (Photo 5). Removal or alterations in vegetative cover on uplands, or high road densities that capture and route surface water runoff, have the potential to increase hillslope erosion and frequency of surface erosion and mass wasting events. Similarly, increased water yield from vegetation removal can accelerate bank erosion downstream through increased peak flows. Erosion from the surface of roads is another potential source of sediment to streams. This also includes sediment contributed from cut and fill slopes along roads, road surface sanding, and impacts associated with culverts and bridges. Removal of large woody debris from the stream channel and riparian areas reduces the opportunities for woody debris recruitment to the channel, decreases channel roughness, and impairs the stream's sediment storage capacity. Finally, significant surface water diversions during the receding limb of the hydrograph and base flow periods may increase sedimentation by reducing stream competency. At such reduced flows, the stream is not capable of carrying its sediment load therefore sediment is deposited.

Several decades have passed since many of the accelerated erosion and mass wasting events described above occurred. However, bed load transport rates are typically very low (especially in C, D and some B and F stream types) (Rosgen, 1996). Coarse sediment loads from historical events can remain within a stream system for long periods, potentially resulting in persistent, degraded water quality or habitat conditions. Other types of impacts from historical activities, such as a reduction in LWD, LWD recruitment, and associated channel adjustments can also last for extended periods, again producing negative impacts to water quality and habitat over those time frames.

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A), roads (Appendix B), and water yield, ECA, and activities in the rain-on-snow zone (Appendix C).

G.2 General Discussion of Fish Habitat, Assessment Methods, and Linkage to Human Activities

In western Montana rivers large woody debris is often essential for creating and maintaining complex habitats necessary for supporting fluvial populations of bull trout (*Salvelinus confluentus*) and westslope cutthroat (*Oncorhynchus clarki lewisi*). Grave Creek fisheries information, including species composition, population estimates, redd count results, and macroinvertebrate data, are discussed in more detail in Appendix D. Nodal habitats (those containing migratory corridors, over wintering areas, and other critical habitat) are essential for maintaining well-connected and sustainable populations. For bull trout and westslope cutthroat trout (WCT), nodal habitats must contain deep pools and complex aquatic habitat. Abundant large woody debris and deep pools provide cover, protection from predators, and stable environments for bull trout (Jakober et al., 1997). These habitats are especially critical for over-winter survival when harsh wintertime conditions make shallow river reaches inhospitable for large fish. Land use activities that remove riparian vegetation, straighten the stream channel, and/or introduce sediment to streams can simplify the stream channel and reduce the persistence of habitats necessary for sustaining healthy bull trout populations (MBTSG, 1998).

Furthermore, large woody debris was systematically removed from the Grave Creek channel prior to the 1990s (Photo 11) on the premise that woody debris degraded water quality, fish habitat, and fish passage (Bohn, 1998, unpublished report data). Wood removal reduced channel stability and the availability of quality aquatic habitat. Bulldozing in-channel and adjacent to Grave Creek main stem to remove wood after flooding in the 1970’s also contributed to channel instability and degraded habitat. LWD removal from tributary streams may have also occurred, but on a much smaller scale than the main stem. Clarence Creek is the most likely tributary to have had wood removal from the stream channel (USFS, 2004).

Potential primary limiting factors in Grave Creek are related to the distribution of deep pool habitats. Adult holding habitats that are essential for fish during fall spawning migrations are infrequently distributed in the lower reaches of Grave Creek due to poor pool development, insufficient woody debris, and homogenous riffle habitat. Poor pool development and distribution degrade the value of the main stem Grave Creek as nodal habitat. Ice formation during the winter and inhospitable summer water temperatures are both attributed, at least in part, to shallow riffle habitats and the absence of complex aquatic habitat typified by large woody debris-generated cover. These conditions may preclude bull trout persistence during stressful summer and winter periods. Shallow riffle habitats devoid of complex woody debris also increase the susceptibility of large fish to terrestrial and avian predators, as well as poachers. Poor riparian vegetation conditions may contribute to elevated water temperatures, poor woody debris recruitment, and inadequate in-stream cover for WCT and bull trout.

Historically, channel morphology created a diversity of complex habitat that provided specific habitat requirements for the various age classes of fish utilizing the main stem of Grave Creek. The apparent changes in riparian vegetation condition, including species diversity and age class, and changes in channel pattern, are the most significant factors affecting both the quantity and quality of available in-stream habitat. Based on review of streams of similar size and morphology, riparian zones were likely comprised of forested riparian community types typified as a mosaic of intermingling riparian forest and deciduous shrub land. Undisturbed riparian stands in a few sections of the project area are well developed, with multi-canopied conditions and a high degree of canopy cover. In these sections, in-stream habitat complexity is significantly improved and characterized by deep pools and complex lateral channel margin habitats with undercut banks, overhanging vegetation, and decadent, recruiting large woody debris.

Data from several sources were reviewed for evaluating the fish habitat conditions on main stem Grave Creek. USFS R1/R4 data characterized habitat in Grave Creek main stem from Highway 93 up to Fondation Creek, as well as in the primary tributaries. Bankfull channel surveys were completed by USFS, MFWP, and private contractors on both privately owned and publicly managed lands. Appendix F describes in detail the methods used to collect each type of data.

G.3 Stream Stratifications

The following section summarizes existing channel geomorphology and fish habitat for Grave Creek and its primary tributaries including Stahl Creek, Clarence Creek, Williams Creek, Blue Sky Creek, Foundation Creek, and Lewis Creek. This information is then used to compare these existing conditions to reference data to update water quality impairment determinations within the watershed (Section 5.0). Appendices I and J provide detailed sediment source loading information consistent with sediment TMDL development requirements. Biological indicators including fisheries and macroinvertebrates are summarized in Appendix D.

To facilitate this effort, two levels of stream channel stratification were used for data collection and analysis of existing channel morphology and habitat conditions. A third level of stratification was used for departure analysis (Section 5.0).

The first level of stratification groups Grave Creek and its tributaries by valley type and associated dominant channel bedforms. This stratification allows for general description of the basin characteristics and associated stream channels. This stratification applies to large stream segments (multiple reaches), which may be further divided according the second level of stratification.

The second, more specific, level of stratification used is the Rosgen stream type classification (Rosgen, 1996). The results of all channel morphogology and habitat data are presented by Rosgen stream types also referred to in this document as “stream types” or “reach types” or “channel types.” The Rosgen stream type classification is based on geomorphologic parameters including entrenchment ratio, width-to-depth ratio, sinuosity, and slope.

All streams have one or more reaches having different Rosgen stream types. Data collection and analysis focused on the middle and lower reaches of each tributary where fish and aquatic habitat is most important and most sensitive to impacts from human activities. All reaches of main stem Grave Creek are included.

The third level of stratification further separates Rosgen stream type reaches by stream size using either average stream width or stream order. This stratification is applied in the Water Quality Protection Goals and Targets section (Section 5.0), which includes development of reference reach conditions and departure analysis. Departure analysis is the comparison of observed conditions (presented in this appendix and summarized in Section 4.0) to reference reach conditions. This third level of stratification was necessary because morphology and habitat measures may be very different for streams with the same stream type but different order/width. For example, pool frequency for higher order C streams is typically lower than lower order C streams, although total pool volume may compensate for lower pool frequency.

Table G-1: Stream Stratifications in the Grave Creek Watershed.

Segment	Location	Valley Type	Dominant Bedform	Rosgen Stream Types
Lower Grave Creek	Fortine upstream to canyon	Unconfined, fluvial	Pool-riffle	C3/4 and D3/4
Lower Grave Creek	Canyon reach	Bedrock controlled	Step-pool	Fb
Lower Grave Creek	Canyon upstream to Williams Creek	Unconfined and Semi-confined	Pool-riffle with Step-pool inclusions	Fb, C3/4, B3/4
Middle Grave Creek	Williams Creek to Blue Sky Creek	Confined and Semi-confined	Step-pool with Step-pool to Riffle-pool transitions	B3/4 and C/3/4
Upper Grave Creek	Blue Sky Creek to Lewis Creek	Semi-confined, Alluvial	Riffle-pool with Step-pool transitions	C3/4 and B3/4
Upper Reaches of Tributaries	Tributary headwaters	Confined	Cascade and Step-pool	A, G
Lower Reaches of Tributaries		Confined and Semi-confined	Step pool with Riffle-pool inclusions	B3/4 also A, Ba, Cb

Inputs of coarse and fine sediment and large woody debris as well as peak flows and catastrophic events including periodic rain-on-snow events and fire, influence channel stability and response to perturbations. Sensitivity to such disturbances varies by dominant bedform and valley type and Rosgen stream types (Table G-2).

Table G-2: Stream Type Sensitivity Characteristics (Based on Morphological Descriptions in Rosgen, 1996).

Stream Types	Bank Erosion Susceptibility	Sediment Supply	Other
A3/4	High	High	High bedload transports rates; debris torrents, avalanches, mass wasting common
B3/4	Low	Low	
C3/4	Moderate to High	Moderate to High	C4 susceptible to vertical adjustment; bank erosion depends upon amount and condition of vegetation
D3/4	High	High	Indicates "flashy" runoff regime
F2	Low	Low	
F4	High	Moderate to High	

G.4 Main Stem Grave Creek Conditions

As discussed above, the main stem of Grave Creek is divided into three major segments due to the varied physical habitat conditions defining main stem Grave Creek (Map 13). The first segment spans from the mouth of Grave Creek to the confluence of Williams Creek and Grave Creek, and includes both private and publicly managed land. There are no substantial tributaries to lower Grave Creek. The second segment (middle Grave Creek) spans from the Williams Creek confluence upstream to the Blue Sky Creek confluence. Middle Grave Creek includes the Clarence Creek-Stahl Creek confluence with Grave Creek. The third segment (upper Grave Creek) covers the remaining portion of Grave Creek upstream from the Blue Sky Creek to the confluence with Foundation Creek. Foundation Creek and Lewis Creek are the largest tributaries in upper Grave Creek.

G.4.1 Lower Grave Creek

G.4.1.1 Lower Grave Creek General Description

For this analysis, lower Grave Creek (Fortine to Williams Creek) is further divided into three sub-sections according to valley type, dominant channel bedforms, and Rosgen stream types as identified below.

- The downstream section of lower Grave Creek from the Fortine Creek confluence to the GLID diversion is characterized by unconfined to semi-confined pool-riffle channel morphology. Below Vukonich Bridge the stream is generally unconfined, has a broad floodplain, and is generally a Rosgen C4d stream type, Above Vukonich Bridge, the channel is semi-confined, has a narrower floodplain is generally a Rosgen B4 stream type.

- Upstream of the GLID diversion Grave Creek is confined by a bedrock canyon for approximately 2,000 feet. This section is generally a Rosgen Fb stream type.
- Upstream of the bedrock canyon to the Williams Creek confluence Grave Creek is again characterized by an unconfined to moderately-confined pool-riffle morphology and narrow floodplain. This section includes Rosgen Fb and B4 stream types.

Each of these three sections and varying stream types maintain different types of fish habitat and channel conditions that support different fish life stages. Unconfined channel morphologies (usually Rosgen C streams) are typically characterized by alternating pool and riffle habitat features. Pools provide deep-water habitat for large adult fish as well as refuge for all life stages during stressful winter and summer periods. Riffles are food production areas and habitat for benthic fish species, juvenile fish, and individuals of smaller fish species. Shallow channel margins, large woody debris accumulations, vegetation, and varied substrate also provide varied habitats for various life stages.

Moderately confined and confined reaches (Rosgen B or F types) also provide important habitat for fish depending on the composition of habitat features. Bedrock scour pools or pools formed by boulders provide diverse flow paths and deep water for fish. Woody debris accumulations may also improve fish habitat diversity in moderately confined and confined channel segments. Where these types of habitats are absent, fish may use moderately confined and confined reaches as migration corridors between higher quality habitat channel segments. A general discussion on the water quality and habitat conditions observed in each section of lower Grave Creek is provided below.

G.4.1.1.1 Fortine Creek to GLID

Below the GLID diversion, Grave Creek is formed in glacio-fluvial landforms characterized by terraces, moraines, and glacial and alluvial outwash deposits. As noted in Tables G-2, the stream types in this reach (C3/4 and D3/4) are highly susceptible to bank erosion and have a high sediment supply. As a result, there is a high potential for response to changes in discharge, sediment, and large woody debris due to its low gradient, riffle-pool morphology and dependence on vegetation for stability. Due to its unconfined nature, the channel is free to adjust its boundaries in response to either increased discharge or sediment supply (Photo 12). This unit has the potential to increase sediment delivery to the channel when the stream banks are eroded or the channel form is altered.

Comprised of mostly private land, this channel unit includes agricultural and residential land uses within the watershed. This reach was extensively modified in the early 1900s to accommodate agricultural development. The historical condition was characterized by multiple channels developed within a vast, well-vegetated spruce bottom wetland. The system may have resembled a stable anastamosed stream (multiple channels, braided) developed on a non-building, stable alluvial fan. This multiple channel system was systematically filled in the early 1900s, diverting the combined flow of all braids into the existing Grave Creek channel.

In the past, portions of lower Grave Creek were bulldozed to “speed up” the water so the channel could maintain its ability to convey the floodwater, sediment, and debris produced by the watershed. In-channel bulldozing compounded flood effects and lengthened the Grave Creek’s recovery time following high magnitude flood events. These activities also inhibited Grave Creek’s natural recovery process following floods and caused the channel to deviate from its potential geomorphic state. Channelization has also resulted in a substantial reduction in floodplain and streamside vegetation, and alteration of the stream’s natural dimension and geometry. Grave Creek is therefore less stable than it generally was historically as exhibited by accelerated lateral erosion rates and excessive sediment delivery to the channel (WCI, 2000), both conditions are further evaluated in this appendix.

Accelerated sediment delivery from historical activities in upstream reaches has likely contributed large quantities of bedload size sediment to lower Grave Creek. Grazing and other impacts to riparian areas has reduces the stream’s ability to resist accelerated bank erosion. Loss of large woody debris in this channel unit may also result in significant morphological channel adjustment affecting the biological community, although large woody debris concentration is expected to be lower in a higher order C-type stream channel. Example channel adjustments would tend to include pool loss, increased effective shear stress, increased stream width and width to depth ratios, and the potential conversion to a plane bed morphology (Montgomery and Buffington, 1997). These processes have likely reduced the frequency of deep pool habitat for native bull trout, westslope cutthroat trout, and other fish species inhabiting or migrating through lower Grave Creek.

G.4.1.1.2 GLID Through the Canyon

This section corresponds to stream reaches located from the Glen Lake Irrigation District point of diversion upstream through the Grave Creek canyon. The channel is formed in a structurally controlled and confined bedrock valley that precludes major shifts in channel plan form and dimensions. Bedrock channels are generally resistant to short-term changes in sediment supply or peak flows. Rosgen stream type is primarily an Fb channel. This channel type is very stable with very low susceptibility to bank erosion and very low sediment supply due to the boulder and bedrock materials and to the lateral confinement of the valley.

G.4.1.1.3 Canyon to Williams Creek

Similar to the lowest section of Grave Creek, Grave Creek from the head of the canyon upstream to the confluence with Williams Creek is formed in coarse glacial moraine deposits and therefore has the potential to contribute significant amounts of sediment to the channel network. Stream reaches are characterized by pool-riffle morphology in both unconfined and moderately confined segments dominated by F stream types with inclusions of C reaches. There are also confined B inclusions.

With the exception of the B type inclusions, the stream types in this reach have a moderate to high sensitivity to sediment and debris loading, peak flows, and periodic catastrophic events. Bank erosion susceptibility and sediment supply are moderate to high. Erosion depends upon the amount and condition of vegetation (Table G-2).

While mass wasting of morainal deposits is common and natural in these channel units, upland harvest activities have the potential to compound any existing sediment supply problems. Additionally, channeled colluvial valleys (face drainages) contribute debris into the reach through various erosional processes including dry ravel, fluvial entrainment, mass wasting, and gravitational failure. Loss of large woody debris in this section of Grave Creek can result in significant morphological changes, including pool loss, increased effective shear stress, and the potential conversion to a plane bed morphology (Montgomery and Buffington, 1993).

Historically, the hillsides adjacent to this unit experienced frequent fires as evident in the historical aerial photo record and from the writings of early travelers in the area (B. Bohn, USFS, personal communication). The suppression of fires during the last 60 years has allowed riparian and hillside vegetation to become denser, with the exception of logged face drainages located south of the Williams Creek confluence.

Historical timber harvest and road construction upstream have increased sediment delivery and peak flows to this section, with the potential for impacts to bank stability (Photo 13). Several timber harvest units situated on lateral moraines adjacent to the channel have accelerated side slope erosion, and in some instances, triggered rotational slumps that have contributed sediment and logging slash directly to Grave Creek (Bohn, 1998, unpublished report). Subsurface flow interception by road cut slopes has the potential to exacerbate slope instability in some areas. Section 6.0 and Appendices I and J describe the source assessment and sediment loading analysis in more detail.

G.4.1.2 Aerial and Physical Assessment Results for Lower Grave Creek

These following subsections provide a summary of aerial and physical assessment data for lower Grave Creek. Reference Appendix F for a description on methodologies.

G.4.1.2.1 Aerial Assessment Results

A comprehensive overview of the geomorphic response(s) of lower Grave Creek to land uses was conducted by RDG using historical and current aerial photography with field verification. Historical photograph review indicated that the project area has been sensitized over time by the cumulative effects of channel alterations, timber harvest, road construction, flow diversions, riparian grazing, and agriculture.

In lower Grave Creek below the canyon, the channel resembled a Rosgen C stream type prior to 1947. When stream bank vegetation was further displaced and the stream was further channelized to support logging drives, stream banks began to lose their competency to resist the erosive forces produced in the channel during floods. Excess upstream sediment loading from historical harvest activities would have contributed to increased erosive forces and increased peak flood flows. Stream channel widening occurred. It is likely that the stream initially began to migrate laterally at an accelerated rate, transitioning from a moderate width/depth ratio, stable C4 stream type to an over-widened, braided, high width/depth ratio D4 stream type (Rosgen, 1994). Over time, and primarily due to accelerated downstream meander migration and bank erosion, the channel eroded through the outside bend of several meanders. This process, referred to as an “avulsion”, decreased the channel length. From 1947 to 1992, channel sinuosity in the section of lower Grave Creek primarily from Highway 93 to Vukonich Lane decreased by approximately 15 percent, from 1.23 to 1.08, and average riffle width increased from 60 feet to 130 feet (WCI, 2000). The resulting over-steepened bed profile and widened condition have increased the hydraulic capacity of the channel, thereby increasing the shear stress applied to the channel perimeter. Under this condition, the stream banks and channel bed become significant sources of sediment to the channel system.

In the canyon section, no changes in channel pattern, geometry, or riparian vegetation conditions were documented from 1954 to 1992 (WCI, 2000). During this same period, the reach from the upper part of the canyon to Williams Creek experienced an increase in average bankfull channel width through bank erosion and lateral adjustment. This would tend to decrease the channel’s sediment transport capacity.

From the top of the canyon reach up to Williams Creek, upland forest activities and in-stream habitat alterations have apparently affected channel stability (Bohn, 1998, unpublished report). Removal of large woody debris from the channel has reduced sediment sorting capacity and energy dissipation formerly provided by woody debris. Channel features are largely associated with extended riffles and infrequent pools generally formed by unstable, smaller diameter logging slash and debris and/or boulders.

G.4.1.2.2 Fish Habitat – Pools

The moderately confined B reaches and confined F reaches maintain higher quality pool habitat in the upper portions of lower Grave Creek than the C reaches below the GLID (Table G-3). Pool characteristics measured during the USFS R1/R4 surveys indicated that the most frequent pools were located in the B inclusions while the deepest pools were found in the F reaches (Table G-3). The shallow, over-widened channel in the disturbed C reaches (see G.4.1.2.5) provides less high quality habitat.

Table G-3: Pool Characteristics from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max) Lower Grave Creek.					
Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Lower Grave Creek	C	9	90 (35, 113, 250)	3.8 (3.0, 4.7, 5.6)	2.7 (1.4, 3.3, 4.7)
	F	9	67 (22, 77, 91)	5.1 (2.9, 5.8, 6.7)	3.5 (1.5, 4.5, 5.2)
	B	19	60 (17, 81, 131)	3.7 (2.8, 4.2, 5.3)	2.1 (0.6, 2.7, 3.5)

G.4.1.2.3 Fish Habitat – Large Woody Debris

USFS evaluated large woody debris accumulations in the three stream types characterizing lower Grave Creek (USFS, 2001, unpublished data provided by P. Price; Table G-4). For each reach, large woody debris counts were made for the number of single pieces, the number of LWD aggregates, and the number of LWD rootwads.

Rootwads and large woody debris aggregates were most frequent in the B reaches of lower Grave Creek (Table G-4). Lower large woody debris counts in the F reaches may be attributed to more efficient debris transport especially in the canyon. Lower counts in the unconfined downstream segment may be due to large woody debris removal (via bulldozing and other means) and riparian clearing that occurred throughout the 1900s.

Table G-4: Lower Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).						
Stream	Stream Type	Count	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Lower Grave Creek	C	77	20 (0, 65, 344)	9 (0, 59, 226)	29 (0, 60, 304)	101 (0, 171, 607)
	F	64	5 (0, 45, 217)	0 (0, 9, 278)	58 (0, 114, 304)	106 (0, 158, 555)
	B	33	61 (0, 119, 192)	0 (0, 15, 244)	0 (0, 9, 83)	81 (0, 159, 305)

G.4.1.2.4 Sediment Particle Size Monitoring Results

Sediment transport capacity is highly variable in lower Grave Creek. Channel and valley morphologies influence the transport and storage of sediment and debris through the reach. Sediment particle sizes influence spawning redd success, larval fish rearing, juvenile fish survival, and aquatic macroinvertebrate production.

Particle size distributions and percent surface fines were derived from data collected by the USFS and WCI using Wolman Pebble counts (Table G-5). Values for 2 mm and 6.35 mm size classes were interpolated from cumulative percent-finer-than plots. Percent surface fines in pool tailouts (glides) where spawning would tend to occur was determined using the 49-point grid toss method during USFS R1R4 surveys (Table G-6).

The highest percentages of fine particles less than 6.4 millimeters measured by either method were in the B and C reaches (Table G-5 and G-6). Increasing percent fines is one indicator of channel response to upland activities and can indicate an increase in sediment supply and /or a decrease in channel transport capacity. Median percent of fines in pool tails was less than 10% for all stream types. Maximum percent of tail out fines was greatest in the lower gradient C and F reaches (Table G-6).

Table G-5: Lower Grave Creek Composite Particle Size Distribution and Percent Surface Fines.

Stream Location	Stream Type	% < 2 mm	% < 6.35 mm	D16 (mm)	D50 (mm)	D84 (mm)	Collected by
Below Canyon	C	≤ 11	≤ 12	18	81	146	WCI (2000)
Canyon	F	3	7	11	60	180	USFS
Above Canyon	F	5	11	not available	not available	not available	USFS

Table G-6: Lower Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, Unpublished Data).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75^{th} Percentile Fines	Max % Fines
Lower Grave Creek	C	42	0	10	20	80
	F	18	0	5	10	40
	B	35	0	7.5	15	25

G.4.1.2.5 Channel Morphology

Existing channel dimensions and potential channel dimensions were developed by WCI for the Grave Creek Demonstration Project downstream from Vukonich Lane (Table G-7). Potential channel dimensions were developed from reference reach data collected on Grave Creek downstream from the Highway 93 crossing. Bankfull channel characteristics measured in the unconfined C stream type segment of lower Grave Creek suggest the channel conditions are functioning below their historical potential due to excessive channel widths and elevated width/depth ratios (Table G-7).

Table G-7: Existing and Potential Channel Conditions (Riffle), and Channel Departure Analysis for Lower Grave Creek Below the Canyon (WCI, 2000) Average (Range).

Bankfull Variable	Existing Dimensions	Potential Dimensions	Departure
Bankfull Discharge (cfs) (Ave)	660	660	-
Cross-sectional Area (ft^2)	145	120 (108-132)	+25
Width (ft)	116	52 (50-54)	+64
Hydraulic Depth (ft)	1.24	2.3 (2.2-2.4)	-1.06
Width/Depth Ratio	93.5	20 (18-22)	+73.5
Sinuosity	1.08	>1.4	-32%
Meander Length Ratio	6.7 (5.2-8.2)	16.5 (13.8-19.2)	+9.8

Table G-8 provides a summary of channel metrics from USFS monitoring in portions of lower Grave Creek. Channel stability ratings for the F segment above the canyon rated good (Table G-8). No rating was provided for the already stable canyon reach. Table G-9 provides a summary of the riffle characteristics for the F reach cross section above the canyon.

Table G-8: Channel Metrics Summary (USFS, 2003). Lower Grave Creek Canyon Reach (XS 2) and Above the Canyon (XS3).

XS	Channel	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
2	F4b	n/a	42.3	19
3	F2b	82 (good)	52.3	15

Table G-9: Lower Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Lower Grave Creek	C	No Data Collected				
	F	42.3	93.1	2.2	19	0.028

G.4.1.3 Other Assessment Results for Lower Grave Creek

G.4.1.3.1 Temperature Monitoring Results from 2003

The USFS installed a DEQ temperature logger in Grave Creek near Highway 93. Temperature was recorded daily at 30-minute intervals from the beginning of July 2003 through the beginning of October 2003. From August 8 to September 15, data more closely reflect air temperature and is therefore not included here. It is possible that the stream either went dry or some other problem occurred. Before and after this erroneous timeframe, temperatures in Figure G-1 are considered representative of actual stream temperatures at that location.

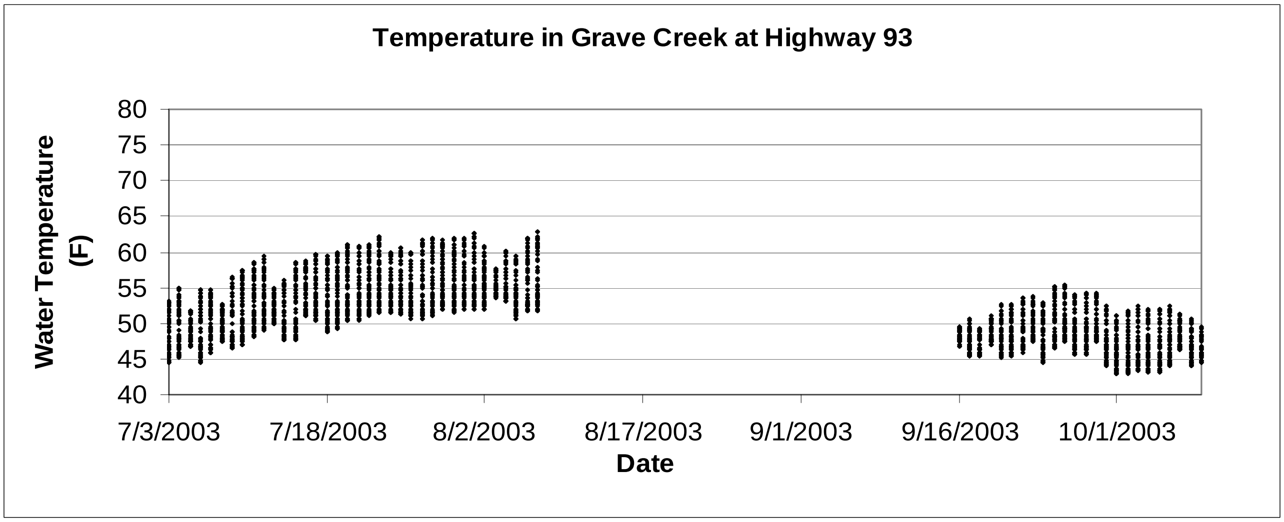


Figure G-1. Daily Temperature of Grave Creek at Highway 93. Temperature Recorded at 30-Minute Intervals. (MDEQ Unpublished Data).

G.4.1.3.2 Fish Passage Information and Flow Alteration (Dewatering)

The GLID diversion is the primary diversion on Grave Creek. Removal of the historical log crib diversion dam has improved fish passage from the lower to the upper watershed as discussed in Appendix D. Fish passage at this location is no longer considered a habitat alteration impairment, although there may still be room for improvements in areas such as reducing entrainment of young fish.

Although GLID has a water right for 220 cfs, typically less than 60 cfs is withdrawn from Grave Creek. As identified in Appendix E, a minimum discharge of 70 cfs, based on a wetted perimeter-discharge relationship and fish passage needs, was recommended by fishery biologists during low flow below the GLID. Flow for September 1986 was at 43 cfs (Marotz and Fraley, 1986), and similar low flow conditions were observed in lower Grave Creek by DEQ assessment personnel during summer, 2003.

G.4.1.3.3 Grave Creek Restoration Project Data

KRN, USFWS, and MFWP have initiated a comprehensive stream restoration program on lower Grave Creek. Three channel reconstruction projects; GLID dam removal and reconstruction (discussed above); the Grave Creek Demonstration Project; and the Grave Creek Phase 1 Project, have been completed to improve channel stability, reduce sediment sources, and to enhance aquatic habitat in lower Grave Creek. The Grave Creek Demonstration Project stabilized a high terrace that was eroding at an accelerated rate. Grave Creek Phase 1 reconstructed nearly a mile of channel and floodplain to improve channel-floodplain connectivity, fish habitat, and sediment transport in the focus reach. Future projects will address other portions of lower Grave Creek to meet similar fisheries and channel stability objectives.

Post run-off monitoring data have been collected by MFWP on the Grave Creek Demonstration Project (MFWP, unpublished data). Based on the post-runoff survey, the total number of pools before and after project construction was similar, but total pool length increased slightly (16.6 percent), and both mean and maximum pool depths increased substantially (36.8 and 53.5 percent, respectively). The total number of pools from 2001 to 2002 decreased because of channel adjustments at bankfull discharge. However, the total length of pools remained similar between the two years. The loss of pools between 2001 and 2002 may partially be explained by the loss of some of the pool tailouts. The large woody debris stems and rootwads used during project construction also likely increased cover available to rearing and migrating salmonids within lower Grave Creek.

Pre and post-construction surveys were also completed in the Grave Creek Phase 1 Project. The baseline channel condition (pre-construction) was characterized by multiple channel braids, shallow pool depths, and poor aquatic habitat (Table G-10). Channel construction increased pool depths, narrowed and deepened the over-widened channel, and increased aquatic habitat complexity with the addition of woody debris and increased habitat volumes (Table G-11).

Table G-10: Lower Grave Creek Bankfull Channel Characteristics in the Phase 1 Restoration Project Reach Prior to Project Construction (MFWP, Unpublished Data).

Cross-section	Feature	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Max Depth (ft)	Width/ Depth
4+48	Pool	83.6	170.0	2.0	2.6	
7+51	Riffle	91.0	117.6	1.3	2.3	70.4
13+79	Riffle	149.8	241.7	1.6	4.7	92.8
23+87	Riffle	149.1	188.0	1.3	2.9	118.2
37+00	Pool	87.4	151.5	1.7	3.4	

Table G-11: Lower Grave Creek Bankfull Channel Characteristics in the Phase 1 Restoration Project Reach Measured After Project Construction (MFWP, Unpublished Data).

Cross-section	Feature	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Max Depth (ft)	Width/ Depth
4+48	Pool	118.0	151.0	1.3	5.2	
7+51	Riffle	48.0	104.8	2.2	3.3	22.0
13+79	Riffle	48.0	186.4	3.9	6.6	12.4
17+90	Riffle	47.0	126.1	2.7	3.8	17.5
23+87	Riffle	48.0	134.7	2.8	5.6	17.1
37+00	Pool	98.0	173.4	1.8	5.1	

G.4.2 Middle and Upper Grave Creek

This section includes discussion on both the middle and upper Grave Creek segments due to similar land use characteristics and due to the fact that some data is presented for the combined lengths of these stream segments.

G.4.2.1 Middle and Upper Grave Creek General Description

Middle Grave Creek extends from the Williams Creek confluence with Grave Creek, upstream to the Blue Sky Creek confluence with Grave Creek. Middle Grave Creek exhibits two general stream types:

- From Williams Creek to the Clarence-Stahl Creek confluence, Grave Creek is a moderately confined step-pool system with a narrow floodplain.
- From the Clarence-Stahl Creek confluence upstream to the Blue Sky Creek confluence, Grave Creek is characterized by alternating unconfined and moderately confined pool-riffle and step-pool morphology reaches. Narrow floodplain areas border the channel.

The upper Grave Creek area extends from the Blue Sky Creek confluence with Grave Creek, upstream to the confluence with Foundation Creek. Primary tributaries within the reach include Foundation, Lewis, and Drip creeks. Channel conditions in upper Grave Creek are generally characterized by unconfined and moderately confined reaches with pool-riffle morphology (Photo 14). Narrow floodplain areas border the channel.

Due to the confined and semi-confined nature of the landforms in middle and upper Grave Creek, sensitivity to peak flows and catastrophic events such as floods was rated moderate (Bohn, 1998, unpublished report). Due to the high-energy nature of these reaches, sensitivity to decreasing levels of large woody debris is high and typically results in pool filling, riffle extension, and a reduction in channel roughness.

Historically, this channel unit likely produced minimal in-channel sediment due to channel stability provided by dense, healthy riparian vegetation and structural controls of the valley and landforms. Engelmann spruce (*Picea engelmannii*) was the dominant riparian tree species prior to large-scale clearcutting by the USFS in the 1950s. Riparian harvesting has increased the proportion of small diameter spruce and Douglas fir (*Psuedotsuga menziesii*) within riparian stands (Photo 3).

Aerial photo records from 1954 to 1992 indicate spruce logging and road building began in the upper basin during the early 1950s. By 1954, all major arterial roads up main stem Grave Creek and major tributaries were constructed. The road supported an extensive spruce logging effort in the basin (Bohn, 1998, unpublished report). During the 1950s, a majority of the riparian areas along this unit of Grave Creek had been salvage logged at some level (Appendix A). Logging often consisted of removing the largest, most merchantable trees and leaving the smaller less valuable trees. Skidding operations by bulldozers were conducted without using the BMPs applied today to protect channel stability and reduce soil erosion. For example, skidding occurred on steep, sensitive slopes sometimes exceeding 40 percent, across stream channels, and through riparian areas (Bohn, 1998, unpublished report). Further harvest activity occurred in the 1980s, creating additional potential for impacts to the main stem and tributary channels. In these segments, channel braiding was common, with excessive in-stream deposition, floodplain cutting, and unstable large woody debris jams composed of short, small diameter logging slash. Localized bed load aggradation, similar to the type of aggradation shown in Photo 15, resulted in channel avulsions and bank erosion (Bohn, 1998, unpublished report).

While stream types like those found in middle and upper Grave Creek are inherently stable and maintain a high sediment transport capacity, increases in sediment loads can result in pool filling, a reduction in channel roughness, and the potential for bank erosion (Whittaker, 1987). Likewise, increased flows can have similar detrimental effects. The effects of spruce logging were manifested in an increase in peak flows and sediment yields and a decrease in the density of riparian areas along this unit of Grave Creek (Bohn, 1998, unpublished report). Increased peak flows and sediment yields from tributary logging likely contributed sediment loads to main stem Grave Creek well above the natural background rate of sediment loading.

Large woody debris removal, direct channel modifications and effects from the main Grave Creek road have also created potential impacts to reaches of Grave Creek. The resiliency of these channel units typically results in minimal plan form modification; although a reduction in large woody debris can reduce the sediment storage potential and pool formation potential. In the 1970s, USFS biologists were concerned that large woody debris would adversely impacts fish passage and channel stability. As a result, a systematic program to remove large woody debris was initiated on the main stem in the middle and upper watershed.

In the1970s, 1980s and early 1990s, the USFS installed numerous log and rock gabion check structures in an attempt to create pool habitat (Photo 16). Fifteen structures were observed and recorded by field crews in the fall 2003. A majority of these structures have failed and/or caused upstream aggradations and lateral cutting. Road fill encroachment has confined the channel in several locations, reducing the width of the floodplain and in some instances, disconnecting the entire floodway from the active channel. Road fill slope erosion has been addressed through riprap bank stabilization, gabion basket installation (Photo 17), and other hardened approaches that have generally reduced habitat quality. Bank armoring and road maintenance sites are most concentrated upstream of the confluence of Blue Sky Creek and Grave Creek.

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A); roads (Appendix B); and water yield, ECA, and activities in the rain-on-snow zone (Appendix C). Based on professional observations and documented impacts from logging activities in the Western U.S., human activities from 1954 to the present would have reduced available complex habitat and channel stability, particularly during the period when most harvest occurred, which was prior to widespread adoption of forestry best management practices in Montana. Much of the stream system in the upper Grave Creek Watershed has likely recovered, with the extent of recovery uncertain based on observations alone.

G.4.2.2 Physical Assessment Results for Middle and Upper Grave Creek

These following subsections provide a summary of physical assessment data for middle and upper Grave Creek segments. Reference Appendix F for a description on methodologies.

G.4.2.2.1 Fish Habitat – Pools

In middle Grave Creek (between Williams Creek and Blue Sky Creek confluences) pool characteristics measured during the USFS R1/R4 surveys indicated that pools were more frequent in the B reaches than the C reaches (Table G-12). Average pool length and maximum depth were similar between the two stream types. The residual pool average maximum depths were higher for the B vs. C reaches.

Table G-12: Middle Grave Creek Pool Characteristics from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Middle Grave Creek	C	12	23 (12, 35, 46)	2.9 (2.6, 3.3, 3.5)	1.2 (0.5, 1.5, 2.5)
	B	62	21 (9, 38, 67)	3.0 (1.4, 3.4, 5.4)	1.5 (0.5, 1.9, 3.5)

For upper Grave Creek (above Blue Sky confluence), pool characteristics measured during the USFS R1/R4 surveys indicated that pools were slightly more frequent in the unconfined C stream type sections than in the moderately confined B sections (Table G-13). Average pool length, average maximum pool depth, and average maximum residual pool depth were greater in the C reaches.

Table G-13: Upper Grave Creek Pool Characteristics from R1/R4 Data (USFS, 2001).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Upper Grave Creek	C	26	27 (8, 34, 108)	2.2 (1.3, 2.6, 4.9)	1.4 (0.6, 1.7, 4.1)
	B	24	10 (6, 12, 20)	1.6 (1.3, 1.8, 3.3)	0.8 (0.5, 1.0, 2.6)

G.4.2.2.2 Fish Habitat – Large Woody Debris

Large woody debris accumulation data in middle Grave Creek (USFS, 2001 unpublished data) are presented in Table G-14. The data show higher total LWD values in the C stream type portion of middle Grave Creek. Maximum LWD counts were higher in the B stream type portion of middle Grave Creek compared to the C stream type reaches.

Table G-14: Middle Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).						
Stream	Stream Type	Count*	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Middle Grave Creek	C	20	29.8 (0, 80, 467)	0 (0, 3, 230)	39 (0, 152, 288)	105 (0, 256, 467)
	B	78	0 (0, 99, 2810)	0 (0, 0, 832)	0 (0, 119, 1807)	56 (0, 233, 5366)

*The "count" is the number of habitat units; there were 20 C habitat units in middle Grave Creek for example.

Large woody debris accumulation data in upper Grave Creek (USFS, 2001, unpublished data) are shown in Table G-15. The data show LWD values in all categories were greater in the C reaches than in the B reaches.

Table G-15: Upper Grave Creek Woody Debris Concentrations from R1/R4 Data (USFS, 2001). Median (Min, 75th Percentile, Max).						
Stream	Stream Type	Count	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Upper Grave Creek	C	133	15 (0, 87, 528)	0 (0, 56, 619)	74 (0, 194, 671)	189 (0, 307, 1320)
	B	43	12 (0, 50, 1870)	0 (0, 21, 619)	0 (0, 49, 619)	61 (0, 174, 894)

G.4.2.2.3 Sediment Particle Size Monitoring Results

McNeil Core Results

MFWP monitors streambed substrate at various sites within the Kootenai River Basin using McNeil core samples. For Grave Creek, MFWP uses McNeil core samples to measure percent fine sediment (< 6.35 mm) in the upper 10 inches of streambed substrate. Cores are collected near bull trout spawning redds located in spawning monitoring reaches on the main stem of Grave Creek in the vicinity of Clarence Creek. MFWP has sampled and reported percent of streambed material less than 6.35 mm in size for 3 of the past 9 sampling years. Median McNeil core results include 22 percent, 25.3 percent and 20.4 percent for the years 1998, 2000, and 2001 respectively (Table G-16).

Table G-16. 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.

Pebble Count Results

Pebble count percent fines data are presented in Table G-17 for both middle and upper Grave Creek. B4 reaches tend to have higher values than B3 reaches as would generally be expected. Percent fines were highest upstream of Lewis Creek. In this segment, avalanche debris paths and direct sediment from eroding road fill slopes were identified as primary impacts to water quality and channel stability.

Table G-17: Particle Size Distribution and Percent Fines for Middle and Upper Grave Creek Segments (<6.35 mm) (USFS, 2003).

Channel Type	D16 (mm)	D50 (mm)	D84 (mm)	%< 2 mm	% < 6.35 mm
B4	11	51	94	10	15
B3	7	90	250	0	6
B4c	8	58	170	6	13
B3	16	88	256	5	13
C4	7	47	115	5	15
B4	6	40	185	5	15
C4	9	35	80	6	13
B4	4.5	42	175	12	18

In middle Grave Creek, average sediment particle sizes were larger in the B stream type reaches relative to the C stream type reaches, as would be expected by the steeper channel gradients and more confined channel morphologies of the B reaches (Table G-18). Table G-19 shows the same relationship for upper Grave Creek, although the smaller size D16 of the C channel units was twice that of the B channel units.

Table G-18: Middle Grave Creek Composite Particle Distribution Measured via the Wolman Pebble Count Method (USFS, 2003).

Stream	Stream Type	D16 (mm)	D50 (mm)	D84 (mm)
Middle Grave Creek	C	7	47	115
	B	10.5	71.8	192.5

Table G-19: Upper Grave Creek Composite Particle Distribution from Wolman Pebble Count Data (USFS, 2003).

Stream	Stream Type	D16 (mm)	D50 (mm)	D84 (mm)
Upper Grave Creek	C	9	35	80
	B	4.5	42	175

Grid Toss Results

Tables G-20 and G-21 present percent surface fines values < 6.35 mm measured during the R1/R4 surveys using the 49-point particle grid method for middle and upper Grave Creek. The median values were 5% for both B and C stream types in middle Grave Creek (Table G-20). The Table G-21 data show the median percent surface fines in pool tails of upper Grave Creek was lowest for the B reaches (0%) and greatest for the C reaches (10%).

Table G-20: Middle Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails Measured using the 49-point Particle Grid Method (USFS, 2001).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75th Percentile Fines	Max % Fines
Middle Grave Creek	C	10	0	5	8.8	10
	B	44	0	5	5	25

Sediment transport capacity is variable in upper Grave Creek. Channel and valley morphologies influence the transport of sediment and debris through the reach. Survey results determined that sediment particles are generally larger in the more competent moderately-confined B stream type reaches relative to the less competent unconfined C stream type reaches. This is apparent by the higher frequency of fine sediment (< 6.35 mm) measured in the unconfined C stream type reaches versus the B reaches. This is shown by the higher grid toss results in Table G-21 and the higher D16 results in Table G-19.

Table G-21: Upper Grave Creek Percentage of Surface Fines (<6.35 mm) in Pool Tails Measured Using the 49-point Particle Grid Method (USFS, 2001).

Stream	Stream Type	Count	Minimum % Fines	Median % Fines	75th Percentile Fines	Max % Fines
Upper Grave Creek	C	70	0	10	15	80
	B	21	0	0	5	15

G.4.2.2.4 Channel Morphology

Table G-22 presents channel morphology data for middle and upper Grave Creek. B stream type reaches are located throughout middle Grave Creek, whereas upper Grave Creek has primarily C stream type reaches. Channel morphology is largely characterized by gravel-dominated and some cobble-dominated, moderately confined reaches. Between Williams and Clarence Creek step-pool features are dominant. From Clarence to Blue Sky Creek, middle Grave Creek transitions from step-pool to riffle pool morphology. Above Blue Sky Creek, riffle–pool morphology is dominant. Pfankuch channel stability ratings ranged from 60 to 91, with the highest scores (higher degree of instability) associated with the C stream types. As would be expected, bankfull width is highest at the lowest cross section (XS 4) and decreases in the upstream direction for middle Grave Creek. Upper Grave Creek has lower bankfull widths than middle Grave Creek. Bankfull width to depth ratio values vary between 13 and 29, with the two highest values found in the lower portions of middle Grave Creek. Tables G-23 and G-24 provide some averaged riffle characteristics for middle and upper Grave Creek.

Table G-22: Channel Metrics Summary for Middle and Upper Grave Creek Segments (USFS, 2003).

XS	Channel	Pfankuch Score	Bankfull Width (ft)	W/D
4 Middle	B4	97 (poor)	79.5	26
5 Middle	B3	60 (good)	49.2	29
6 Middle	B4c	66 (fair)	50.2	13
7 Middle	B3	62 (fair)	50.8	18
8 Middle	C4	84 (good)	37.7	21
9 Upper	B4	75 (fair)	26.2	13
10 Upper	C4	91 (fair)	34.4	20
11 Upper	B4	83 (fair)	29.5	17

Table G-23: Middle Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Middle Grave Creek	C	37.7	67.7	1.8	21.0	0.007
	B	57.4	153.4	2.7	21.5	0.023

Table G-24: Upper Grave Creek Riffle Characteristics (Bankfull Channel Dimensions Data; USFS, 2003).

Stream	Stream Type	Channel Width (ft)	Channel Area (ft^2)	Mean Depth (ft)	Width/ Depth	Channel Slope (ft/ft)
Upper Grave Creek	C	34.4	59.2	1.7	20	0.02
	B	29.5	51.2	1.7	17	0.019

G.4.2.2.5 Fish Passage Information

There are not any physical fish passage problems noted within middle or upper Grave Creek. .

G.4.2.3 Section 7 Bull Trout Habitat Assessment for Grave Creek

The summary results from the USFS Section 7 consultation (USFS 2000) are presented in Table G-25. In general, most habitat indicators were classified as Functioning at Risk. Note that the sediment category is noted as functioning appropriately/functioning at risk. Review of the analysis used to reach this conclusion shows that the focus was on fine sediment contributions and impacts. This also applies somewhat to the analysis on substrate that also concluded functioning appropriately (FA). The large woody debris (LWD) functioning at risk (FAR) determination is based primarily on a lack of stable LWD.

The FA determination for pool frequency is based on 1992, 1993 and other historical survey data that indicates a pool frequency of 35 to 36 pools per mile. It is concluded that these values generally meet INFISH standards. It is further noted that approximately 25 log/pool structures were installed in these reaches to improve pool habitat during the 1980's, and because of the high volume of bedload movement (large cobbles) through these reaches, a number of these structures filled and/or failed over time. Based on 2002 data, Tables G-3, G-12 and G-13 show pool frequency values of 12, 19, 24, 26, and 62 pools per mile for the B and C reaches of lower, middle, and upper Grave Creek.

The FAR determination for pool quality is based on 1992 and 1993 surveys that concluded that most pools were generally shallow, less than three feet deep. This seems consistent with 2002 values (Tables G-3, G-12, and G-13) showing average maximum depths generally less than three feet and average maximum residual pool depths of less than or equal to 1.5 feet for middle and upper Grave Creek.

The FAR determination for off-channel habitat is attributed to conditions in lower Grave Creek along private lands where limited off-channel cover is expected. In the discussion on the FAR determination for prime habitat (refugia), it is noted that the majority of Riparian Habitat Conservation Areas along Grave Creek are intact, although other concerns are noted to justify the FAR determination.

The FAR determination for streambank conditions is linked to bank instability in portions of the Grave Creek drainage. It is noted that over the past 30 years, Grave Creek has experienced a number of small slumps, some of which have altered streambank conditions. The discussion goes on to note that even though most of the channel substrate is comprised of large cobble and boulders, a significant portion of this moves yearly, especially in those reaches (of lower Grave Creek) modified by channel work after the 1974 floods.

Table G-25: Bull Trout Species Indicators for the Tobacco/Grave Subpopulation (USFS, 2000).

Indicator Metric	Condition
Temperature	FA
Sediment	FA/FAR
Nutrients and Contaminants	FA
Physical Barriers	FAR
Substrate	FA
Large Woody Debris	FAR
Pool Frequency	FA
Pool Quality	FAR

Table G-25: Bull Trout Species Indicators for the Tobacco/Grave Subpopulation (USFS, 2000).	
Indicator Metric	Condition
Off-channel Habitat	FAR
Refugia Habitat	FAR
Pool Width/Depth Ratio	FAR
Streambank Conditions	FAR
Floodplain Connectivity	FAR
Peak and Base Flows	FA
Drainage Network	FAR
Road Network	FAR
Disturbance History	FAR
RCHAs	FAR
Disturbance Regime	FAR

FA = Functioning Appropriately, FAR = Functioning at Risk

G.5 Tributary Overview

G.5.1 General Description of Tributary Stream Types and Potential Land Use Impacts

The tributary streams can be divided into three general categories.

1) The lower sections of the primary tributaries to Grave Creek (Stahl Creek, Clarence Creek, Foundation Creek, Lewis Creek, Blue Sky Creek, and Williams Creek). These lower stream sections tend to be characterized by step-pool channel types with riffle-pool inclusions developed in alluvial and semi-confined or transitional valleys landforms These sections also tend to be either Rosgen B or C stream types. Large woody debris and coarse sediment (e.g. boulders) provide the dominant pool forming structure.

2) Upper and middle sections of the tributaries with residual soils occurring as colluvium, landslide debris, glacial till, and other similar depositional materials typically form channel types classified as A and G types according to Rosgen (1996). While fluvial sediment transport does occur, the dominant mechanism by which colluvial sediments are transported downstream is through mass wasting. Intermittent scour by debris flows govern valley form and incision (Montgomery and Buffington, 1993). Because of their colluvial nature, these sections produce high sediment supply for downstream reaches, especially in the presence of disturbance.

In the absence of disturbance these channels are inherently stable (Table G-2). The bedform morphology of these channel units is largely maintained by the presence of large, stable woody debris and coarse substrate. Changes in sediment supply and woody debris delivery can alter channel stability and pool habitat formation. Therefore, channel conditions in the A and G stream types above the lower tributary reaches have a strong influence on the lower tributary channel condition. Some of the A3/4 and G3/4 channel types in the upper tributaries; particularly first order drainages are extremely sensitive and tend to provide a high natural bed load supply to downstream reaches. In the presence of disturbance, this sediment supply may become excessive and beyond the transport capacity of the downstream reaches. This excess supply coupled with other impacts to the lower tributary reaches can result in channel instability and degraded habitat conditions.

3) Upper and middle sections of the tributaries with bedrock and other structural control are characterized by more stable, low sediment supply cascade channels. These are typically steep, deeply entrenched, and confined channels associated with structurally controlled first and second order drainages (also Rosgen A, B, and G stream types). Landforms supporting these channel units include bedrock canyons, steep side slopes, talus fields, and coarse colluvial deposition. Due to stable nature of these structurally controlled landforms, these cascade channel types are generally resistant to altered sediment supplies and flow volumes (Montgomery and Buffington, 1993). Due to their location high in the watershed, they are subject to debris flow impacts (Montgomery and Buffington, 1993).

Spatial analyses of land uses in the watershed are detailed in several Appendices: timber harvest (Appendix A), roads (Appendix B), and water yield, ECA, and activities in the rain-on-snow zone (Appendix C). These land uses have the potential to still impact water quality and overall physical habitat in the tributaries in the same manner that impacts could occur to the main stem of Grave Creek, particularly in the lower sections of the tributaries with Rosgen B and C stream types. This includes extensive road and skid trail networks within the tributary drainages built during the 1950s and 1980s. Many historical harvest units were fairly large averaging approximately 40 acres and oftentimes-spanned colluvial draws and intermittent drainages, in addition to removal of riparian trees along some lower tributary reaches. During the 1950s harvest activities, stream crossings typically consisted of placing logs in the active channel to provide a road surface, a practice commonly referred to as “corduroying” (S. Johnson, USFS Kootenai National Forest Watershed Program Manager, personal communication, July 21, 2004 stakeholder meeting). The lack of BMPs during historical logging would have contributed large amounts of fine and coarse sediment load to the tributaries and Grave Creek downstream. Mass wasting locations still provides evidence of some of this loading. Much of the harvests in the 1980s were concentrated in several of the primary tributaries, including Stahl Creek, Clarence Creek, and Foundation Creek.

Following completion of harvest activities, most of the road network was left in place with minimal effort made to minimize the long-term impacts on basin hydrology and sediment regimes (Bohn, 1998, unpublished report). Today, many of these jammer and skid roads may still be functioning, at least in part, as ephemeral drainages, increasing drainage efficiency and peak flows.

Tributary reaches are labeled from the downstream to upstream, reach 1 being the most downstream reach.

G.5.2 Physical Assessment Results for Tributaries

G.5.2.1 Williams Creek

Williams Creek, a fourth order tributary to Grave Creek, flows approximately 5.9 miles from its headwaters at Mt. Locke and Mt. Petery through USFS-managed lands to its confluence with main stem Grave Creek, defining the division between lower and middle Grave Creek main stem. Management activities in the watershed date back to 1952 when the original access road was constructed off FS Road 114 north of the confluence of Williams Creek and Grave Creek. The original road crossed main stem Grave Creek, switch-backed to the south and entered the Williams Creek drainage in the northeast corner of Section 26. This original access route was apparently abandoned between 1954 and 1992 following construction of FS Road 7019.

FS Road 7019 was constructed adjacent to main stem Williams Creek and in many locations, encroaches on the channel with little to no buffer between the bankfull channel and road fill slope. Commercial logging in 1957 and 1965-1967 included construction of an extensive skid trail and jammer road network to access spruce basins and riparian zones in the upper watershed. The vast road network is still visible in the 1998 photo series.

G.5.2.1.1 Fish Habitat – Pools

Pools in Williams Creek are related to step pool channel morphology in the A stream type reach. Pools in the B stream type reach are associated with large substrate and possibly large woody debris accumulations. Pools were moderately frequent in Williams Creek relative to pool frequencies in other tributaries in the Grave Creek Watershed (Table G-26).

Table G-26: Williams Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Williams Creek	B	38	16 (4, 21, 45)	2.1 (1.2, 2.6, 3.9)	1.3 (0.5, 1.8, 3.4)
	A	40	16 (9, 18, 36)	2.5 (1.3, 2.9, 5.1)	1.5 (0.5, 1.9, 4.2)

G.5.2.1.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the B stream type sections of Williams Creek (Table G-27). Total woody debris accumulations were moderate to high relative to accumulations measured in other tributaries in the watershed.

Table G-27: Williams Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Williams Creek	B	0 (0, 168, 4308)	0 (0, 0, 4261)	88 (0, 355, 8389)	239 (0, 594, 12697)
	A	0 (0, 0, 350)	0 (0, 0, 447)	0 (0, 140, 519)	55 (0, 187, 894)

G.5.2.1.3 Sediment Particle Size Monitoring Results

Sediment gradation data for Williams Creek based on pebble count results are summarized in Table G-28.

Table G-28: Williams Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).					
Reach	D16	D50	D84	% < 2 mm	% < 6.4 mm
1	26	80	200	6	7
2	17	70	270	3	6
3	23	65	150	6	7
4	27	102	200	1	4
5	18	80	310	1	7

Percent fines values < 6.35 from grid toss sampling are presented in Table G-29. Median percent surface fines in pool tails was highest in the Williams Lake tributary, possibly linked to the upstream lake in the drainage. Median percent pool tail out fines in Williams Creek reaches (A and B) was relatively low (5%).

Table G-29: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Williams Creek.						
Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Williams Lake Creek	B	0.0	10.0	10.0	23.8	65.0
Williams Creek	A	0.0	0.0	5.0	5.0	20.0
	B	0.0	5.0	5.0	10.0	70.0

G.5.2.1.4 Channel Morphology

Table G-30 presents morphology data for Williams Creek. Bankfull channel widths ranged from 17.3 ft to 38.7 ft and width/depth ratios ranged from 15 to 35 with all values below 20 except the one high value of 35 for a steep A stream type. Channel stability rated fair to good, with the most unstable segments occurring in the upper reaches of the watershed.

Table G-30: Williams Creek Channel Metrics Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B3a	76 (fair)	28.1	15
2	A3a+	76 (good)	38.7	35
3	B3a	63 (fair)	22.6	18
4	B3	71 (fair)	17.3	20
5	A3a	63 (good)	15.7	17

G.5.2.2 Clarence Creek

Clarence Creek headwaters in a series of first order ephemeral channels at elevations ranging from 7,203 feet at Mt. Wam to 7,435 feet at Stahl Peak. A primary tributary to Grave Creek and the most important bull trout spawning tributary in the watershed, land management in Clarence Creek dates back to the 1950s when major arterial roads were constructed in the basin to facilitate logging in response to the spruce bark beetle epidemic.

The first timber harvest entry in Clarence Creek occurred in the mid 1950s following construction of FS Road 7022. The initial road was constructed to the southeast corner of Section 35 (approximately). In the late 1950s, the road network was expanded to include the upper headwaters of the drainage and one major crossing (FS Road 7036) was installed in the northeast corner of Section 2 to access units to the east. A network of jammer roads and skid trails was constructed throughout the upper basin. Still visible in the 1998 photo series, much of the extensive road network is currently overgrown with dense alder, and may no longer serve as a chronic source of sediment to the channel.

Approximately 5.3 miles of channel were surveyed in the Clarence Creek watershed.

G.5.2.2.1 Fish Habitat – Pools

Table G-31 presents pool frequency results. Pools were more frequent in the B stream type section of Clarence Creek although all pool size values were greater for the C stream type portions of Clarence Creek. These higher pool values, particularly the residual pool depth in C reaches may offset the relatively low pool frequency to some extent.

Table G-31: Clarence Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Clarence Creek	C	9	19(10, 26, 49)	2.8 (1.6, 3.0, 3.3)	2.0 (0.7, 2.2, 2.4)
	B	29	17 (7, 24, 121)	2.0 (1.2, 2.3, 3.9)	1.5 (0.5, 1.6, 1.9)

G.5.2.2.2 Fish Habitat – Large Woody Debris

Total large woody debris accumulations were most frequent in the B stream type sections of Clarence Creek (Table G-32). Woody debris accumulations were high relative to other tributary accumulations in the watershed, particularly for the B stream type. Wood aggregates, typically the most stable form of woody debris, were the most numerous in the watershed relative to single large woody debris pieces and rootwads.

Table G-32: Clarence Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Clarence Creek	C	20 (0, 37, 393)	20 (0, 60, 310)	95 (0, 260, 537)	167 (0, 329, 619)
	B	0 (0, 163, 3520)	0 (0, 0, 1509)	165 (0, 626, 2347)	571 (0, 993, 4526)

G.5.2.2.3 Sediment Particle Size Monitoring Results

Sediment particle size distributions from pebble counts for Clarence Creek are presented in Table G-33.

Table G-33: Clarence Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% <6.35 mm
1	30	64	150	2	3
2	11	38	100	8	10
3	15	56	120	1	5
4	60	150	500	1	2
5	18	50	128	4	5
6	24	62	512	3	3

Percent fines values < 6.35 from grid toss sampling in Clarence Creek are presented in Table G-34. Median percent surface fines values in pool tails was the same for both B and C channel types (5%).

Table G-34: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Clarence Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Clarence Creek	C	0.0	1.3	5.0	5.0	10.0
	B	0.0	0.0	5.0	5.0	20.0

G.5.2.2.4 Channel Morphology

Channel morphology data for Clarence Creek is presented in Table G-35. Channel stability ratings ranged from 60 (good) to 74 (fair), with channel width/depth ratios ranging from 5 to 14.

Table G-35: Clarence Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	62 (good)	17.0	5
2	C4b	68 (good)	16.4	6
3	B4a	69 (fair)	13.7	11
4	B3a	60 (good)	16.8	14
5	B4a	63 (good)	16.6	12
6	B4a	74 (fair)	6.7	9

G.5.2.3 Stahl Creek and South Fork Stahl Creek

South Fork Stahl Creek originates in a series of first order ephemeral and intermittent channels on the eastern flanks of Mt. Gibraltar at an elevation of 7,313 feet. The most significant impacts to channel conditions in this sub-basin are related to past riparian management and construction, and “reclamation” of FS Road 7029. The road was constructed in the 1980s to facilitate logging activities and included five to six major stream crossings constructed with rock gabions, riprap, and undersized culverts. Following logging activities, many of the roads and crossings were left in place with no mitigation actions or BMPs applied. Those that were obliterated were stabilized with riprap and bridge deck materials. Approach grades were not recontoured according to standard BMPs and may continue to recruit hillslope sediment due to lack of vegetation. Several crossings contain gabion baskets that continue to cause channel aggradation and bank cutting. These structures may impede upstream fish migration.

Stahl Creek headwaters at an elevation of 7,435 feet at Stahl Peak and flows approximately 4.3 miles to its confluence with Clarence Creek. Stahl Creek exhibits channel morphologic characteristics common to steep, mountainous tributaries. Timber harvest in the drainage occurred primarily in 1957 and 1988 with evidence of mass wasting and riparian harvest.

R1/R4 data collected by USFS were used to evaluate fish habitat conditions in Stahl Creek. Approximately 1.7 miles of channel were surveyed in the Stahl Creek watershed.

G.5.2.3.1 Fish Habitat – Pools

Table G-36 provides pool values for Stahl Creek. Pool frequency and volume was greater in A reaches than B reaches. Relatively high pool values may be associated with the relatively high large woody debris frequency values presented below.

Table G-36: Stahl Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Stahl Creek	B	82	17 (9, 22, 42)	2.2 (1.3, 2.6, 4.2)	1.2 (0.4, 1.6, 2.8)
	A	106	16 (8, 21, 53)	2.0 (1.1, 2.4, 5.9)	1.2 (0.3, 1.6, 5.2)

G.5.2.3.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the A stream type sections of Stahl Creek (Table G-37). Large woody debris accumulations were relatively moderate to high in comparison to other tributaries. Single pieces of wood were the most frequent form of large woody debris in Stahl Creek. Single pieces of large wood are generally less stable than accumulations that can provide complex, persistent habitat features.

Table G-37: Stahl Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Stahl Creek	B	0 (0, 91, 826)	0 (0, 62, 644)	161 (0, 305, 947)	274 (0, 488, 1238)
	A	171 (0, 374, 1558)	0 (0, 0, 671)	115 (0, 285, 947)	377 (0, 596, 1558)

G.5.2.3.3 Sediment Particle Size Monitoring Results

Sediment gradation data from pebble counts for Reaches 1-6 on main stem Stahl Creek and a representative reach in the South Fork Stahl Creek sub-watershed are summarized in Table G-38. Percent fines less than 6.4 mm were highest in Reaches 4 and 6 of Stahl Creek and in the South Fork Stahl Creek.

Table G-38: Stahl Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).					
Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	10	40	120	8	9
2	24	100	415	1	4
3	11	100	200	6	7
4	3	35	85	8	17
5	11	80	220	1	7
6	8	50	160	5	14
S. Fork Stahl	8	50	175	9	15

Percent fines values < 6.35 from grid toss sampling in Stahl Creek are presented in Table G-39. The Median percent surface fines in pool tails in Stahl Creek were greater in the B reaches (10%) than the A reaches (5%).

Table G-39: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Stahl Creek.						
Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Stahl Creek	A	0.0	0.0	5.0	5.0	40.0
	B	0.0	10.0	10.0	15.0	50.0

G.5.2.3.4 Channel Morphology

Channel morphology data for the main stem Stahl Creek and South Fork Stahl Creek are presented in Table G-40. Bankfull channel widths ranged from 11.9 to 32.9 feet, width/depth ratios ranged from 8 to 18. Channel stability rated fair to good, with the most unstable segments occurring in the South Fork Stahl Creek and Reach 6, or the upper headwaters of the main stem.

Table G-40: Stahl Creek Channel Metrics Data Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	60 (good)	32.9	17
2	A3	65 (good)	19.9	11
3	A3a+	87 (good)	17.0	10
4	A4a+	90 (good)	17.0	8
5	B3a	54 (good)	16.4	13
6	B4a	74 (fair)	12.2	13
S. Fork Stahl	B4a	71 (fair)	11.9	18

G.5.2.4 Blue Sky Creek

Blue Sky Creek is the largest sub-basin tributary to Grave Creek. Comprising over 6.3 stream miles, major tributaries include Jiggs Creek and Kopsi Creek. Management of the Blue Sky Creek drainage followed similar trends observed for the other primary tributaries. Initial timber harvest and road construction activities commenced in 1955, with subsequent management in the 1960s. Extensive skid trails were constructed in the headwaters and in the Kopsi and Jiggs Creek drainages. Skidding occurred on steep slopes oftentimes paralleling ephemeral and intermittent drainages. Numerous crossings of Kopsi Creek and Jiggs Creek are apparent in the 1998 aerial photo series. The crossings likely consisted of corduroying the channel with logs and whole trees. Jammer or temporary roads connected the skid trails to main arterial roads paralleling the main stem Blue Sky Creek. Main arterial roads constructed within the valley bottom of the watershed encroach on the channel with minimal to no buffer provided between the road fill slope and active bankfull channel.

Although the USFS has removed many of the road crossings and the main arterial road paralleling Blue Sky Creek, major sediment sources inventoried during the fall 2003 were associated with road fillslope erosion and slope failures that delivered sediment and debris to the main channel (Section 6.0). Apparently, minimal BMPs or erosion control measures were installed prior to closure.

The combined effects of increased water yield followed by a reduction in root density on steep slopes continue to sensitize riparian units and steep glaciated slopes along Blue Sky Creek to mass wasting (Photo 9). While human caused slope failures are most prevalent in the drainage, natural events continue to cause similar impacts to channel morphology and sediment production. For example in 1998, a major stand replacement wildfire consumed approximately 1,094 acres in the watershed. Several debris flows contributed sediment and debris directly to the channel. It is not documented whether or not historical harvest was linked to any of the debris flows. The slide paths were revegetated by the USFS in 1999. The effectiveness of this mitigation activity in alleviating sediment delivery to the channel is unknown.

Approximately 4.4 miles of channel were surveyed in the Blue Sky Creek watershed.

G.5.2.4.1 Fish Habitat – Pools

Blue Sky Creek pool values for B reaches are summarized in Table G-41. Overall frequency values are similar to other tributary results.

Table G-41: Blue Sky Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Blue Sky Creek	B	24	15 (7, 17, 66)	2.4 (1.5, 2.6, 3.9)	1.5 (0.7, 1.7, 3.1)

G.5.2.4.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations results for Blue Sky Creek are summarized in Table G-42. Median woody debris concentrations are very low, possibly due to riparian harvest.

Table G-42: Blue Sky Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Blue Sky Creek	B	0 (0, 0, 732)	0 (0, 0, 460)	0 (0, 67, 732)	36 (0, 320, 732)

G.5.2.4.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts are presented in Table G-43 for Blue Sky Creek. Note the relatively high percent fines values for the Reach 3 cross section.

Table G-43: Blue Sky Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).					
Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	11	48	115	1	6
2	6	32	100	2	16
3	4	38	120	12	20

Percent fines values < 6.35 from grid toss sampling in Blue Sky Creek are presented in Table G-44. The median percent surface fines in pool tails in Blue Sky Creek were 0%.

Table G-44: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Blue Sky Creek.						
Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Blue Sky Creek	B	0.0	0.0	0.0	5.0	35.0

G.5.2.4.4 Channel Morphology

Table G-45 presents the channel morphology data for Blue Sky Creek. Bankfull channel widths ranged from 17.0 ft to 23.3 ft, with with/depth rations ranging from 10 to 13. Bank stability ratings were all rated as “good”.

Table G-45: Blue Sky Creek Channel Metrics Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	57 (good)	17	10
2	B4a	61 (good)	23.3	13
3	B4a	61 (good)	18.8	11

G.5.2.5 Lewis Creek

Lewis Creek is a third order tributary to the upper Grave Creek sub-watershed, flowing approximately 3.4 miles in a northwesterly direction from its headwaters along the western divide of the Whitefish Range to its confluence with Grave Creek. Construction of FS Road 114 began in the 1950s and extended only a few miles up the drainage. By the mid 1980s, the road was completed and linked with FS Road No. 114 on the Flathead National Forest. The full length of the road is located at mid-slope and bisects numerous first order drainages characterized by residual soils occurring as colluvium, landslide debris, avalanche chutes, glacial till, and other similar depositional materials. Due to the steep nature of the valley, road cut slopes were extensive and resulted in headward erosion of the steep, colluvial draws and avalanche chutes. While these channel units naturally contribute relatively high sediment loads to Lewis Creek via mass wasting, debris flows, and avalanches, road construction appears to have exacerbated channel instability and sediment production.

Road construction facilitated logging in the 1950s and 1980s in response to the spruce bark beetle epidemic. A majority of the harvest units were located on sensitive soil types and in riparian valley bottoms which would be expected to deplete the availability of large woody debris to the channel system. In response to these activities, the USFS initiated a program to reintroduce structure into the channel through installation of high stage log check dams and drop structures, as observed on the main stem Grave Creek. Since installation, the structures have caused segments of the channel to aggrade and laterally migrate causing partial or complete failure of the log dams. These failures have delivered sediment to the channel through floodplain head cutting. The remaining structures will continue to pose a threat to channel stability and sediment routing if left in place.

Approximately 0.9 miles of channel were surveyed in the Lewis Creek watershed.

G.5.2.5.1 Fish Habitat – Pools

Table G-46 presents pool data for Lewis Creek. Pool characteristics were typical compared to other tributaries in the watershed.

Table G-46: Lewis Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Lewis Creek	C	26	11 (9, 16, 45)	1.8 (1.4, 2.1, 2.7)	1.2 (1.0, 1.7, 2.2)
	B	36	14 (7, 17, 35)	2.0 (1.0, 2.3, 3.6)	1.5 (0.7, 1.7, 3.1)

G.5.2.5.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations were most frequent in the B stream type sections of Lewis Creek (Table G-47). Woody debris concentrations reflect mass wasting and channel avulsion processes that contribute sediment and large woody debris to the channel. Single pieces of large wood were most frequent in the B stream type section of Lewis Creek. The frequent distribution of single pieces suggests higher instability of woody debris in this stream type as would be expected due to higher gradients. Lewis Creek had the second highest frequency of large woody debris in the Grave Creek Watershed.

Table G-47: Lewis Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Lewis Creek	C	0 (0, 71, 383)	0 (0, 0, 23)	125 (0, 481, 596)	270 (0, 481, 596)
	B	121 (0, 304, 1288)	0 (0, 0, 644)	34 (0,152, 732)	304 (0, 393, 1932)

G.5.2.5.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts for Reaches 1-5 in Lewis Creek are summarized in Table G-48. The highest percent fine levels less than 6.35 mm were measured in Reach 1 and 3, with the Reach 3 value representing one of the highest results in comparison to other streams. The corresponding values for < 2 mm were similar to results for other streams and not particularly high.

Table G-48: Lewis Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).

Reach	D16 (mm)	D50 (mm)	D84 (mm)	% < 2 mm	% < 6.35 mm
1	11	30	88	7	10
2	14	45	98	2	6
3	4.5	21	55	5	19
4	11	40	96	3	8
5	21	75	185	2	3

Percent fines values < 6.35 from grid toss sampling in Lewis Creek are presented in Table G-49. Median percent surface fines values in pool tails in Lewis Creek were greater for C reaches (10%) than for B reaches (5%).

Table G-49: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-Point Particle Grid Data (USFS, 2001). Lewis Creek.

Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Lewis Creek	C	5.0	7.5	10.0	12.5	25.0
	B	0.0	1.3	5.0	8.8	70.0

G.5.2.5.4 Channel Morphology

Table G-50 presents channel morphology results for Lewis Creek. Similar to other tributaries in the Grave Creek Watershed, geomorphic conditions are characterized by moderately entrenched, gravel and cobble dominated channels with average bankfull widths ranging from 6.9 ft to 16.1 feet. Width to depth ratios are all less than 17, and stability ratings (Pfankuch) range from “fair” to “good”.

Table G-50: Lewis Creek Channel Metrics Summary.

Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4	66 (fair)	11.9	12
2	C4b	78 (good)	13.1	10
3	B4a	n/a	16.1	17
4	B4	69 (fair)	6.9	5
5	B3a	56 (good)	12.3	9

G.5.2.6 Foundation Creek

Foundation Creek originates in a series of small sub alpine lakes situated to the south of Mt. Wam at an elevation of 7,203 feet. A relatively small watershed, Foundation Creek flows approximately 2.5 miles east to its confluence with Grave Creek.

Forest management in Foundation Creek occurred throughout the 1950s in response to the spruce bark beetle epidemic. Approximately 244 acres of timber were harvested, a majority of the units concentrated in the lower to middle reaches of the basin. Harvest units were located on north aspect slopes above the main channel and were accessed by a network of skid trails and jammer roads. Riparian units extended through a majority of the lower reaches and multiple channel crossings are evident in the photo series.

Review of the 1998 aerial photo record indicates that most of the skid trails appear to be fairly well vegetated with alder and other shrubs. While these roads are likely no longer sources of sediment to the system, they likely alter the volume and timing of runoff to Foundation Creek through subsurface flow interception, increased snow pack deposition, and increased drainage efficiency.

The main skid trails traversing the north aspect slopes remain exposed and unvegetated. These particular skid trails may continue to be a sediment source in addition to modifying the hydrology in Foundation Creek.

Approximately 0.4 miles of channel were surveyed in the Foundation Creek watershed.

G.5.2.6.1 Fish Habitat – Pools

Summary pool characteristics for Foundation Creek are included in Table G-51. Pool frequency values are similar to other tributary streams, although pool size values are generally smaller.

Table G-51. Foundation Creek Pool Characteristics (USFS, 2001). Median (Min, 75th Percentile, Max).

Stream	Stream Type	Pool Frequency (pools/mi)	Ave Pool Length (ft)	Ave Max Pool Depth (ft)	Residual Pool Ave Max Depth (ft)
Foundation Creek	B	32	14 (9, 16, 27)	1.6 (1.2, 2.0, 3.3)	1.0 (0.7, 1.5, 2.3)

G.5.2.6.2 Fish Habitat – Large Woody Debris

Large woody debris accumulations results for Foundation Creek are summarized in Table G-52. Median woody debris concentrations are very low, possibly due to riparian harvest.

Table G-52: Foundation Creek Large Woody Debris Concentrations (USFS, 2001). Median (Min, 75th Percentile, Max).					
Stream	Stream Type	Single LWD/mi	Rootwads/mi	LWD Aggregates/mi	All LWD/mi
Foundation Creek	B	0 (0, 35, 575)	0 (0, 0, 41)	0 (0, 110, 847)	70 (0, 196, 847)

G.5.2.6.3 Sediment Particle Size Monitoring Results

Sediment gradation data based on pebble counts for Reaches 1-4 in Foundation Creek are summarized in Table G-53. All values have low percent fines results for < 2 mm and < 6.35 mm.

Table G-53: Foundation Creek Composite Particle Size Distribution and Percent Fines Measured via the Wolman Pebble Count Method (USFS, 2003).					
Reach	D16 (mm)	D50 (mm)	D84 (mm)	%< 2 mm	% < 6.35 mm
1	14	47	100	6	9
2	12	30	88	4	9
3	10	28	120	4	10
4	21	40	160	2	6

Percent fines values < 6.35 from grid toss sampling in Foundation Creek are presented in Table G-54. Median percent surface fines in pool tails in Foundation Creek were 0%.

Table G-54: Percentage of Surface Fines (<6.35 mm) in Pool Tails from R1/R4 49-point Particle Grid Data (USFS, 2001). Foundation Creek.						
Stream	Stream Type	Minimum % Fines	25th Percentile	Median % Fines	75th Percentile Fines	Max % Fines
Foundation Creek	B	0.0	0.0	0.0	0.0	5.0

G.5.2.6.4 Channel Morphology

Table G-55 presents channel morphology results for Foundation Creek. The lower reaches of Foundation Creek are characterized by moderately entrenched, gravel dominated channel types with bankfull widths ranging from 6.3 ft to 18.4 ft. The upper reaches transition to step-pool morphologies, with cobble being the dominant substrate and pool formative structure. The confined valley and structural controls imposed on the channel by the existing landforms make the channel inherently stable. Channel stability rated fair in the lower to middle reaches associated with past harvest activities, and good in the upper unmanaged portion of the drainage. Width to depth ratios are all less than 19.

Table G-55: Foundation Creek Channel Metrics Summary.				
Reach	Channel Type	Pfankuch Score	Bankfull Width (ft)	W/D Ratio
1	B4a	84 (fair)	18.4	19
2	B4a	77 (fair)	12.6	11
3	B3a	64 (fair)	6.7	16
4	A3	66 (good)	6.3	10

G.5.2.6.5 Fish Passage

The culvert which passes Foundation Creek on the Grave Creek road is a likely fish passage barrier. It is uncertain how this potential barrier may affect the overall fishery in Grave Creek. It is not known if bull trout use Foundation Creek. It is also unknown whether pure strains of westslope cutthroat (WSCT) may be isolated above the culvert. If pure strains of WSCT do exist above the culvert and the culvert is a fish passage barrier, it may be deemed a positive impact on the WSCT fishery. If, however, critical bull trout habitat is identified above the culvert and the culvert is identified as a barrier restricting access to the critical habitat, then the culvert may be having a negative impact on the bull trout fishery. It may be both a limitation to the bull trout fishery and a positive impact on the WSCT fishery from a genetic perspective. Further investigation is warranted to determine the situation and what possible actions might be taken.

APPENDIX H
REFERENCE VALUE DEVELOPMENT FOR THE GRAVE CREEK WATERSHED

Reference development is focused on those parameters that can be linked closely to the beneficial use support (Figure H-1). Ideally, the best parameters would include robust measures of fishery and aquatic life from reference water bodies where all sediment and habitat conditions are functioning at their potential given historic land uses and the application of all reasonable land, soil and water conservation practices. There has been and continues to be significant progress toward the development of macroinvertebrate and periphyton reference values throughout Montana. These reference values, along with reference values for habitat parameters such as percent fines, can provide vital information to make aquatic life beneficial use determinations. On the other hand, a robust reference data set to represent the primary species of cold-water fish found in the Grave Creek Watershed represents a difficult challenge given the multitude of variables that can influence fishery data. For this reason, cold-water fish beneficial use support decisions linked to sediment and habitat impairments often rely on fish habitat and channel condition parameters because of the impact that these parameters, represented within Figure H-1, can have on fishery health.

Reference values were developed and/or discussed for the following parameters to help determine impairment for cold water-fish and/or aquatic life:

- 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

The above 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).

Management activities, natural events, watershed and riparian processes, and stream inputs such as sediment loading also play an important role in the watershed cause and effect pathway (Figure H-1). Most of these must be considered when evaluating the applicability of reference values, when making impairment determinations, and when applying the adaptive management approach discussed in Section 5.2.1. This includes consideration of historical land use and linkages to sediment loading and habitat impacts, as well as consideration of anticipated natural variability as part of the process of selecting, developing and applying reference parameters to the Grave Creek Watershed. Data to incorporate these considerations were presented and discussed within Sections 2.0 and 4.0 and their accompanying appendices.

The following subsections provide details on reference value development for each of the above parameters. Many parameters such as pool frequency were stratified by bankfull width and/or stream order since stream size represents an important stratification. Stream order is an indicator of stream size, with lower stream orders representing smaller tributary or headwater stream segments. Another important stratification includes Rosgen channel types, referred to as either A, B or C reaches or stream types.

The goal is to apply a primary approach for reference development (Section 3.2.3.1). Given the potential widespread historical human impacts throughout the Grave Creek Watershed, the use of internal reference values from within the watershed for reference development cannot be justified for many parameters, and historical data is not available for many parameters. This leaves the use of regional reference data as a remaining primary approach used in many of the following sections.

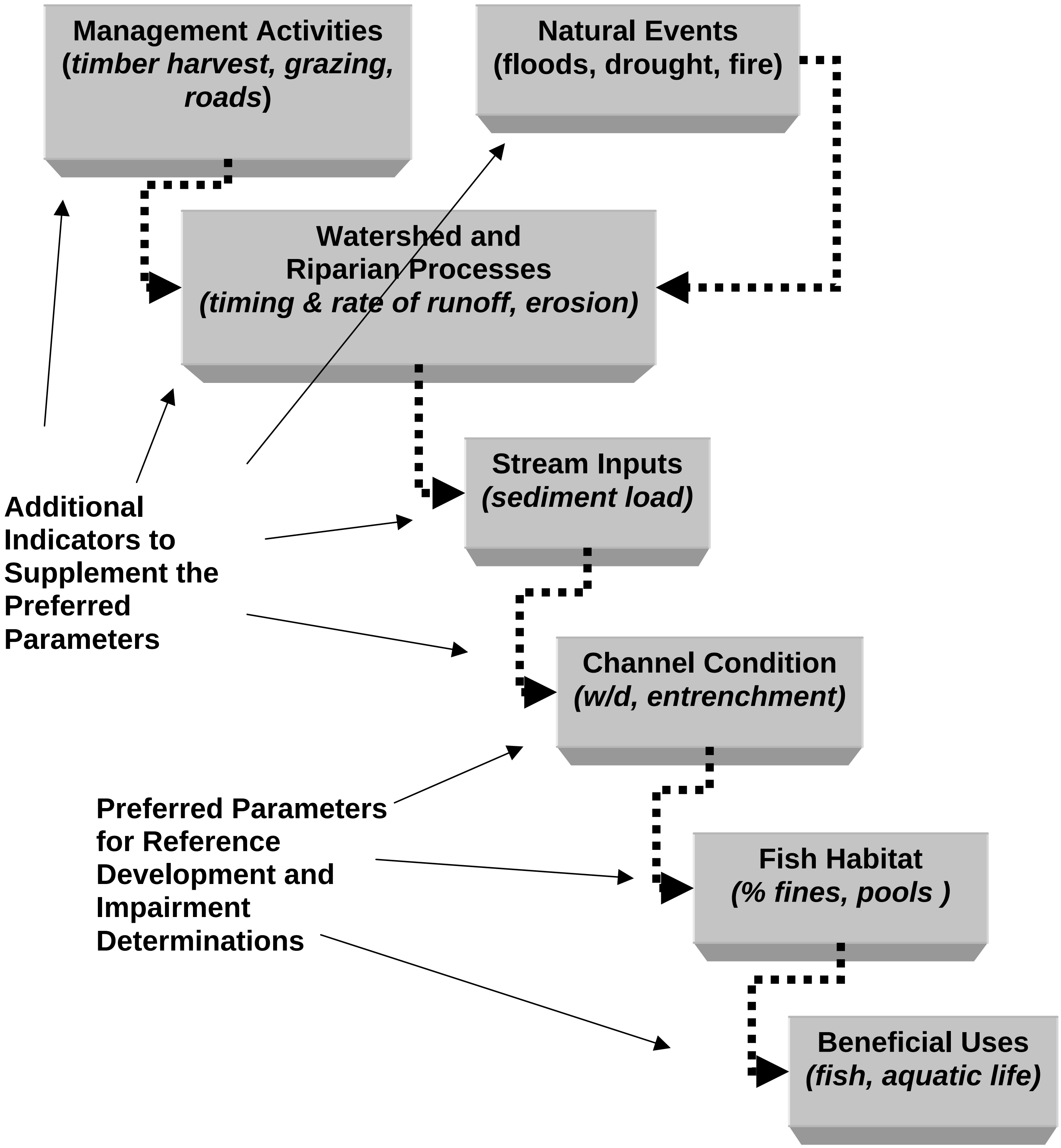


Figure H-1: How various measures and potential reference parameters fit in the watershed cause and effect pathway for Sediment and Habitat Measures.

H.1 Pool Frequency

Pool frequency (pools/mile) is an important physical habitat parameter. Pools provide critical habitat for cold-water fish and are linked to the storage, deposition, and sorting of sediment within the channel. Several sources were used to develop pool reference values. These include: 1) data from the Swan Lake Watershed used for TMDL development (MDEQ, 2004d), 2) unpublished reference data provided by the Libby Ranger District of the KNF, 3) unpublished reference data provided by the Rexford Ranger District of the KNF, 4) reference data from the Lolo National Forest (USFS, 1998), 4) interim INFISH Riparian Management Objectives (RMOs) from the National Forest (USFS, 2000), and 5) an internal reference reach for lower Grave Creek. Methods varied between studies although the various methods can result in similar values, particularly for the 2nd and 3rd order streams and smaller 4th order streams. Appendix F provides a summary of methodologies. Table H-1 presents the pool frequency data from many of the above reference sources.

The development of pool reference values are focused on identifying a reference range, with focus on the minimum level that should exist in each stream category to fully support cold-water fish. This is because the higher the pool frequency, the better the habitat conditions within the ranges discussed in this section. Therefore, values above the high end of the reference range would be desirable in most situations, and values below the low end suggest a potential problem.

Based on a review of the Grave Creek Watershed assessment results (Section 4.0 and Appendix G), and a review of the reference data sets, reference development was broken into four categories for applying pool reference conditions to streams in the Grave Creek Watershed. These categories include 2nd and 3rd order B and C streams with bankfull widths that tend to range from 10 to 20 feet; 3rd and 4th order B and C streams where bankfull widths tend to range from 20 to 35 feet; 4th order B and C streams where bankfull widths tend to range from greater than 35 to 50 feet; and wider B, C or F streams similar to the width of lower portions of Grave Creek.

H.1.1 Pool Frequency Reference Values for B & C Streams with Bankfull Widths of about 10 to 20 Feet (Typically 2nd and 3rd Order Streams)

The data in Table H-1 show that the smaller streams tend to have larger pool frequency values. The Libby Ranger District values for B and C streams with a 10 to 20 feet bankfull width had an average value of 106, a median of 102 a 25th percentile of 77 pools per mile, and a 75th percentile of about 118. For the Rexford Ranger District data set, streams approximately 10 to 20 feet bankfull width had an average value of 73 pools per mile. Data from the Lolo NF indicate an average of 39 and 37 pools per mile for B and C streams respectively although results were not differentiated by stream width. The RMO values represent a range of 96 to 56 pools per mile, with a midpoint of about 73 pools per mile. No data for streams with bankfull widths less than 19 feet in the Swan Lake Watershed were collected.

The Table H-1 data allows for application of a primary reference development approach based on regional data. The Libby and Rexford Ranger District Data appear to be most robust, with a preference for the Libby data because of the ability to apply a non-parametric statistical approach as discussed in Section 3.2.3.2.2 and due to the similarity to RMOs. Also note the similarity between B and C results in Table H-1 for this data set. Application of this data would result in a reference range of 77 to 118 pools per mile, representing the 25^{th} to 75^{th} percentile range from the Libby reference data set. This value is modified to 73 to be consistent with the Forest Service RMOs, and where streams widths approach 20' the range can be lowered to as much as 56 pools per mile. This provides a higher range than the Lolo data and helps provide a margin of safety for stream protection, although the Swan data for larger streams does suggest a potentially higher achievable pool range.

Variations between reference stream data add uncertainty to chosen values. These and similar uncertainties exist throughout the development of reference conditions and are further addressed within the adaptive management approach for applying reference values as beneficial use support objectives, including the application of TMDL targets.

H.1.2 Pool Frequency Reference Values for B and C Streams with 20 to 35 Feet Bankfull Width (Generally 3^{rd} and 4^{th} Order Streams)

For B and C streams with 20 to 35 feet bankfull width, the data in Table H.1 show a median value of 80 for Swan tributaries with a 25^{th} to 75^{th} percentile range of 70 to 95 pools per mile. The Table H.1 data for Libby reference streams greater than 20 feet wide (and generally less than 30 feet wide) show a median value of 60 for B and C streams with a 25^{th} to 75^{th} percentile range of 47 to 66 pools per mile. The Rexford database average pool frequency implies lower values of 48 pools per mile for streams with approximately 20 to 30 feet bankfull width, as does the Lolo data although the Lolo data is not stratified by width. Whereas the Libby data show consistent results for B and C streams in the 10 to 20 feet wide range, the data for C and B streams greater than 20 feet suggests that the C streams have significantly fewer pools. The Libby C stream results are based on only three data points, with one result for the widest stream of the three (32 feet) contributing significantly to the low statistical values, possibly due to the requirement that pools must be equal to one-third the bankfull width per the Libby pool counting method. The RMO range for this width category would be 56 to about 35 pools per mile, with 47 pools per mile at the 25' midpoint, about 42 pools per mile at 30' width, and about 35 pools per mile at about 35' width.

A primary reference development approach based on regional data is used. The Libby and Rexford Ranger District Data appear to be most robust, with a preference for the Libby data because of the ability to apply a non-parametric statistical approach and due to the similarity to RMOs. Application of this data would result in a reference value range of 47 to 66 pools per mile, representing the 25^{th} to 75^{th} percentile range from the Libby reference data set. The low end of 47 is consistent with the Forest Service RMO, and where streams widths approach 35' the range can be lowered to as low as 35 pools per mile on a case by case basis. This provides a higher range than the Lolo data and helps provide a margin of safety for stream protection, although the Swan data does suggest a potentially higher achievable pool range.

H.1.3 Pool Frequency Reference Development for B and C Stream Reaches Generally 35 to 50 Feet Wide (Generally 4th or 5th Order Streams)

For B and C stream reaches 35 to 50 feet bankfull width, pool frequency ranges from 21 to 52 with both a median and average value of 38 in Swan tributaries. The 25th percentile is 29 and the 75th percentile is 47. Rexford data for streams greater than 29.5 feet wide is consistent with the Swan values at an average pool frequency of 32 pools per mile. The Lolo data is also similar with average values of 39 and 37 for B and C streams respectively, although the Lolo data are not stratified by width. The Libby data did not include streams within this width range. The Forest Service RMOs would result in a range of 35 pools per mile at 35' width, to 26 pools per mile at 50' width.

The preferred primary reference value development approach is the application of the Swan data due to the available statistical distribution and also due to the fact that the Swan median and average values (38 pools per mile) are both similar to the Rexford average value of 32 pools per mile for wider streams, and similar to the RMOs. Application of this data would result in a reference value range of 29 to 47 pools per mile, representing the 25th to 75th percentile range from the Swan reference data. The low end of the range can be decreased down to 26 pools per mile consistent with the RMO values at the 50' width. Again the higher range is used to help provide a margin of safety for stream protection.

H.1.4 Lower Grave Creek Pool Frequency Reference Development

Lower Grave Creek consists of some Rosgen C, B and F reaches that tend to fall between 40 to 60 feet wide, although some C reaches below the GLID are even wider. One primary target development approach would be to use data from the lower Grave Creek internal reference reach, suggesting a value of 12 pools per mile for the C stream type. A secondary target development approach for the C stream reaches is to apply a literature value of 3 to 4 pools per meander wave length (Rosgen, 1996), based on one to two pools per meander bend. Using the Section G.4.1.2.5 design/reference dimensions, the meander wavelength would ideally be about 858 feet long, or about 6 meanders per mile for a pools per mile range of about 12 to 24 if it assumed that the meanders would form one to two pools each. This value is consistent with the low end of the design range. There is also the potential for additional pool development due to large woody debris in the channel. Therefore, for the C stream reaches of lower Grave Creek, the reference target range is 12 to 24 pools per mile based on a combination of internal reference data (primary approach) and applied literature (secondary approach).

The 29 to 47 target range developed for 35 to 50 foot wide streams is applied to the B and F reaches of lower Grave Creek due to size similarities, with potential modifications to be consistent with RMOs as discussed above. Although not presented in Table H.1, Libby reference data from two F stream reaches greater than 30 feet wide result in pool frequency values of 39 and 48. Both results are consistent with the 29 to 47 reference range.

Table H-1: Pool Frequency Reference Sources.

Source	Stream Type and/or Bankfull Width	Pool Frequency (pools/mile)			
Swan River Tributaries: Piper, Goat, Jim and Elk Creeks	B & C 19'-35' (generally 3rd order)	Range: 52-114 25th Percentile: 70 75th Percentile: 95 Median: 80 Average: 85			
Four Swan River Tributary Reaches in Jim, Elk, & Goat Creeks;	B & C 35'-45' (generally 3rd and 4th order)	Range: 21– 52 25th Percentile: 29 75th Percentile: 47 Median: 38 Average: 38			
Lolo NF Undeveloped Conditions	B C	39 (average value) 37 (average value)			
Kootenai NF, Libby RD		**Range**	**25th/75th**	**Median**	**Average**
	B < 20'	47-251	78/116	100	109
	C < 20'	55-120	79/112	103	93
	B&C < 20' (& > 10')	47-251	77/118	102	106
	B > 20'	42-110	52/71	61	65
	C > 20'	8-64	16/44	23	32
	B&C >20' (& < 32")	8-110	47/66	60	56
Kootenai NF, Rexford RD	< 9.8'	113 (average value)			
	9.8 - 19.7'	73 (average value)			
	19.7 - 29.5'	48 (average value)			
	> 29.5'	32 (average value)			
INFISH RMOs	10'	96			
	20'	56			
	25'	47			
	50'	26			

H.1.5 Reference Values Summary

Table H.2 provides a summary of pool frequency reference values/ranges applied to the Grave Creek Watershed. As additional reference data become available, pool frequency reference values/ranges may be refined. Furthermore, pool frequency reference application 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. This is further discussed under the beneficial use support objectives (Section 5.2). Note that application of the pool frequency reference values allow for some overlap, particularly in the 3rd order streams with widths ranging from 15 to 20 feet. This is because of the desired grouping of assessment results by longer stream segments as reported within Section 4.0. Under these conditions, specific application of RMO reference values that fall between the two pool frequency ranges should be incorporated. This is discussed more within the target development Section 5.2.

Table H-2: Summary of Pool Frequency Reference Values for Grave Creek Watershed.		
Stream Order & Type (Bankfull Width)	Streams	Pool Frequency (pools/mile)
B & C, Mostly B, 10'-20' (generally 2nd and 3rd order)	Williams Lake; Clarence (14'-17', 7'); Stahl (12'-20', 40'); S. Fk. Stahl (12'); Lewis (7'-16'); Foundation (7'-18')	73 – 118 Low end of range can be modified down to 56 when streams approach 20' width
B & C 20'-35' (generally 3rd and 4th order)	Upper Grave (30'-34'); Williams (16'-39'); Clarence below Stahl; Blue Sky (17'-23')	47 – 66 Low end of range can be modified down to 35 when streams approach 35' width
B & C; 35'-50' (generally 4th or 5th order)	Middle Grave (38'-57');	29 – 47 Low end of range can be modified down to 26 when streams approach 50' width
Lower Grave Creek B & F (> 40")	Lower Grave Creek	29 – 47 Low end of range can be modified down to 26 or lower when streams approach or exceed 50' width
Lower Grave Creek C (>40')	Lower Grave Creek	12 - 24

H.2 Large Woody Debris (LWD)

Large woody debris frequency (total pieces of LWD/mile) is a parameter used as a physical habitat indicator. Large woody debris (LWD) is considered an important habitat feature for cold-water fish, particularly for bull trout. In many streams, LWD can play an important role in forming pools or creating pools with greater residual pool depths. LWD can also help establish streambed stability, dissipate energy, and directly influence sediment storage (Rosgen, 1996).

The same sources for developing pool reference data were used for developing large woody debris reference values. Additional sources of information include information in the Plum Creek Timber Company Habitat Conservation Plan (Plum Creek Timber Company, 2000), which includes reference data from Western Montana streams.

Factors that can influence a stream's ability to retain LWD within the active channel will be a function of stream size, stream gradient, and the overall size of the LWD piece (both diameter and length) relative to stream size and energy. Higher numbers of LWD are typically associated with narrower and lower order streams. Overall, the LWD results tend to show high variability within data sets.

Streams were broken into the same size categories for developing and applying LWD reference values as was done for pool reference development (Section H.1.1). Similar to pool frequency, the higher the number of LWD, the better the habitat conditions within the ranges discussed in this section. Therefore, values above the high end of the reference range would be considered desirable in most situations, and values below the low end of the reference range would typically be considered undesirable. Table H.3 presents the LWD frequency data from the reference sources. Not included is the Forest Service RMO of about greater than 20 pieces greater than bankfull width per mile since this value is not protective given the much higher reference range results.

H.2.1 Large Woody Debris Reference Values for B & C Streams with Bankfull Widths of about 10 to 20 Feet (Generally 2nd and 3rd Order Streams)

Data in Table H-3 show that the smaller streams tend to have larger numbers of LWD. The Libby Ranger District values for B and C streams 10 to 19 feet in bankfull width had an average of 293, a median of 252, a 25th percentile of 163, and a 75th percentile of 371. The Rexford streams less than 20 feet wide had an average LWD value of 181, less than the Libby average possibly due to the 1910 fire impacts discussed above. Data from the Lolo National Forest shows an average value of 772 for 2nd order B and C streams, implying much higher obtainable values in small streams. For the Table H-3 results not stratified by size, the Hayes western streams data has a median of 450 with a 25th to 75th percentile range of about 290 to 820; and the Plum Creek HCP streams east of the Cascades have a median value of 290 with a 25th to 75th percentile range of 105 to 450. Data were not collected for streams less than 19 feet in bankfull width in the Swan watershed.

The Libby reference information was chosen as the best representation of reference conditions based on a regional information approach for primary reference development and available statistics. Using the 25th to 75th percentile from this data set results in a LWD reference range of 163 to 371 pieces per mile.

H.2.2 Large Woody Debris Reference Values for B and C Streams with 20 to 35 Feet Bankfull Width (Generally 3rd and 4th Order Streams)

The data in Table H-3 show the Libby Ranger District Data for B and C streams with widths between 20 and 32 feet had an average of 301, a median of 264, a 25th percentile of 112 and a 75th percentile of 443. The Lolo results for 3rd and 4th order streams averaged 156 pieces per mile, and the Rexford average for streams greater than 20 feet was 152. In the Swan, 3rd and 4th order streams with bankfull widths between 19 and 35 feet had an average of 336, a median of 259, a 25th percentile of 123, and a 75th percentile of 507. Other data in Table H-3 also show relatively high values with significant variability.

The Libby reference information was chosen as the best representation of reference conditions based on a regional information approach for primary reference development and the availability of non-parametric statistics. Using the 25^{th} to 75^{th} percentile from this data set results in a LWD reference range of 112 to 443 LWD pieces per mile. Although there are only three C stream values from the Libby data set, the Table H-3 results suggest much higher LWD values for wider C streams. This may be due to high gradient, relatively wide upstream B reaches that are efficient at transporting LWD to the lower gradient C reaches.

H.2.3 Large Woody Debris Reference Development for B and C Stream Reaches Generally 35 to 50 Feet Wide (Generally 4^{th} or 5^{th} Order Streams)

In Table H-3, the Swan data set from four stream reaches provides the only reference results for streams with bankfull widths that tend to range from greater than 35 feet to 50 feet. The data show an average value of 206, a median of 108, a 25^{th} percentile of 104, and a 75^{th} percentile of 210. The difference between the median (108) and the average (206) shows the big influence one high result can have on the average value using parametric (normal) statistics, whereas the median value from non-parametric (non-normal) statistics applied to this small data set is not influenced as heavily by one data point.

The Swan reference information was chosen as the best representation of reference conditions using a regional information approach for primary reference development. Using the 25^{th} to 75^{th} percentile from this data set results in a LWD reference range of 104 to 210 LWD pieces per mile.

H.2.4 Lower Grave Creek Large Woody Debris Reference Development

Lower Grave Creek consists of some Rosgen C, B and F reaches that tend to fall between 40 to 60 feet wide, although some C reaches below the GLID are even wider. Due to the similar size ranges, the reference value range of 104 to 210 developed above is also applied to the sections of Grave Creek above the GLID where the riparian forest is similar to the upper watershed. The lower section below the GLID opens into more of a cottonwood – conifer mix, with greater uncertainty about the role of LWD and application of the Table H-3 reference information. The 104 to 210 pieces of LWD per mile reference range is applied only as an indicator to help assess overall conditions in this reach.

H.2.5 LWD Aggregates

An overlooked feature is the importance of LWD aggregates, which also play an important habitat and water quality role similar to individual pieces of LWD. A stream with low LWD values may actually have significant LWD related habitat in the form of LWD aggregates. These aggregates can also play a significant role in establishing streambed stability, dissipating energy, and influencing sediment storage similar to single pieces of LWD. Based on review of the Swan Watershed aggregate data and the large number of aggregates found in the Grave Creek Watershed, an additional LWD related reference condition that incorporates aggregates also applies. This condition requires an additional 40% increase in single pieces of LWD or aggregates above the reference levels defined above. For example, if there was a reference value of 100 pieces of LWD per mile, an additional reference value is 140 pieces of LWD and/or aggregates. The 40% is derived from the average number of aggregates divided by the average number of pieces of LWD in Swan stream reaches where lower levels of LWD were encountered (from 100 to 158 single pieces of LWD). This relatively high percentage of shows that these LWD aggregates play an important habitat role and can compensate for lower single LWD counts in healthy streams. Rootwads also play an important role in habitat formation, similar to LWD. Where assessment data identify rootwads, these can be counted toward the total summary of LWD type features when comparing to reference conditions.

H.2.6 Reference Values Summary

Table H-4 summarizes the LWD reference values developed above. The reference value that includes both the single LWD pieces along with the aggregates is the preferred value where a data set includes both single pieces and aggregates. This is the situation for the Grave Creek Watershed dataset, which also includes rootwads that can be counted toward meeting the reference value.

Similar to the application of pool reference ranges, the LWD reference values also allow for some overlap, particularly in the 3rd order streams with widths ranging from 15 to 20 feet. This is because of the desired grouping of assessment results by larger stream segments as reported within Section 4.0. Under these conditions, values that fall between the two LWD frequency ranges may need to be considered to compensate for this overlap.

Table H.3: Large Woody Debris Reference Sources and Data.

Source	Stream Order and/or Type (Bankfull Width)	LWD pieces/mile (not including aggregates)			
Swan River Tributaries: Jim, Goat, Piper, and Elk Creeks	B & C, 19’-35’ (generally 3rd and 4th order)	Range: 105-734 25th Percentile: 158 75th Percentile: 507 Median: 259 Average: 336			
Four Swan River Tributary Reaches in Jim, Goat, and Elk Creeks;	B & C, 35’-45’, (generally 4th or 5th order)	25th Percentile: 104 75th Percentile: 210 Median: 108 Average: 206			
Plum Creek HCP Target	Various streams east of Cascades	412 ± 301			
Reported in PCTC HCP, 2000	Western Montana Streams	25th to 75th Percentile: 290-820 Median: 450			
Unpublished Plum Creek Data	Various streams east of Cascades	25th to 75th Percentile: 105-450 Median: 290			
Lolo NF Undeveloped Conditions	2nd Order B & C	Average: 772			
Lolo NF Undeveloped Conditions	3rd and 4th Order B & C	Average: 156			
Kootenai NF, Libby Ranger District		**Range**	**25th/75th**	**Median**	**Average**
	B < 20’ (10’ - 17’)	100-660	168/409	293	333
	C < 20 (15’ – 19’)	68-211	119/191	170	150
	B&C < 20’ (10’ – 19’)	68-660	163/371	252	293
	B > 20 (21’ – 26’)	12-754	74/451	149	274
	C > 20’ (23’ – 32’)	264-480	321/429	377	374
	B&C > 20’ (21’ – 32’)	12-754	112/443	264	301
Kootenai NF, Rexford Ranger District	<19.7’	181			
	>19.7’	152			

Table H-4: Summary of LWD Reference Values for Grave Creek Watershed.			
Stream Order & Type (Bankfull Width)	Streams (Bankfull Width)	LWD / Mile Reference Value (minimum)	LWD and/or Aggregates per Mile Reference Value (minimum)
B & C, mostly B, 10'-20', (generally 2nd and 3rd order)	Williams Lake; Clarence (14'-17', 7'); Stahl (12'-20', 40'); S. Fk. Stahl (12'); Lewis (7'-16'); Foundation (7'-18')	163 - 371	228 - 519
B & C, 20'-35', (generally 3rd and 4th order)	Upper Grave (30'-34'); Williams (16'-39'); Clarence below Stahl; Blue Sky (17'-23')	112 - 443	157 - 620
B and C, 36'-50', generally 4th or 5th order)	Middle Grave (38'-57'); Lower Grave F Reach (42')	104 - 210	146 - 294
Lower Grave Creek C, F & B (40' – 60' and wider)	Lower Grave Creek C, F & B (47'-48'; 50'-54')	104 - 210	146 - 294

H.3 Reference Development for Macroinvertebrate Metrics

Macroinvertebrate metrics are commonly evaluated and used to help with beneficial use support conditions throughout Montana. The MDEQ applies standard protocols for evaluating the macroinvertebrate data based on a primary reference development approach that is commonly updated as more information becomes available. No additional reference development is required within this document; any macroinvertebrate results will be subject to standard MDEQ protocols for evaluating the data against reference conditions. Unfortunately, there are limited macroinvertebrate sample results from the Grave Creek Watershed (Section D.5).

H.4 Substrate and Surface Fine Sediment Measures

Excess fine sediment is typically referred to as a “siltation” cause of impairment on Montana’s 303(d) list, with potential impacts often relating to excess subsurface fines in spawning gravels or excess surface fines in riffles. Excessive surface and substrate fines may limit fish egg and embryo survival. Macroinvertebrate richness may also be limited by excess surface fines, thus limiting aquatic life and potentially having a negative impact on cold-water fish that rely on macroinvertebrates as a food source (Suttle et al., 2004).

Fine sediment on the channel bed surface and within the channel substrate may be evaluated in several ways. McNeil core samples may be used to determine the percent of fines in the upper several inches of channel substrate, usually in pool tail outs where fish spawning is likely to occur. The 49-point grid toss method may be used to determine percent surface fines < 6.35 mm at pool tail outs and riffles, although data from pool tail outs is used in this document. Pebble counts may also be used to evaluate surface fines in riffles and pools, with composite data from both riffles and pools used in this document. Grid-toss and pebble count measures of surface fines can also be used as surrogates for assessing substrate fines. For pool tail outs, McNeil coring is believed to be a more consistent method for evaluating the impacts of fines on spawning success than the grid-toss method, and is therefore a preferred method. However, McNeil core data were available for only a few sites in the Grave Creek Watershed, whereas there was significant surface fines data using both the grid toss and pebble count methods

H.4.1 Relationships Between Subsurface and Surface Fine Sediment and Beneficial Uses

A study by Weaver and Fraley (1991) showed a direct correlation between successful fry emergence and fine sediment in spawning gravels, with increases in the percentage of fine sediment < 6.35% resulting in a decrease in fry emergence. Research by macroinvertebrate specialists (EPA, 2004) indicates that surface fines (< 2 mm) need to be elevated to levels between 20 – 40%, based on riffle pebble count data, to result in a decrease in macroinvertebrate richness. Therefore, values less than 20% may not be contributing to impairment, even if elevated at levels greater than comparable reference streams. Fine sediment levels in pool tail outs (glides), riffles, and/or composite pebble count results can be used as an indicator of potentially high levels of surface fines in riffles, as an indicator of impacts to macroinvertebrate, or as an indicator of excess fines in subsurface material where McNeil Core data is not available. Elevated fine sediment results from riffle pebble counts can also be an indicator of a potential impact to fish spawning substrate, even if the values are below the 20% level where impacts to macroinvertebrate populations could be anticipated.

Unlike LWD and pool frequency, where higher values are generally considered better, the development of reference values for surface or subsurface fines is typically based on a maximum value of acceptable fine sediment. This is because lower values are considered more desirable unless the values get so low that the data could be an indication of a different type of sediment and habitat problem such as a degrading system. The reference value development can focus on using a 75th percentile or one standard deviation added to the average of a reference database to determine an acceptable maximum value. The 25th percentile or one standard deviation subtracted from the average of a reference database can be used as a minimum value below which the data may be an indication of a degrading system or other problems.

H.4.2 Reference Development for Substrate Fines < 6.35 mm

Table H-5 presents reference data for substrate fines. MDEQ and the Flathead National Forest established McNeil core percent fine reference conditions for the Big Creek TMDL of less than or equal to 30 percent substrate fines (< 6.35 mm) for a McNeil core sample. This was based on historical data from Big Creek. Other TMDL target conditions are based on local or regional reference conditions typically in the range of

28 to 35 percent fines < 6.35 mm. These reference conditions are generally based on a 75^{th} percentile or upper end of a reference range.

McNeil Core data from Grave Creek (Table 4-3) range from 20 to 25 percent from three recent years of sampling. Results from McNeil Core sampling by the Kootenai National Forest show average percent substrate fines at reference sites monitored from 1997 – 2003 ranged from 17 to 29 percent with similar median values (Table H-5). The 75^{th} percentile values typically fall below 28 percent, and the 25^{th} percentile values are all greater than 15 percent. This data is considered a reasonably applicable representation of expected conditions in Grave Creek. Therefore, for Grave Creek, a McNeil Core sample reference value range of 15 to 28 percent substrate fines < 6.35 mm is selected using a regional reference primary approach, supplemented by the fact that internal reference data suggests that results from Grave Creek should continue to fall within this range. Although the focus is on the upper limit, values below 15 percent should be investigated as a potential problem that could be associated with a lack of adequate spawning sites linked to pool/glide formation problems.

Table H-5: Reference Data for Substrate Fines (< 6.35) Using McNeil Core Sampling.

Source	Percent Fines				
Big Creek (Flathead)	30 (based on average plus one standard deviation)				
TMDL Targets from Other Watersheds in Western Montana	28 – 35 (generally based on 75^{th} percentile or upper end of reference range)				
Kootenai Sampling (1997-2003)	**Average**	**Stnd Dev.**	**25^{th} Percentile**	**75^{th} Percentile**	**Median**
Bear Creek	19.0	6.0	16.7	22.5	19.5
Flattail Creek	26.7	7.2	23.2	28.3	26.0
Himes Creek #1	29.1	4.4	26.4	28.2	27.5
Libby	25.4	4.5	24.4	27.9	26.0
West Fork Quartz (Upper)	17.1	3.6	15.2	18.0	16.5
Upper Silver Butte	21.0	4.3	19.2	23	21.5

H.4.3 Reference Development for Surface Fines in Riffles Based on Pebble Count Results

Reference development considered existing watershed conditions and ongoing reference development work in the Yaak Watershed. Pebble count results for surface fines < 2 mm from throughout the Grave Creek Watershed (Table 4-4) are all less than 9 percent except for one 10% and one 12% result from B4 reaches in middle and upper Grave Creek and one 12% result in a B4(a) reach of Blue Sky Creek. In these situations, the < 6.35 mm pebble count results are also relatively high at 15% for the middle Grave Creek reach, 18% for the upper Grave reach and 20% for the Blue Sky reach. All other < 6.35 mm pebble count results are less than or equal to 15% with the exception of one 17% result in Stahl Creek (B3(a) stream type) and one 19% result in Lewis Creek (B4(a) stream type). Since the majority of results for the < 2 mm data are equal to or below 9%, this 9% is chosen as an indicator of potential increasing fine sediment in the watershed. Similarly, the majority of results for the < 6.3 mm data are equal to or below 15%, making this 15% an indicator of potential increasing fine sediment. These are not true reference values since Grave Creek is not a reference stream, but they do represent values that can be tracked to indicate potential increased fine sediment inputs.

The reference development work in the Yaak (EPA and KNF unpublished data) has resulted in < 6.35 mm pebble count percent fines reference data mean values ranging from 10 to 13% for B3, B4, C3 and C4 stream types. These results are similar to the average results for the Grave Creek Watershed. The applicability of the pebble count information will be further discussed in Section 5.2, taking into consideration the apparent 20% threshold for surface fines < 2 mm while also considering the fact that percent fines can be an indicator of other beneficial use support impacts, or lack of such impacts.

H.4.4 Reference Development for Surface Fines in Pool Tails (Glides) Based on Grid Toss Results

Reference development for percent surface fines using the grid-toss method is based on results from several studies (Table H-6). Percent surface fines impairment threshold for the Blackfoot Headwaters TMDL was set at about 6 percent to 8 percent, representing the 75^{th} percentile of the reference condition. This data was collected using a variation of the grid toss approach referred to as a “viewing bucket” approach. Average grid toss reference condition values measured in undeveloped watersheds on the Lolo National Forests (USFS, 1998) ranged from about 6 percent to 8 percent surface fines, with the upper end of one standard deviation values in the approximate range of 15 to 20%. If non-parametric statistical analysis had been performed on this data set, the 75^{th} percentile would be lower than this 15 to 20 percent range, probably in the 10 to 15 percent range. This is based on graphical data presentations from the USFS report and the fact that the low end of one standard deviation is cropped at 0, both of which imply a skewed distribution. The median percent surface fines values collected during R1/R4 surveys (grid toss) along Grave Creek and within tributary streams all range from 0 to 10%, with 75^{th} percentile values typically between 5 and 15% fines < 6.35 mm (Section 4.0).

Based on existing conditions in the watershed, and the reference information presented in Table H-6, a median value of 10% < 6.35 mm is used as a reference condition based on a preference toward using the more robust Lolo data set which used comparable methodology to the data collection in Grave Creek Watershed. The Lolo data suggests a 10 – 15% upper range, which is supplemented by internal Grave Creek Watershed data that suggest the median value from multiple grid tosses in a reach should remain below 10%. Values above this indicate increasing sediment loading in the watershed and can be an indicator of negative impacts to a beneficial use.

Table H-6: Reference Data for Grid Toss Surface Fines (< 6.35 mm)	
Source	Percent Fines
Lolo NF (USFS, 1998)	6 – 8 (Average); 15 – 20 (upper end of one standard deviation); 10 – 15 probable range of 75th percentiles
Blackfoot Headwaters TMDL Reference Condition	6 – 8 (75th percentile)
Grave Creek Watershed median values	5 - 10

H.4.5 Summary of Substrate and Surface Fines Reference Conditions

Table H-7 summarizes the substrate and surface fines reference conditions. It should be noted that the substrate fines (McNeil Core sampling) reference development is based on a primary approach using regional reference streams. The same holds true for the grid toss results. The pebble count reference approach is a combination of internal reference information, limited regional reference data, and professional judgment. The selected pebble reference values can be used as an indicator of increased sediment loading, but needs to be used cautiously for any other reasons. Fortunately, the expected < 2 mm upper range value is well below the 20% value at the lower end of potential impact to aquatic life (EPA, 2004) and all results in Grave Creek are well below 20%. Note that these pebble count results are composite pebble counts as described in Appendix F, and care must be taken in directly comparing these results to the 20% potential impacts to aquatic life value.

Table H-7: Summary of Substrate and Surface Fine Reference Values for the Grave Creek Watershed.	
McNeil Core Substrate Fines (< 6.35 mm)	15 - 28%
Grid-toss Surface Fines (< 6.35 mm)	≤ 10%
Pebble Count Surface Fines (< 2 mm)	≤ 9 - 12%
Pebble Count Surface Fines (< 6.35 mm)	< 10 to 15%

H.5 Width to Depth Reference Development

Width to depth is an important indicator of proper channel function. Rosgen stream types represent important data stratification for any width to depth measures. Also, stream width is an important consideration, with larger, wider streams generally having a naturally higher width to depth ratio. Width to depth is normally measured as bankfull width to average bankfull depth at riffle cross sections.

Reference data sets for width to depth include the Lolo National Forest information (USFS, 1998), reference summary data from the Kootenai National Forest (unpublished data, 1998), results from within the Grave Creek Watershed, and the internal reference reach results for lower Grave Creek (Section G.4.1.2.5). Historical stream width information from the aerial assessment work (Section G.4.1.2.1) also provides an important indicator of width to depth changes over time from 1947 to 1992 since a significant increase in width can indicate a significant increase in width to depth. This is in realization of the fact that in 1947 the stream may have already been overly wide due to human impacts prior to that date. Table H-8 provides a summary of the reference information.

Table H-8: Width to Depth Reference Sources and Results.

Data Source	Stream Types & Other Stratification	Results
Lolo National Forest Reference Streams (recommended ranges based on reference data sets)	B3 & B4 C3 & C4	12 – 22 10 – 33
Kootenai National Forest Reference Data	B3 (stream widths 18 ± 9) B4 (stream widths 13 ± 4) C3 (stream widths 26 ± 4) C4 (stream widths 15 ± 3)	20.9 ± 9.0 (n = 34) 19.4 ± 6.9 (n = 22) 16.0 ± 7.4 (n = 4) 14.7 ± 3.2 (n = 3)
Grave Creek Watershed	B and C tributary reaches Middle and Upper Grave B & C	All < 20 All < 21 except one value at 29 where width = 49
Lower Grave Design Values from Reference Reach	C (50 – 54 ft design width)	18 – 22
Aerial Assessment Data for Lower Grave Creek	C Section from Canyon to Williams	Width increased 60 – 130 ft from 1947 to 1992; Width increase noted between 1954 and 1992

H.5.1 Lower Grave Creek C Stream Type Width to Depth Reference Development

The internal reference data for lower Grave Creek C reaches; supplemented by historical and regional data, provide primary reference approaches to help identify the width to depth reference range. The internal reference information results in a restoration design reference range of 18 to 22 for width to depth ratio. This range probably does not account fully for potential natural variability that could be experienced over time. To help evaluate this potential variability, the variability in other reference data is used. The standard deviation for the KNF C3 and C4 reference stream data ranges from about 3 to 7. The standard deviation range for B streams is about 7 to 9, with the B streams having much higher number of results. Using this information, “7” is chosen as a typical deviation and is added to the middle of the design range resulting in reference range of 13 to 27. This provides a more reasonable expectation for all of lower Grave Creek, including sections that may not undergo active restoration based on the 18 – 22 width to depth design range. Design values should still shoot for this 18 –22 width to depth ratio, but a measure of success over time would be based more on a 13 to 27 suggested reference range.

H.5.2 Width to Depth Reference Development for Other Stream Reaches in the Grave Creek Watershed

For other streams throughout the watershed, the Kootenai National Forest (KNF) width to depth reference information provides the best reference data due to the presentation of the average values and standard deviations, although the Lolo recommended ranges appear to be based on similar statistics. The KNF data is for streams with mean widths similar to the size of upper Grave Creek and tributaries to Grave Creek. The KNF data shows upper ranges of one standard deviation varying by stream type. The B stream upper width to depth values are 30 (B3) and 26 (B4); whereas the C stream data, based on significantly fewer measures, result in upper width to depth values of 23 (C3) and 18 (C4). This compares to the Lolo upper recommended values of 33 for B reaches and 22 for C reaches.

Review of the Lolo and KNF data suggests a skewed condition that would result in 75th percentile values that would perhaps be about midway between the average and one standard deviation if non-parametric statistics were applied to the data. This 75th percentile value would be close to 25 for both the B and C stream types when both data sets (Lolo and KNF) are considered and weighted by the number of results for each stratification. This 25 is therefore used as the upper end of the reference range for the Grave Creek Watershed above the GLID based on the regional reference data and applied professional judgment. The lower end of the range is 10 based on the lower end of the literature value of 12, with consideration for variability as suggested by the Rosgen classification approach. Therefore, the width to depth reference range is 10 to 25 for all other B and C stream segments other than the lower Grave C reach discussed above in Section H.1.5.1. This range is modified for reaches where existing data shows lower values already exist, as is the case throughout most of Grave Creek. Under these conditions, a 20% increase in width to depth would be considered outside the range of a reference value that is based on known stream conditions.

Table H-9 provides a summary of the reference value ranges for width to depth.

Table H-9: Summary of Width to Depth Reference Ranges.

Stream	Range
Lower Grave Creek	13 - 29
Grave Creek Watershed B & C Reaches	10 – 25; **and** no more than a 20% increase in reaches that currently fall within this range

H.6 Sinuosity

Sinuosity reference data was developed for the lower Grave Creek C section. For sinuosity, a commonly accepted value for C type streams is > 1.2 (Rosgen and Silvey, 1998). A value based on the lower Grave Creek internal reference reach is 1.4. Historical 1947 data showed a sinuosity of 1.23. Even in 1947 the stream had been impacted by channelization, suggesting the possibility of even higher sinuosity values. Therefore, a sinuosity reference range of 1.2 to 1.6 is applied based on internal reference data and the design goal of 1.4 with a plus or minus .2 incorporated. Higher values would likely be acceptable, but care should be taken in using higher values for design purposes. Values below 1.2 suggest an undesirable and over-straightened reach.

H.7 Meander Length Ratio

This parameter is based on the dimensionless ratio of the stream meander divided by the stream width using reference design values for the lower Grave Creek C reaches (Section G.4.1.2.5). It is an important stream restoration design parameter and can be used as an indicator of overall stream health. The meander length design value range of 13.8 to 19.2 will be used for meander length ratio reference value range. This value will only be used as an indicator of potential stream health problems in lower Grave Creek C reaches.

APPENDIX I
ROAD SURFACE SEDIMENT ANALYSIS METHODS AND RESULTS

I.1. Methods

Sediment delivery from roads to main stem Grave Creek is a potential source contributing to water quality impairment. Appendices B and C provided detailed results of general roads analysis measures including road density, road lengths, roads in the rain-on-snow zone and roads on sensitive land types. Table I-1 provides a summary of the primary results from Appendices B and C.

The Kootenai National Forest analyzed road source contributions in the Grave Creek drainage using the WEPP: Road interface (Elliot et al. 1999) of the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston 1995). WEPP: Road estimates road bed erosion and resulting sediment delivery. WEPP: Road allows users to easily describe numerous road erosion conditions. Variables used in the WEPP: Road model include climate, soil and gravel addition, local topography, drain spacing, road design and surface condition, and ditch condition. Road fill slope and vegetative buffer conditions may also be described. Additional physical variables including road gradient, road width and surface type, road design (insloped vs. outsloped), and traffic volume were used to predict sediment production

Climatic information included mean annual precipitation (46.6 inches) and 123 wet days per year. Topography data included elevation (5,081 ft). Road design was represented by a contributing road surface distance of 800 ft, and road gradients measured from USGS topographic maps. Road design was further categorized according to outsloped, insloped, and crowned roadbeds. Road surfaces included paved, gravel, and native material. The same values for the fill and buffer parameters were used for all runs. The fill gradient was set at 50 percent, fill length was set at 15 ft; buffer gradient was set at 25 percent, and buffer length was set at 33 ft. Unlike other road sediment modeling approaches which focus solely on sediment contribution from roads at stream crossings (XDRAIN, Washington Method, and others), WEPP: Road attempts to account for sediment production and delivery along the entire road length within sediment contributing distance to streams. Therefore measures of fill and buffer lengths and gradients are required input parameters.

Table I-1 provides a general description of the roads evaluated in this analysis. The road network was evaluated based on characteristics of primary and secondary roads. Primary roads are classified as main arterial roads within the watershed. Secondary roads included other forest roads that comprised the rest of the network not including the main arterial roads. The analysis focused on surface erosion from roads including cut slopes, fill slopes, and the roadbed. Composition of particles from these sources is mostly likely fine sediment. The analysis does not cover impacts from culvert failure, water routing, increased flows, or increased potential for mass wasting associated with roads. Analyses of other factors affecting road-associated sediment contributions (not sediment from road surface erosion) are presented in Appendices B and C (road density, roads in rain-on-snow zone, and roads on sensitive landtypes) and Appendix J (mass wasting and bank erosion from road encroachment).

Table I-1: Road Network Statistics.

Stream	Miles of Road	Road Density (mi/mi²)	Miles of Road in ROS* Zone	Miles of Road in RHCA
Williams	16.6	1.8	3.5	4.1
Clarence-Stahl	36.6	2.0	19.7	9.2
Blue Sky	25.6	2.1	16.8	8.8
Upper Grave-Foundation-Lewis	19.4	1.4	11.8	n/a
Lower Grave Creek Main stem	71.8	3.3	0	6.2

Sediment modeling results from WEPP: Road include the projected amount of sediment produced as well as projected amount of sediment delivered. Delivered sediment is usually lower than produced sediment as a result of buffer characteristics.

At the time of road building there was an initial pulse of sediment over several years from road construction and from the presence of the new roads. Over time, this sediment input has likely diminished to a relatively steady state, as modeled in this analysis. Much of this recovery would be due to re-vegetation of cut and fill slopes. Current levels of sediment from roads are relatively low when compared to the sediment load from bank erosion in the lower portion of the watershed. Current levels of sediment from roads in the upper watershed areas are probably also relatively low when compared to 1) historic road sediment loading levels when the roads were in greater use for timber harvest purposes prior to the implementation of BMPs; 2) relatively high sediment pulses when mass wasting linked to historic riparian harvest first occurred and 3) the initial road building discussed above. In several cases, field observations document continued sediment loading from roads as a result of road maintenance practices (snow plowing into ditches and culvert inlets and outlets and ditch and culvert clean-out) and lack of road BMPs. BMP upgrades implemented since sediment modeling occurred, or which were otherwise not accounted for in the sediment modeling process, have likely further reduced the sediment loading from roads.

Table I-2: Miles of Road and Road Conditions in the Main Stem Grave Creek Watershed and Tributary Sub-watersheds. Road Miles Measured From GIS Dataset.

Drainage	Total Road Length (mi)	Paved/ Chipsealed Roads	Total Paved Road (mi)	Main Road Numbers	Main Road Length (mi)	Other Road Length (mi)
Foundation	6.4	None	0.0	None	0.0*	6.4
Lewis	4.5	None	0.0	114	2.1	2.4
Blue Sky	25.6	None	0.0	7020	25.6	0.0
Clarence	13.0	None	0.0	114, 7021, 7022	5.8	7.2
Stahl	19.9	None	0.0	7021, 7022	5.1	14.8

Table I-2: Miles of Road and Road Conditions in the Main Stem Grave Creek Watershed and Tributary Sub-watersheds. Road Miles Measured From GIS Dataset.						
Drainage	Total Road Length (mi)	Paved/ Chipsealed Roads	Total Paved Road (mi)	Main Road Numbers	Main Road Length (mi)	Other Road Length (mi)
Williams	16.4	None	0.0	7019 (in HUC 0203)	4.5	11.9
Upper Main Stem Grave	8.5	None	0.0	114, 319	4.7	3.8
Upper Middle Main Stem Grave	3.8	114	2.6	7021	0.1	1.1
Lower Middle Main Stem Grave	24.3	114	4.4	7019, 7061, 7066	7.2	12.7
Lower Main Stem Grave	47.3	93, 114	6.2	7019, 7061, 7066	2.7	38.4

I.2. Results

I.2.1 Grave Creek Watershed

WEPP: Road modeling results indicate that for the Grave Creek watershed, 203 tons of sediment from road surface erosion is delivered to the stream network (Table I-3). Of the total sediment delivery related to the road network, 98 tons per year are delivered to tributaries, and 105 tons per year are delivered to main stem Grave Creek. Primary and secondary roads yielded an average of 1.2 and 1.1 tons of sediment per mile, respectively. Primary roads in the Stahl Creek drainage had the highest loading per road mile (3.97 tons/mi). Loading per mile of road is compared in Tables I-4 and I-5).

Table I-3: Summary of Annual Sediment Delivery From Roads in the Grave Creek Drainage.			
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 Grave	0.3	1.7	2.0
Lower Middle Main Stem Grave	21.2	19.6	40.8
Lower Main Stem Grave*	2.2	46.5	48.8
Total	81.3	121.3	202.7

*Most of these roads are private.

Roads in lower Grave Creek contribute 24% (49 tons) of the sediment load from road surface erosion. The road networks along middle Grave Creek contribute 21% (43 tons) of the total road surface sediment load. The tributaries each deliver between 5% and 15% of the sediment load from road surface erosion to the channel network. A summary of road surface erosion assessment results is presented in Section 6.0. Sediment load from In-stream sources associated with road encroachment is described in Appendix J.

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.

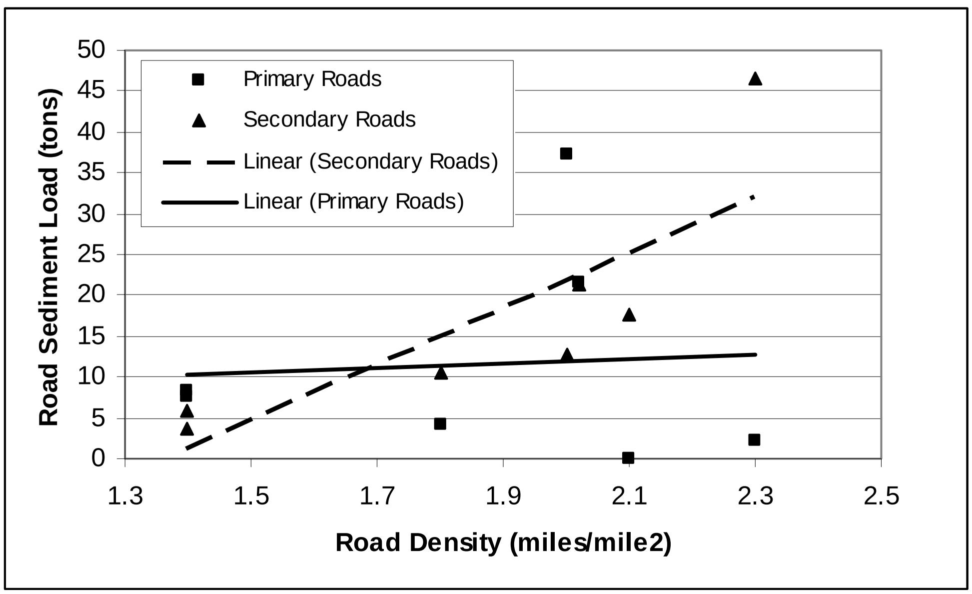


Figure I-1: Relationship between road density and sediment load from road surface erosion.

I.2.2 Williams Creek

The road surface erosion contribution to Williams Creek is estimated to be 14.9 tons per year (Table I-3). The road transportation network consists of 16.6 miles of closed roads, with an average road density of 1.8 miles per square mile (Table I-1). Twenty-five percent of the network is within the Riparian Habitat Conservation Area (RHCA), or within 300 ft of surface water and over 21 percent within the rain-on-snow zone (Table I-1).

I.2.3 Clarence Creek

An estimated 17.1 tons and 6.4 tons per year of sediment are delivered annually from primary and secondary roads in Clarence Creek (Table I-3). The total road sediment load for the Clarence Creek drainage was estimated to be 23.5 tons per year.

Clarence Creek road density analysis incorporated roads within the Stahl Creek sub-watershed. There are over 36.6 miles of road in the Clarence-Stahl sub-watershed, with approximately 53.8 percent of the road mileage located in the rain-on-snow zone. Approximately 25 percent of the road system is within 300 ft of surface water (Table I-1).

I.2.4 Stahl Creek

An estimated 20.2 tons and 6.4 tons per year of sediment are delivered annually from the surface of primary and secondary roads in Stahl Creek watershed (Table I-3). The total road sediment load for the Stahl Creek drainage was estimated to be 26.7 tons per year (Table I-3).

I.2.5 Lewis Creek

Road surface erosion contributes an estimated 12 tons of sediment per year to surface water in Lewis Creek (Table I-3). The road transportation network in Lewis Creek consists of 19.4 miles of road, with an average road density of 1.4 miles per square mile (Table I-1).

I.2.6 Blue Sky Creek

An estimated 17.6 tons of sediment are delivered annually to Blue Sky Creek from secondary roads in the sub-watershed (Table I-3). The road transportation network consists of 25.6 miles of secondary road, with an average road density of 2.1 miles per square mile (Table I-1). Sixty-five percent of the system is constructed within the rain-on-snow zone in the watershed. Thirty-four percent of the system is within 300 ft of surface water.

I.2.7 Foundation Creek

Road tread erosion contributes an estimated 2.8 tons per year to surface water in Foundation Creek (Table I-3). Sediment delivery occurs from closed, secondary roads that were decommissioned in the 1980s following logging activities. Roads in Foundation Creek were grouped with roads from the upper main stem and Lewis creek to generate road network statistics (Table I-1).

Table I-4: Characteristics of Primary Roads and Estimated Sediment Contributions From Road Surface Erosion.									
Drainage	Total Road Length (mi)	Road Gradient	Road Width (ft)	Road Surface	Road Design	Traffic Level	Per Segment Erosion Rate (lbs/yr)	Per Segment Sediment Delivery (tons/mi)	Total Sediment Delivery (tons)
Foundation	0	-	-	-	-	-	0.0	0.00	0.0
Lewis	2.1	8%	12	Gravel	Insloped	High	1202.5	3.97	8.3
Blue Sky	0	-	-	-	-	-	0.0	0.00	0.0
Clarence	5.8	6%	16	Gravel	Insloped	High	892.1	2.94	17.1
Stahl	5.1	8%	16	Gravel	Insloped	High	1202.5	3.97	20.2
Williams *	4.5	4%	16	Gravel	Insloped	Low	285.7	0.94	4.2
Upper Main Stem Grave	4.7	6%	16	Gravel	Crowned	High	499.4	1.65	7.7
Upper Middle Main Stem Grave	0.1	6%	16	Gravel	Insloped	High	892.1	2.94	0.3
Upper Middle Main Stem Grave	2.6	2%	16	Paved	Outsloped	High	22.1	0.07	0.2
Lower Middle Main Stem Grave	7.2	6%	16	Gravel	Insloped	High	892.1	2.94	21.2
Lower Middle Main Stem Grave	4.4	2%	16	Paved	Outsloped	High	22.1	0.07	0.3
Lower Main Stem Grave	2.7	2%	16	Gravel	Insloped	High	249.8	0.82	2.2
Lower Main Stem Grave	6.2	2%	16	Paved	Outsloped	High	22.1	0.07	0.5
Total	45.4						6182.4	20.4	82.3

* Includes recently closed portion of 7019 that actually has no traffic; assumed that road is not yet vegetated.

Table I-5: Characteristics of Secondary Roads and Estimated Sediment Contributions From Road Surface Erosion.

Drainage	Total Road Length (mi)	Road Gradient	Road Width (ft)	Road Surface	Road Design	Traffic Level	Per Segment Erosion Rate (lbs/yr)	Per Segment Sediment Delivery (tons/mi)	Total Sediment Delivery (tons)
Foundation	6.4	4%	10	Native	Insloped	None	131.6	0.43	2.8
Lewis	2.4	8%	10	Native	Insloped	None	468.4	1.55	3.7
Blue Sky	19.7	6%	10	Native	Insloped	None	270.6	0.89	17.6
Clarence	7.2	6%	10	Native	Insloped	None	270.6	0.89	6.4
Stahl	14.8	4%	10	Native	Insloped	None	131.6	0.43	6.4
Williams	11.9	6%	10	Native	Insloped	None	270.6	0.89	10.6
Upper Main Stem Grave	3.8	8%	10	Native	Insloped	None	468.4	1.55	5.9
Upper Middle Main Stem Grave	1.1	8%	10	Native	Insloped	None	468.4	1.55	1.7
Lower Middle Main Stem Grave	12.7	8%	10	Native	Insloped	None	468.4	1.55	19.6
Lower Main Stem Grave	38.4	4%	10	Native	Insloped	Low	367.2	1.21	46.5
Total	118.4						3316.0	10.9	121.3

APPENDIX J
IN-STREAM SEDIMENT SOURCE ANALYSIS

J.1 Methods

Data collected during the 2003 bank erosion inventory provided the basis for estimating sediment loading from stream banks on main stem Grave Creek and tributary streams. Two different source types were identified during the bank erosion inventory. Collectively, these two sources are referred to as “in-stream sediment sources” (Figure J-1). The first source type was eroding banks. The second source type was slope failures that extend down to stream channels. While the second source type is typically not the same as a disturbed stream bank, for sediment loading purposes, the slope failures, particularly the slope toes, have replaced the stream banks or the toe area of the accessible floodplain. These eroding toe slopes are contributing sediment to the channel network in a similar way as a disturbed bank would.

Actual bank erosion sites were found almost exclusively in Grave Creek main stem reaches 1 and 2. Nearly all other in-stream sediment sources were related to mass wasting failures that are contributing sediment directly to the stream. Where in-stream sources in the upper watershed were similar to an eroding bank, it was determined that the mass wasting modeling approach adequately captured sediment loading. Eroding bank material and slope failure material is composed of a mixture of both fine and coarse sediment sizes ranging from silt to boulder usually with a concentration of sand, gravel and cobble.

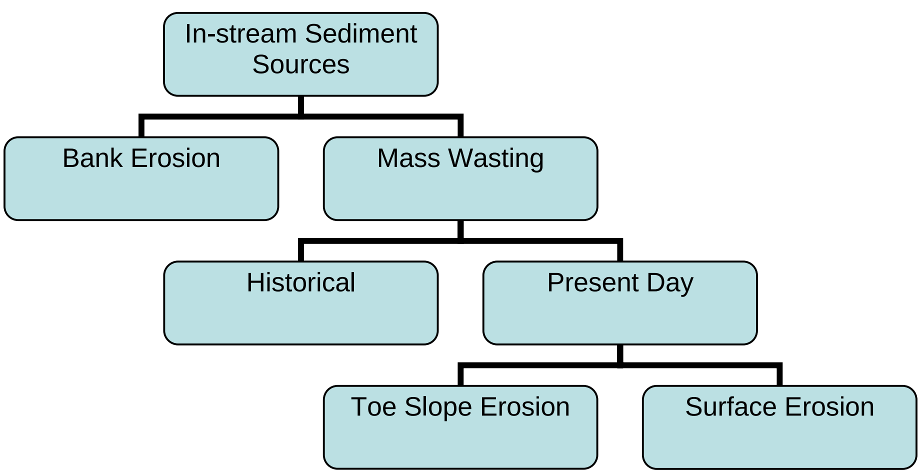


Figure J-1: Hierarchical Organization of In-Stream Sediment Sources.

RDG inventoried approximately 20 miles of main stem Grave Creek, including 100 percent Grave Creek below the canyon, representing approximately 60 percent of the main stem. An additional 8.5 miles (36 percent) of the tributary streams were also inventoried. Sites characterized as sediment sources were defined according to the following variables:

- Site length
- Site height
- Qualitative erosion risk assessment based on bank materials, the bank height ratio, vegetation condition, bank angle, and flow vectors relative to the site (modified BEHI)
- Land ownership
- Primary and secondary causes of erosion (e.g. natural, riparian modification)
- Overstory, understory, and herbaceous vegetation coverage
- Canopy density

Riparian modification included any type of alteration of the natural riparian community. Examples of riparian modifications included conversion to pasture or cropland, land clearing for development and residential construction, alterations for access (recreation, diversion, transportation, etc), and timber harvest.

J.1.1 Bank Erosion Sources

To estimate the annual sediment load produced by the first source type, eroding banks, an average rate of bank erosion was estimated for each inventoried bank erosion site. Because there were no field measures of bank erosion rates, literature references were used to determine a range of bank erosion rates measured on other gravel bed, moderate gradient streams. A similar analysis was completed for the *Blackfoot River Headwaters Planning Area Water Quality and Habitat Restoration Plan and TMDL for Sediment* (MDEQ, 2004b).

Bank erosion rates calculated by Rosgen for the Colorado Front Range (Rosgen, 2001) were selected. Glaciated, metasedimentary belt rock geology characterizing the Colorado Front Range is similar to the geology of the Grave Creek drainage. Table J-1 includes the stream bank erosion rates used for the Grave Creek bank erosion analysis. Near bank sheer stress data were not collected in Grave Creek, but in general near bank stress conditions ranged between moderate and extreme. Therefore, bank erosion rates were interpolated from Colorado Front Range data, approximately midway between moderate and extreme near bank stress categories.

Table J-1: Bank Erosion Rates Based on Bank Erosion Hazard Index (BEHI) Scores From the Colorado Front Range (Rosgen, 2001).

Bank Erosion Hazard Index (BEHI)	Predicted Stream Bank Erosion Rate based on Lamar River Data Set (ft/yr)
Low	0.2
Moderate	0.6
High	1.1
Extreme	2.3

Soil bulk densities were required to determine the tonnage of sediment delivered to stream channels from eroding banks. Soil bulk densities were interpreted from the *Soil Survey Kootenai National Forest Area, Montana and Idaho* (USFS, 1995a). Because the mapped soil unit information did not include bulk densities, similar soil series with calculated saturated bulk densities were substituted for the mapped soil units (C. Sibley, NRCS, personal communication). Saturated bulk densities were similar for the three soil series (Table J-2).

Table J-2: Saturated Bulk Densities for the Three Substituted Soil Series Characterizing Floodplain Soils on Main Stem Grave Creek and the Primary Tributaries.

Channel Segment	Soil Map Unit	Substituted Soil Series	Bulk Density
Lower Grave Creek (Reaches 1-2)	**103** – Andic Dystrochrepts, alluvial terraces	Backroad and Halfmoon soil series	1.5
Middle Grave Creek (Reaches 4-8) and Upper Grave Creek (Reaches 9-11)	**108** – Andic Dystric Eutrochrepts, lacustrine terraces-Andic Dystrochrepts, glacial outwash terraces complex	Beaverdump soil series	1.6
Tributaries	**407** – Andic Cryochrepts, moraines	Ashworth soil series	1.55

Sediment loading was estimated by multiplying the length and height of each eroding bank by the predicted erosion rate and the bulk density of the substituted soil series (Figure J-2).

Sediment Load from Eroding Banks (tons/yr) =

Eroding Bank Length (ft) * Eroding Bank Height (ft) * Erosion Rate (ft/yr) * Bulk Density (tons/ft^3)

Figure J-2: General Equation for Calculating Sediment Delivery from Eroding Bank Sites.

At the time of road building and riparian modification, particularly timber harvest, there may have been an initial pulse of sediment from bank erosion. It is expected that this pulse is primarily a result of removal of bank-stabilizing trees. In some cases, sediment sources from such activity may have recovered over time via revegetation. In other cases, these bank erosion sources may have been exacerbated into larger sources now recognized as mass wasting.

J.1.2 Mass Wasting Sources

Sediment loading from mass wasting sites (also referred to as historic mass wasting sites or events) was categorized in several ways. First, a temporal distinction was made to separate historic loads from present day loading.

For the initial mass wasting events, the sediment pulse produced by the event is estimated. For present day erosion from these sites, loading is separated by erosion mechanism into surface erosion and toe slope erosion categories (Figure J-1).

J.1.2.1 Initial In-stream Sediment Loading from Historic Mass Wasting Events

It is important to note that the current sediment load contributed from surface and toe slope erosion of the historic mass wasting sites 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 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, 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 (404 tons annually in Williams Creek as determined in the below sections), the initial mass wasting pulse produced the majority of the coarse and fine sediment contributed to the channel network in comparison to current yearly loading from these sites. Sediment loading from the mass wasting sites continues to occur (Section J.1.2.2), diminishing over time with revegetation and stabilization. This initial mass wasting pulse load is also significantly higher than the lower Grave Creek bank erosion loads identified below.

It is assumed that most of the fine sediment from the initial pulse has been transported out of the system. However, the coarse material likely remains in the bed material load, as bedload transport rates can be very low and limited to fewer flow events than required for transport of finer and/or suspended sediment loads (Leopold, 1994; Watson et al., 1998; Dunne et al., 1980). As a result, the coarse sediment from these events, which remains in the system, can contribute to a loss of pool habitat due to pool filling by the excess bed material load as discussed in Section 5.4 and Appendix G.

Most of the historic mass-wasting sites are attributed to human causes. Historic natural loads are assumed similar to present day natural loads.

J.1.2.2 Current In-stream Sediment Loading from Remnants of Historic Mass Wasting Events

Presently at these mass-wasting sites, two mechanisms of continued sediment contribution were observed. The first mechanism is hillslope erosion from the slumped mass of material and scarp, also referred to as surface erosion. The second mechanism is toe slope erosion. During field observation it was noted that while some of the wasted material has partially revegetated, inchannel and above bank streamflows could potentially activate the toes of the failed material, thereby increasing sediment loading on occasion.

J.1.2.2.1 Surface Erosion

For the natural mass wasting sites length and height dimensions were also collected. A sediment load for the contributing area was calculated using an annual erosion rate of 24 tons/mi^2/year and a delivery ratio of 60% (USFS, 1991). For human caused mass wasting sites the Disturbed WEPP model (Elliot et al., 2000) was used to determine erosion rates and sediment delivery. Inputs to WEPP for both upper and lower hillslope facets included 65% gradient, 20% cover and 20% rock. For the treatment variable, "low severity fire" was used. The Disturbed WEPP model documentation explains that the low severity treatment is similar to "a sparsely vegetated, newly exposed surface following excavation where material has not been highly compacted, such as a road cut". This scenario was deemed most similar to the slope failures being modeled. Other variable inputs included soil texture and climate. The same climate file and soil texture used for the WEPP: Road runs for road surface erosion analysis were also used here for the slope failure erosion analysis (See Appendix B).

J.1.2.2.2 Toe Slope Erosion

For each mass wasting site, erosion of the toe slopes by stream flow is another source of sediment loading. An estimate of annual sediment load from erosion of toe slope by streamflow was generated by applying a BEHI erosion rate to the area of toe slope exposed to the most frequent flows. Based on field observations of toe slope stability, angle, and revegetation, it was determined that most toe slope are relatively stable and a BEHI rating of Low (0.2 feet of erosion per year) would be appropriate. The area of toe slope susceptible to this type of erosion was determined by multiplying the length of the failure by a height of 5 feet. Five feet was selected based on the average height at which bankfull flows and slightly out of bank flows would impact the mass wasting site.

J.1.3 Total Sediment from In-Stream Sources

The field inventory covered a majority of the Grave Creek main stem and portions (lower and middle) of each tributary stream. Although the inventoried channel lengths likely captured the majority of the sediment sources on each tributary, sediment sources in the uninventoried reaches likely exist. To account for the sediment loading attributed to the uninventoried reaches, inventoried reach results were extrapolated to the portions of each tributary that were not field inventoried. A correction factor was applied to the total sediment loading per mile calculated for the inventoried reaches before applied the inventoried load rate to the uninventoried reaches (Figure J-3). The correction factor was deemed necessary because it is believed that a different proportion of human caused versus natural loads was inventoried. For example, it is likely that approximately 70% of the human caused erosion sites were inventoried due to a focus in areas with historical timber harvest; therefore a correction factor of 30% was applied to the inventoried load rate before applying that load rate to the uninventoried stream lengths. Similarly, it is believed that approximately 50% of the natural sources were captured in the inventoried reaches. Therefore a 0.5 correction factor was applied to the inventoried load rate before applying that load rate to the uninventoried stream lengths for these natural loads.

Total Sediment Load from In-stream Sediment Sources (tons/yr) =

Inventoried Sediment Load (tons/yr) + (**CF** * (Inventoried Sediment Loading (tons/mile/yr) * Uninventoried Channel Length (mile))

Figure J-3: The Total Sediment Load Equation that was Used to Estimate Total Sediment Load from In-Stream Sediment Sources in the Grave Creek Tributaries. CF is a Correction Factor of 0.3 for Human Caused Sources and 0.5 for Natural Sources.

J-2 Results

J.2.1 Grave Creek Watershed

J.2.1.1 Comparison of Human and Natural In-stream Sediment Loading by Stream

The total calculated (inventoried segments) and extrapolated (uninventoried segments) sediment loading was combined to get a total load for human caused sediment sources. A comparison of human-caused versus natural sediment loading from mass wasting sites is presented in Table J-3. A total of 2,253 tons of sediment from mass wasting sites is contributed to lower Grave Creek. Human caused sources account for 1,547 tons of sediment from mass wasting sites. An additional 706 tons is associated with natural sediment sources.

Combining the Table J-3 sediment loading from mass wasting sites with the total sediment load in lower Grave Creek results in approximately 11,686 tons/year of sediment delivered to the Grave Creek drainage network from in-stream sediment sources (Table J-4, Figure J-4). These results strongly suggest that human influences are increasing sediment inputs to the channel network. Approximately 10,940 tons of the total annual sediment loading from in-stream sources in the Grave Creek watershed is attributed to human activities. For the inventoried segments, this load is broken down further by cause in the following section. Sediment loading in Lewis Creek is predominantly linked to natural sources, mainly avalanche chutes.

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 15 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 Table J-3, and would result in an additional 44.8 tons to the total watershed values of 2253 total tons with 1547 tons attributed to human-related mass wasting sites and 752 tons from natural mass wasting sites.

Mass Wasting Sites

Table J-3: 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

Table J-3: 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)	(%)
Total	2.8	100	69.3	100	4.2	100	116.8	100	7.0	100	186.1	100	193.1	100
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	

Mass Wasting Sites and Bank Erosion Sites

Table J-4: Total In-stream Sediment Load Calculated for Inventoried In-Stream Segments and Extrapolated to Uninventoried Segments.

Reach	Human-Induced Sediment Loading (tons/yr)			Natural Sediment Loading (tons/yr)	Total (tons/yr)
	Bank Erosion	Mass Wasting	Total Human		
Lower Grave	9393		9393	40	9433
Middle-Upper Grave		331	331	107	438
Foundation		42	42		42
Lewis		54	54	555	609
Blue Sky		150	150	44	193
Williams		404	404		404
Clarence		223	223		223
Stahl		242	242		242
SF Stahl		104	104		104
Total	9393	1547	10940	746	11686

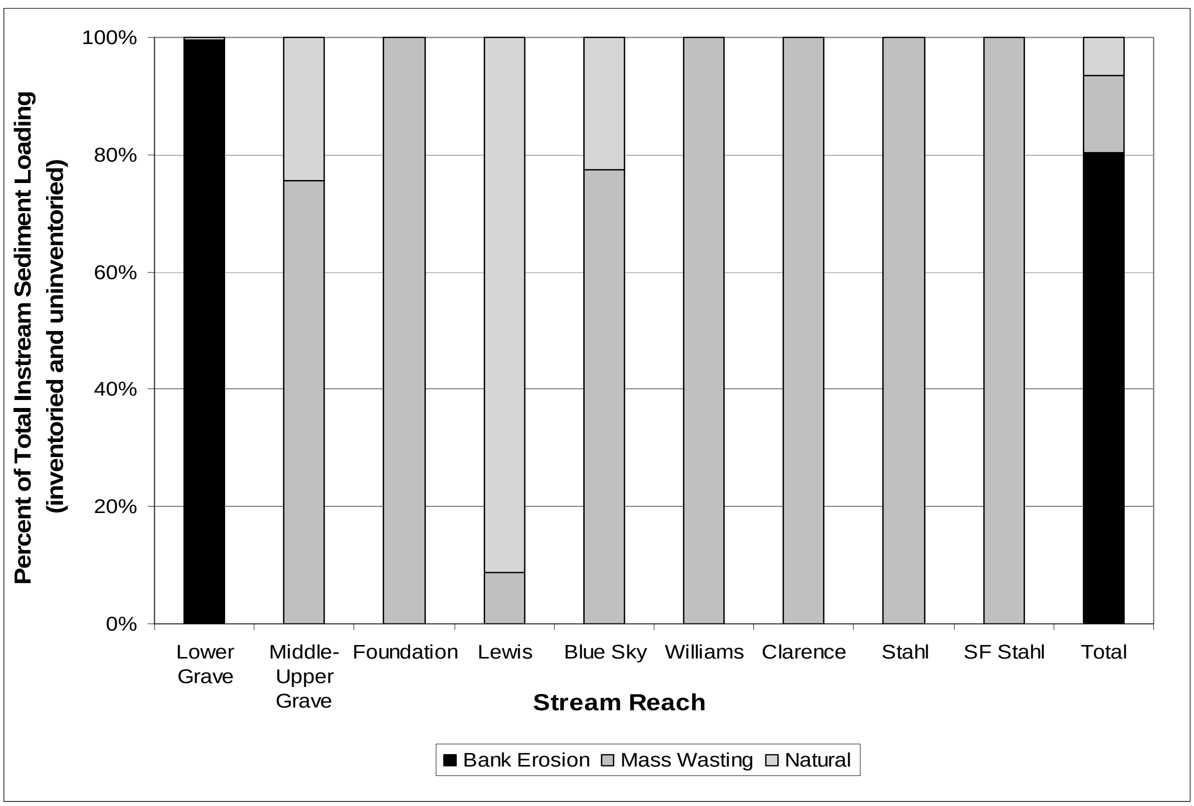


Figure J-4: Histogram of Total In-Stream Sediment Load (Mass Wasting and Bank Erosion) for Inventoried Segments and Extrapolated to Uninventoried Segments (Does Not Include Small Extrapolated Natural Background Loads of about 3 to 5% for Stahl, S. Fk. Stahl, Clarence and Foundation, and about 5 to 10% for Williams).

J.2.1.2 Distribution of In-stream Sediment Sources and Loading by Cause and by Stream

The inventoried in-stream sediment sources were stratified by primary cause. Causes include road encroachment, riparian modifications, channel alteration, bank armoring and bridges. Most sites were affected by multiple causes, for this portion of the sediment loading analysis, only the primary cause is considered.

Table J-5 presents a tally and percent distribution of the inventoried in-stream sediment sources. Of the 126 sources identified, most sources were related to human-caused sediment sources. Natural sources of in-stream sediment contribution accounted for 13 of the 126 sites primarily in Lewis Creek and in upper main stem and Foundation Creek. The total load for each cause was also calculated for the inventoried in-stream sediment sources and is described below.

Table J-5: Count of In-Stream Sediment Source Sites by Sub-Watershed and Cause. Percent of Total Eroding Area Within Sub-Watershed is also given by Cause.								
Stream		Riparian Modifications	Natural	Roads	Channel Alterations	Bank Armoring	Bridges	Total
Lewis								
	#	2	6		1			9
	% area	*60.1*	*39.4*		*0.5*			
Blue Sky								
	#	5	1					6
	% area	*98*	*2*					
Clarence								
	#	7		3				10
	% area	*80.7*		*19.3*				
Stahl								
	#	9		2		1	1	13
	% area	*55*		*37.9*		*< 0.1*	*6.6*	
South Fork Stahl								
	#	11		2				13
	% area	*91*		*9.1*				
Williams								
	#	11		9				20
	% area	*37*		*63*				
Main Stem Grave/Foundation								
	#	39	7	6	3			55
	% area	*73*	*13.5*	*10.8*	*2.7*			
Total								
	#	84	13	22	4	1	2	126

Riparian Modification

Over 92% (9,753 tons) of the total inventoried load (10,549) from in-stream sources was attributed to riparian modification (Table J-6, Figure J-5). Most of this load (9,139 tons) from riparian modifications is contributed from bank erosion in lower Grave Creek. Riparian modification in middle and upper Grave Creek is attributed to the next largest load from inventoried in-stream sources, 184 tons, followed by Clarence Creek with 124 tons. The remaining load from inventoried in-stream sites due to riparian modification ranges from 33 tons in Lewis Creek to 98 tons in Williams Creek.

Table J-6: In-stream Sediment Source Loading* of Inventoried Segments By Stream and By Cause.

Reach	Sediment Source Cause					Total Sediment Loading (tons/yr)		
	Riparian Modification	Natural	Road Encroachment	Channel Alteration	Bank Armoring	Total	Human	Natural
Lower Grave	9139.0	40.0	105.5	148.0	0.0	9432.5	9392.5	40.0
Middle Upper Grave	183.6	66.4	61.1	6.6	0.0	317.7	251.2	66.4
Lewis	33.0	225.3		1.7		259.9	34.7	225.3
Blue Sky	56.9	12.4				69.3	56.9	12.4
Williams	97.8		92			189.8	189.8	0.0
Clarence	124.2		19			143.2	143.2	0.0
Stahl	61.5		33		6.6	101.1	101.1	0.0
SF Stahl	57.3		14			71.4	71.4	0.0
Total	9753.3	344.0	324.6	156.3	6.6	10584.8	10240.7	344.0

***** Only includes toe slope erosion contributions from mass wasting sites; the smaller hillslope surface erosion component is not incorporated into the values within this table

Natural Sources

In-stream sediment from natural sources in the inventoried segments is 344 tons per year Table J-6). This does not include the modeled natural background surface erosion load (Table 6-1) or other sources of natural sediment loading such as those in uninventoried reaches (sediment loading was not extrapolated by cause) and natural background bank erosion. The modeled load from natural sources in inventoried segments represents a little over 3% of the total load from inventoried sources. Most of this load is associated with mass waste loading from avalanche locations in Lewis Creek (225 tons). When computed for the watershed above GLID, the natural sources percentage is of greater significance at about 45% of the load from inventoried sources.

Road Encroachment

Road encroachment on the stream channel, whether by a bridge or other crossing or road fillslope causing erosion or mass wasting contributes 325 tons of sediment per year. This road related load is in addition to sediment from road surface erosion presented in Appendix I. Sediment from road encroachment accounts for another 3% of the total in-stream sediment load from inventoried stream segments, with a higher percentage of contribution in upper areas of the watershed.

Channel Alteration

Channel alteration is attributed to sediment loading of 156 tons per year from in-stream sources of inventoried stream segments. This represents 1.5% of the total inventoried in-stream source load, although there may be much greater impacts due to linkages between historic channel alterations and greater susceptibility to erosion in areas of riparian modifications.

Bank Armoring

Erosion at one in-stream sediment source was associated with bank armoring. A riprapped bank at the Stahl Creek campground was identified as the cause for erosion of the downstream right bank. Over 6.6 tons of sediment per year is the estimated contribution to the channel network at that site. Ten feet of bank retreat was observed over 80 feet in length of the 5 foot-high bank. This one site is responsible for 0.1% of the total load from inventoried segments.

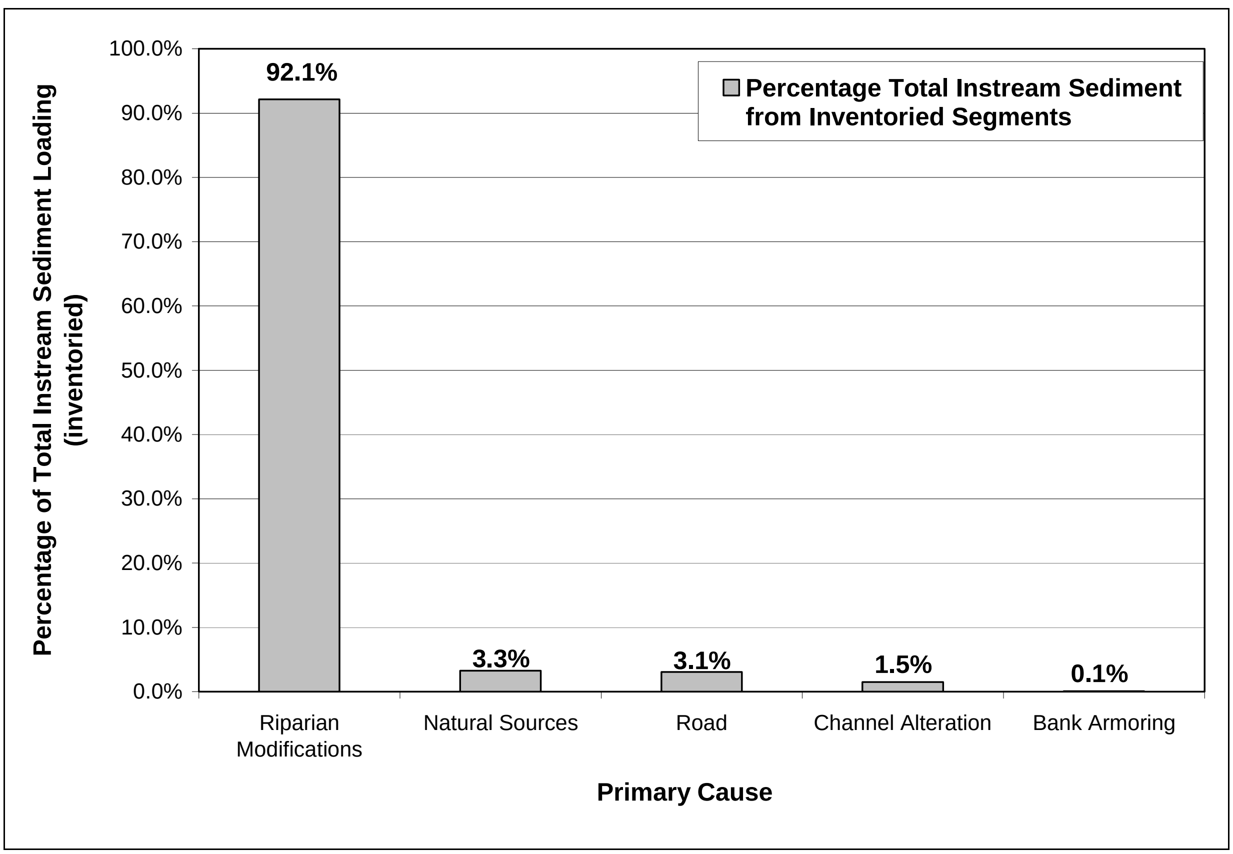


Figure J-5: Percentage of Sediment Loading Related to In-Stream Sediment Sources (Bank Erosion and Mass Wasting) by Sediment Source Cause for Inventoried Segments in the Grave Creek Drainage.

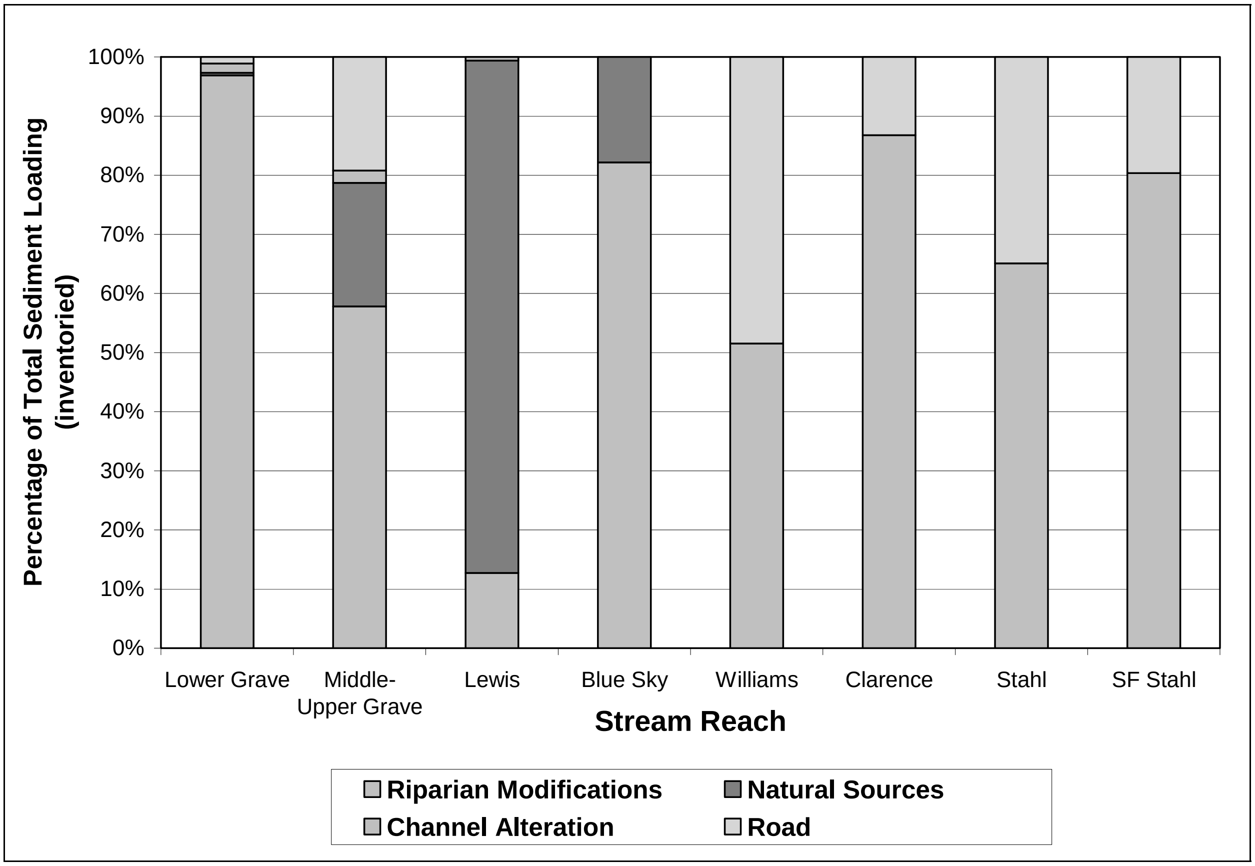


Figure J-6: Percentage of Total Sediment Loading Related to In-Stream Sediment Sources (Bank Erosion and Mass Wasting) by Stream/Reach and Cause of Sediment Source (Inventoried Segments Only).

J.2.1.3 Conditions by Inventoried Segment Length

Channel segment sediment contributions associated with human disturbance vary by tributary and the reaches of main stem Grave Creek. Tables J-7 and J-8 illustrate the relative impacts for the several types of human activities. Human activities associated with in-stream sediment sources include riparian modifications, roads, channel alterations, bank armoring, and bridges. Some of these activities, such as grazing, are likely more controllable via BMPs than other, potentially more permanent impacts such as some types of historical channel alterations. Another important factor than can influence erosion processes in rivers is the influence of sediment from upstream sources. Sediment deposited from upstream sources or delivered from upslope eroding areas, increase bank pressure along downstream reaches, which in turn, contributes to further bank erosion. Some of these upstream and upslope sources are due to controllable human activities, although it is difficult to quantify the impact that these upstream human sources have on downstream bank erosion. Allocations in Section 7.0 and recommended mitigation measures described in Section 8.0 of this document address reducing upstream sediment sources as well as reducing eroding banks in the Grave Creek drainage.

Table J-7: Bank Lengths Affected By Human-related Activities for Inventoried Portions of Main Stem Grave Creek and the Tributary Channels. Percentage Refers to the Relative Percentage of Each Type of Human Disturbance Relative to the Total Inventoried Human-induced Eroding Bank Length.

Reach	Riparian Modifications		Channel Alterations		Road Encroachment		Bank Armoring		Bridges		Total	
	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)	(ft)	(%)
Upper-Middle Grave	2,225	13	80	9	740	27					3,045	15
Lower Grave	9,500	56	800	89	200	7					10,500	51
Lewis	400	2	20	2							420	2
Blue Sky	690	4									690	3
Williams	1,185	7			1,115	40					2,300	11
Clarence	1,505	9			230	8					1,735	8
Stahl	745	4			300	11	80	100	100	100	1,225	6
SF Stahl	695	4			170	6					865	4
Median	965	6	80	9	265	10	80	100	100	100	1,480	
Total	16,945		900		2,755		80		100		20,780	

Table J-8: Total Eroding Bank Lengths of the Inventoried Portions of Main Stem Grave Creek and the Tributary Channels. Percentage Refers to the Relative Percentage of Each Type of Human Disturbance Relative to the Total Inventoried Human-Induced Eroding Bank Length.

Human Disturbance	Length of Human-Influenced Bank Erosion (ft)	Percentage of Total Human-Influenced Eroding Bank Length (%)
Riparian Modification	16,945	81.5
Channel Alterations	900	4.3
Road Encroachment	2,755	13.3
Bank Armoring	80	0.4
Bridges	100	0.5
Total	20,530	100.0

J.3.1 In-stream Sediment Sources and Vegetation

Vegetation data were collected during the in-stream sediment source inventory. Parameters included the cover type (overstory, understory or ground cover) and density or percent cover class for each cover type at each site. Riparian vegetation data collection methods are describe in more detail in Appendix F.

Figures J-7 and J-8 display the results of the vegetation survey. Results clearly demonstrate a positive correlation between lack of a healthy riparian area and bank erosion. Most of the area of eroding bank is associated with a total lack of overstory cover, with sparse understory and with very heavy ground cover (Figure J-7). This strongly suggest that overstory cover such as larger trees and associated root networks provide a significantly higher level of streambank protection than areas with more understory vegetation and ground cover in the Grave Creek Watershed. Where overstory is removed and ground cover and sparse understory vegetation remains, banks are unstable and susceptible to erosion. As the percent cover class of overstory vegetation increases, the area of eroding bank decreases.

The relationship between cover type and density of vegetation cover is similar. The greatest lengths of eroding bank are associated with absent overstory, sparse understory and very heavy ground cover. Heavy ground cover, usually grasses and forbs do not have the rooting density or depth to stabilize banks. Where overstory and understory is very heavy, there is very small length of eroding bank. Cottonwoods, conifers, alder, willow and dogwood provide greater bank stability with deeper and denser root systems. These are significant findings given historical removals of larger trees in the watershed and ongoing riparian impacts that limit larger trees in places.

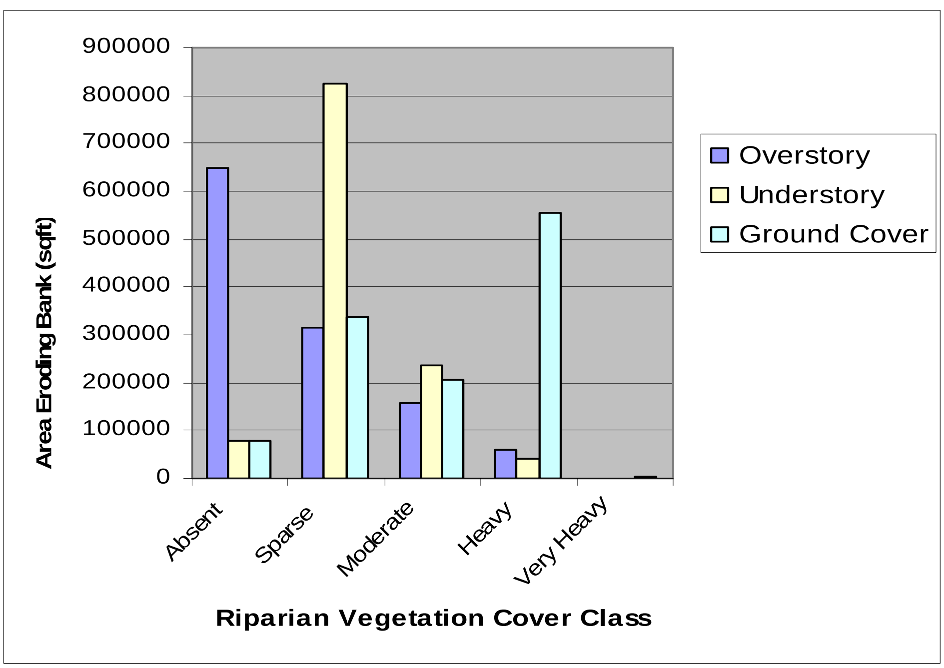


Figure J-7: Area of Eroding Banks by Vegetation Cover Class.

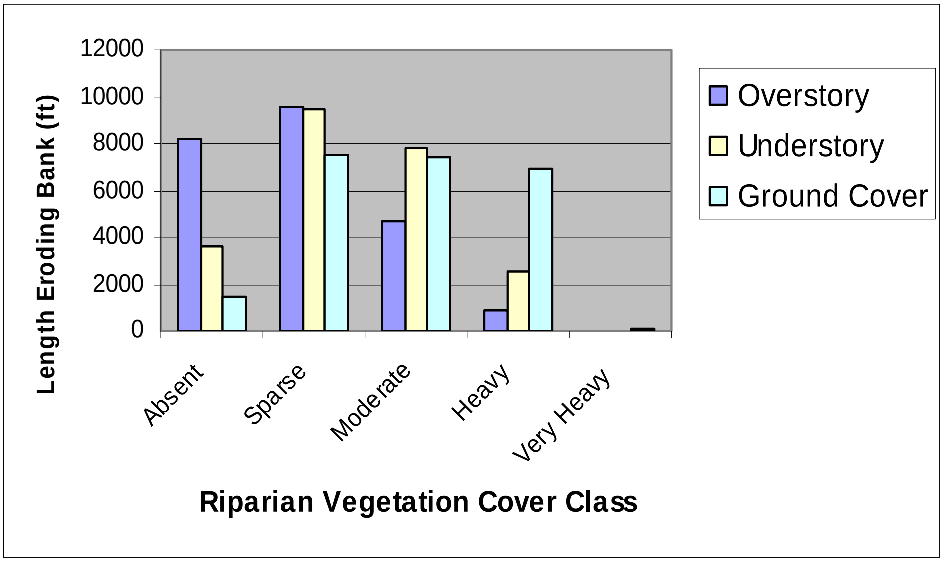


Figure J-8: Length of Eroding Bank by Percent Vegetation Cover Class.

APPENDIX K
RESPONSE TO COMMENTS

As described in Section 10.0, the formal public comment period for the Grave Creek Water Quality Restoration Plan and Sediment TMDL extended from November 24 to December 20, 2005. Nine different individuals, agencies, organizations, or other entities submitted formal written comments. The comments have been organized by primary topic headings, although comments often span several topics and sections. MDEQ responses follow each of the comments. It is noted when essentially the same or similar comment was received by more than one entity. Under these circumstances, one or more comments covering the range of all similar comments were used for example purposes or the comments were paraphrased. Italics are used where language was added to clarify a comment that may have been taken out of context as part of the effort to organize the comments by subject matter or document section. There were a few requests to extend the comment period. The MDEQ was not able to extend this comment period due to scheduling and resource commitments.

The most significant modification to the document involves impairment updates and determinations, as noted in the comment responses in Section K.5 of this appendix. This includes an improved discussion on the application of targets and supplemental indicators for making an updated sediment impairment determination on Grave Creek consistent with the impairment status in the most recent 2004 303(d) list. Also, the MDEQ has decided to no longer identify any of the Grave Creek tributaries (Foundation, Lewis, Blue Sky, Clarence and Williams) as being impaired. This is also consistent with the most recent 2004 303(d) list since the MDEQ has not made any previous impairment determinations for these tributaries. Nevertheless, the sediment TMDL for Grave Creek includes sediment load allocations for sources throughout the watershed. These sediment load allocations provide a level of protection from excess sediment loading to the tributaries by specifically addressing both fine and coarse sediment loading sources at the watershed scale.

K.1 General Process Related Comments and Responses

Comment 1-1: There were several comments suggesting that the document could not withstand critical scientific or legal review, and that the document did not adequately follow the Federal Clean Water Act. There were also several comments implying or stating that the authors were biased against timber management on National Forest System lands.

> **Response to Comment 1-1:** The document defines a process for compliance with Federal Clean Water Act and Montana State Law requirements for TMDL development and water quality protection. The process includes development of target conditions for the water quality status update as defined in Section 3.0 and applied in Section 5.0, with modifications identified in this response to comments section. This process is consistent with the EPA-approved approach defined within the State’s 303(d) list and associated documentation.

As far as the accusations of bias against timber management on National Forest lands, the Montana Department of Environmental Quality takes responsibility for all that is written within this and other water quality plans and TMDLs developed by the State. State law allows logging and forest management activities where such activities can be accomplished in a way that is consistent with what is necessary to meet water quality standards. Historic logging activities as recent as 15 years ago often were not protective of water quality. It is our conclusion that current logging/timber management, with the application of best management practices and other water protection measures, can be protective of water quality in the Grave Creek Watershed. One important component of the TMDL that land managers need to focus on is the allocations. Note that harvest activities within the Grave Creek Watershed can continue in a manner consistent with the Section 7.0 allocations, even where streams are identified as impaired.

Comment 1-2: A group could pick up the *(impairment)* designation to fight logging, recreation, roads, hunting, snowmobiling, or whatever they chose based upon your designation that Grave Creek is impaired. That designation would be with the creek for at least five years and that assumes that in five years the state has the money for a new study.

Response to Comment 1-2: Grave Creek, as well as several hundred other streams within the State of Montana, has been identified as impaired for several years. Yet logging and other activities continue in many of the watersheds with impaired waters. Montana law is written in a manner that allows the use of National Forests or other lands for multiple uses such as those listed in the comment, as long as the activities are pursued in a manner consistent with BMPs and/or reasonable land, soil and water conservation practices. The load allocations and the restoration objectives developed within this plan (Section 7.0) identify any limitations or corrective measures that, if implemented, would protect and improve the water quality in Grave Creek Watershed as necessary to address the sediment and habitat impairments. Significant effort went into developing a set of allocations that would provide protection while avoiding any unnecessary restrictions or hardships, and we feel that we have been successful in this effort. The real test for any lawsuit aimed at preventing an activity from occurring in an impaired watershed should be whether or not the activity is consistent with the allocations portion of the TMDL once one has been developed, or is consistent with all reasonable land, soil and water conservation practices prior to TMDL development.

Comment 1-3:
- We ask that you review the Flathead River Headwaters Water Quality Assessment and TMDL document (Flathead Headwaters). We would like consistency on all the TMDLs on the Forest. We believe the Headwaters document provides a valuable template and process.
- The addition of “number of pools” as a seemingly primary target seems like kind of a manipulation to keep upper and middle on the impaired list. We are led to believe

that number of pools does not have to be a target. Coal Creek, which is within the Headwaters TMDL Plan for the Flathead, and just "over the hill" from Grave Creek, did not include number of pools as a requisite target. Coal Creek is particularly similar to Grave Creek in many ways, including historical management circumstances, yet does not appear to have been used as a reference stream.

- Knowing the history of Grave Creek management efforts since the 1960's, I find it very hard to believe this stream is in an impaired state. If this stream is impaired, then there are very few streams in the state that are not impaired. It appears to me that different standards were used here than those used elsewhere in the state. Are the standards used here the same as the standards on the Flathead National Forest? If they were not the same, why weren't they the same?
- *Page 35, first through third paragraph* – "…provides updated impairment determinations for streams in the Grave Creek Planning Area and justifies new impairment determinations for tributary streams." Then goes on to explain the process. Note the Headwater TMDL method on page 53 of that Flathead River Headwaters TMDL document which states, "Habitat alterations, flow alteration, and bank erosion are considered *pollution,* while siltation and suspended solids are considered *pollutants*. It is EPA's position that TMDLs are required only for pollutants that are causing or contributing to water body impairments. Therefore, because TMDLs are required for only pollutants and flow alteration, habitat alteration, and bank erosion are not pollutants, the focus of this document is on the sediment related pollutants and nutrients. Flow alteration, habitat alteration, and bank erosion might certainly constitute potential sources or causes of sediment related impairments, and while no TMDLs are established to specifically address these issues, they will be addressed as sources, as appropriate."

Response to Comment 1-3: We have not only reviewed the Flathead Headwaters Assessment and TMDLs for the Flathead Headwaters Planning Area but also worked with the EPA in the development of the TMDL process reflected within both the Flathead and Grave Creek documents. The approach used in each document utilized a suite of parameters to measure/validate impairment via targets and supplemental indicators. When addressing the fine sediment impairment question, both documents are consistent within the context of varying types and amount of data as well as varying land uses and sediment sources. The Grave Creek assessment approach included additional evaluation of habitat alteration conditions to address the channelization impacts in lower Grave Creek and to address other potential habitat limitations based on the available literature for the Grave Creek Watershed. As noted in Section E.1.1, the "other habitat alterations" cause can sometimes be linked to other pollutant loading impacts such as those from excess coarse or total (coarse plus fine) sediment loading. Based on the assessment data for Grave Creek, a linkage between pool habitat and excess total sediment loading conditions, particularly below the GLID was identified, thus justifying development of a total sediment TMDL.

In summary, the approach used in both documents is consistent with EPA sediment TMDL guidance (EPA, 1999), and a review of all Montana TMDL documents approved by EPA to date would show that other documents have used approaches similar to the Grave Creek TMDL as well as the Flathead Headwaters TMDL. Both documents addressed the "pollutants" identified on the 303(d) list. One document (Grave Creek) further evaluated habitat conditions linked to the 303(d) list and identified an additional link between the habitat impairment and excess total or coarse sediment load within the stream.

Review Section K.5 below for further comment response regarding impairment determinations.

Comment 1-4: *Page 1, third and fourth paragraphs and page 2, first paragraph* – "There are several tributaries with the upper portion of this watershed that also have sediment and habitat impairments addressed with this document." "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." "This deviation from desired conditions provides the basis for validating impairment conditions. Where impairment is validated, restoration objectives are developed to define conditions that, if implemented, would result in meeting reference parameter conditions and lead to full support of beneficial uses." Why? This does not appear to be the process or logic used in other TMDLs.

Response to Comment 1-4: This is a water quality restoration plan that includes restoration objectives in the form of all necessary TMDLs and load allocations where a pollutant is linked to impairment, consistent with other TMDL documents. Where the impairment is linked to pollution, restoration objectives are defined in a way that does not incorporate TMDLs and load allocations. This is further defined in the document in Section 7.0 and is consistent with how the MDEQ has pursued their approach to water quality restoration planning in many watersheds that address both pollution and pollutants. These other plans include the *Water Quality Protection Plan and TMDLs for the Swan Lake Watershed* (MDEQ, 2004d) and the *Blackfoot Headwaters Planning Area Water Quality and Habitat Restoration Plan and TMDL For Sediment* (MDEQ, 2004b). By taking such an approach, the MDEQ is able to develop plans that come closer to addressing all known fishery or other beneficial use limitations consistent with satisfying goals within the Federal Clean Water Act and Montana State Law, versus just addressing goals and problems linked to a pollutant on the 303(d) list. This approach can provide improved flexibility and opportunity for restoration planning, including improved opportunities for future funding.

Comment 1-5: *Page 23, Table 3-1* – Data does not indicate excess fine sediment. There is no data referenced in the document regarding excess bed material.

Response to Comment 1-5: Table 3-1 was meant to present the 303(d) list impairments and potential TMDL requirements as they existed at the start of the water quality planning and TMDL development effort pursued in this document. Presenting the most recent 303(d) listing information, as well as any relevant historical listing information, is a critical component of MDEQ water quality restoration plans. Table 3-1 in the draft is now Table 3-2, and the table and text have been modified, along with Table E-2 and language in Appendix E, to clarify the fact that the listing conditions presented in Section 3.0 could end up being modified via the water quality impairment status update (Section 5.4).

Refer to further comments and responses in Sections K.3 through K.5 regarding excess fine sediment and excess bed material indicators identified within this document.

Comment 1-6: *Page 26, fourth paragraph* – " The recovery represents the greatest potential and the reference condition." What does this mean?

Response to Comment 1-6: This means that the reference condition can be used to represent the recovery condition from existing and/or past impacts, as further developed and applied in the document, within the context of adaptive management. This is defined in detail in Section E.2.3.1 in both the public review and this final document.

Comment 1-7: (there were a overlapping comments on data collection, including concern about developing a plan during long term drought conditions; below is the most comprehensive):

A concern with the upper section is when was the data collection. Was the collection after the culverts were removed from Williams creek and other drainages or was it collected after the many snow slides that occurred two years ago. Was it collected during the rainy season or during spring runoffs? Was it collected soon after the fire on Blue Sky Creek? No one could answer when the data was collected and I think that is crucial.

Response to Comment 1-7: Most data was collected after 2001 using standard methods during post runoff conditions as defined in Appendix F. This was several years after the Blue Sky Creek fire. Note that the pool frequency values in Blue Sky Creek are comparable to other streams (Table 5-7) and the mass wasting loading from natural events that could be linked to fire-produced landslides should be captured in Table 6-2. The fact that some data may have been collected after culvert removals is reflected by the road erosion allocation in Section 7.1.3.2. MDEQ observed the snow slide before the snow all melted and noted that there was little to no sediment from this event, and the photo of this slide area does not reveal an exposed hillside (Photo 18). It is, however, noted (Section 5.4) that the large woody debris (LWD) values for Upper Grave would now be higher because of the LWD recruitment from this snow slide.

The drought conditions in the area would not be expected to impact the monitoring results for the pool and geomorphic parameters used for targets in Grave Creek, and would not be expected to impact the targets and supplemental indicators for other parameters such as LWD. Nevertheless, the application of adaptive management incorporates these types of concerns. Flow conditions and other natural events have the potential to impact percent fines values in a watershed, which is also incorporated into the discussion on adaptive management. Given the general lack of issues linked to percent fines, impacts from natural events as implied in the comment are not considered a significant factor in making updated impairment determinations and for making determinations on allocation requirements.

Comment 1-8: I know there was a blurb in the local newspaper about your meeting at Jerry's because I put it there. Other than that, though, did you publicize that meeting locally?

Response to Comment 1-8: The MDEQ submitted a press release to a local radio station and several local and state newspapers when the document was released approximately one week prior to the public meeting. Also, local landowners were contacted by the KRN to facilitate public comment and meeting attendance.

K.2 Comments and Responses Primarily Linked to the Watershed Characterization (Section 2.0) and Related Appendices (A, B, C and D)

Comment 2-1: *Page 4, Figure 2-1* – Doesn't MT Fish, Wildlife, and Parks have some of this data?

Response to Comment 2-1: Yes, MFWP has some additional discharge data from discrete sampling events over the past few years. This has been noted in the document.

Comment 2-2: Rain-on-snow events are not common in the Grave Creek watershed, as is hinted at on page 10, paragraph 4. See the Kootenai National Forest Hydrologic Guide.

Response to Comment 2-2: The rain-on-snow language has been modified on Page 10 to avoid making a judgment on occurrence. Relative to other KNF rain-on-snow dominated systems (such as Bobtail Creek and Pipe Creek), Grave Creek experiences rain-on-snow events on a less frequent basis. Nevertheless, rain on snow events do occur periodically in the Grave Creek watershed and can be of significant magnitude. A review of the Stahl Peak SNOTEL site suggests the possibility of a number of such occurrences over the past few decades. In fact, temperatures were above freezing just recently during the January 19 to January 20, 2005 period when precipitation increased by 1.7 inches and the snow water equivalent was reduced by about 0.6 inches at Stahl Peak, suggesting a 2.3 inch total precipitation amount contributing to runoff volume from rain on snow. This was consistent with higher flows noted in Grave Creek during this time.

Comment 2-3: *Page 16, second paragraph* – "…most damaging of these influences was the periodic bulldozing of the channel that occurred following large flood events in a misguided attempt to stabilize or clean the channel of sediment and debris." Misguided is a value judgment and should not be used in this document. Historic practices occurred with the best knowledge of the time. To judge that based on what we have learned since is not appropriate. As we have stated previously, this did not happen on Forest System lands. Disclose where this practice occurred.

> **Response to Comment 2-3:** The terminology has been changed and it has been noted that these activities have only been documented on private lands below the National Forest boundary.

Comment 2-4: *Page 16, last paragraph* – "The management of the spruce beetle epidemic dramatically changed the character of the entire Grave Creek basin." Define dramatic change. Later in the same section it is estimated that 13% of the watershed has been harvested at least once. Is 13% harvest dramatic?

> **Response to Comment 2-4:** We agree that the term "dramatic" is not necessary and have removed it, but note that a 13% harvest could have numerous negative impacts on a stream, including sediment loading and mass wasting where BMPs are not implemented and riparian areas are not protected. We have added additional language in Section 2.11 to refer to additional evidence of such impacts from aerial photos.

Comment 2-5 (refer to Pages 16-17): The same section also lists harvested acres by the decades harvested and then again by the harvest methods. By doing so the document is confusing and could lead to an interpretation that the number of acres harvested was twice what it actually was.

> **Response to Comment 2-5:** We agree and have clarified this language to help avoid any confusion.

Comment 2-6 (Pages 16-17):

- It makes no sense to lump intermediate harvest acres with regeneration harvest acres. The effects of each are quite different. Regeneration harvesting leads to very little retained vegetation immediately after harvest since most trees are removed. Intermediate harvest selects only individual trees to remove and in many cases leaves fully stocked stands in place immediately after harvest.
- *Page 17, first paragraph* – "Of this, a little over 5 miles squared (7%) was harvested in stands that are in or adjacent to the riparian corridor." Studies have shown that fine sediment movement from timber harvest and roads travels a maximum of 300'. Only acres harvested within 300' of a stream should be included in this figure. This would accurately reflect the area in which harvest could affect sediment and large woody debris in the stream. The fact that harvest occurred in stands in or adjacent to a riparian corridor does not necessarily mean it had any measurable effect on the stream. This is because stands can be quite large and only a percentage of them would be within 300' of the stream. Page A-1, last paragraph states that the stands shown in these figures may not have had any harvest with the 300' riparian buffer. It

also states that the acres figure we have requested above cannot be obtained. That is not true. With GIS, aerial photos, and TSMRS data this figure could be calculated quite easily.

- Using miles squared as a unit of measure for harvested acres and acres that are impacted by roads does not make sense. All timber harvest reporting is by acres and the total acres in the watershed are known. Therefore acres should be the unit of measure used. It is more accurate and will also give a more accurate value for percentages.
- How much harvest actually occurred (show in acres and percentage of watershed)? What percentage of that harvest was within 300' of a stream?

Response to Comment 2-6: In many situations, the data is presented in a variety of manners based on how the data was made available or how it could be best incorporated within the document. The eventual use of most this data is as a supplemental indicator of potential impacts from past activities. Greater detail and accuracy as requested is not necessary given the ultimate use of the information as a linkage to historical and existing loading conditions, although Appendix A does discuss some of the points brought up in the above comments. There are two questions being addressed as part of the source identification and assessment effort within this document: 1) were there historic activities that would be expected to increase sediment loading to the system (answer is "yes"), and 2) are there still existing sources that could be increasing loading to the system (answer is "yes"). The actual quantification of loading as used for TMDL development purposes is based more on the Section 6.0 mass wasting loading estimates (historical and current) and existing roads loading analysis. More detailed loading analysis was not necessary and was outside the scope of this document.

Intermediate harvest can include roads, skid trails, or riparian activities that can have an impact, especially under historical management conditions lacking BMPs, and therefore is included in the discussion although it is noted that the two are different in potential impacts linked to total land clearing. We agree that under current BMP applications sediment movement to a stream beyond 300 feet is unlikely, but in this document historical information within and beyond the 300-foot length is used to provide information about historical loading conditions during a time prior to BMP implementation, since sediment loads can remain in a stream for extended periods. Note that the Forest Service's WEPP and X-Drain models show that sediment yields can more than double when roads greater than 300 feet in distance without BMPs contribute increased sediment loading to a channel. Historical harvest activities in excess of 300 feet from the channel where little or no riparian buffers were in place or road lengths were greater than 300 feet without drain dips or other BMPs have the potential to contribute sediment based on the WEPP model and field observations. Increased runoff and water routing from harvest, roads, and skid trails (USFS, 2000), some of which may have been more than 300 feet from the stream, could also have contributed to the initiation of the mass wasting events observed in the watershed (refer to Photos 2 and 8 for examples of large clearcuts adjacent to riparian areas).

Comment 2-7: Page 17, second paragraph – This section fails to disclose how many of the roads are actually in Lower Grave and on private land. This paragraph also fails to disclose how many of the Forest system roads in the middle and upper watershed are currently closed, how many have had BMPs implemented, and how many of the skid trails and jammer roads are now fully revegetated because the harvest occurred 25-50 years ago.

> **Response to Comment 2-7:** The revegetation condition is noted and the reader is referred to Appendix I where many of these questions were addressed using an analysis of road impacts provided by the Kootenai National Forest.

Comment 2-8:

- *Page 17, third paragraph* –There is no data to support the statement "Jammer or skid road construction on steep, sensitive soils within the rain-on-snow zone coupled with extensive removal of large diameter trees generally increased water yield, peak flows, and sediment production in the watershed." Please define "extensive removal of large diameter trees." Where did jammer or skid road construction occur on steep, sensitive soils with-in the rain-on-snow zone? How many acres were so impacted?
- *Page 17, fourth paragraph* – "the timber salvage program was expedited so rapidly those timber sales were implemented without adequate erosion controls and streambank protection measures." This statement is speculative and appears biased. These sales were implemented with the standard operating practices of the time. BMPs were not developed in the 1950s or 1960s to the level they are today and therefore were not implemented.

> **Response to Comment 2-8:** The term "extensive" has been removed as suggested and the language has been modified to note the expected linkage between such activities and potential for sediment loading as would be predicted by any model given the lack of BMPs during the time of harvest. The fourth paragraph on Page 17 is unnecessary and has been deleted, although we do not consider the use of this language, obtained from an existing USFS document (USFS, 2000) as speculative and biased given the fact that erosion modeling would reveal increased sediment loading where BMPs were not applied and modeling shows increases in peak flows even today from the historical logging activities. Reference the comments and responses in Section K.3 regarding sediment contributions from historical activities and the request for a more detailed quantification of the activities.

Comment 2-9: Section 2.0 Watershed Characterization- This section describes a pre-European settlement condition with the eventual encroachment by homesteaders in the 1890's. Even though prime creek bottoms and meadows in the Grave Creek valley had been claimed by 1897 the valley today, as back in the late 1800's, is very sparsely populated. The Grave Creek valley has not succumbed to agriculture pressures, as the draft plan states. Disturbance to channel stability, fish habitat, and riparian conditions has been the direct result of natural disturbances such as flood and several rock and snow slides down avalanche chutes.

Response to Comment 2-9: Stream channelization to allow settlement and facilitate agricultural development along lower Grave Creek has modified the character of the stream channel. We feel that the description of impacts to lower Grave Creek from agricultural and other activities, as defined in Section 2.11, is accurate. We are encouraged by efforts within the agricultural community to protect water quality in the Grave Creek Watershed.

Comment 2-10: *Page 18, Figure 2-2* – "hi-grade logging" is an inflammatory, value-laden, and non-measurable term. Delete it. In our October 6th meeting we asked to be consulted to verify these figures. That has not occurred.

Response to Comment 2-10: The term "hi-grade logging" has been removed, although it is interesting to note that the term was obtained from within a publication from the agency providing this comment (USFS, 2002). Identifying the precise historical acreage details is not considered as important as identifying the overall occurrence of such activities as utilized within this document, which is sufficiently accomplished by Figure 2-2. A note is added to the document here and other places pointing out that future detailed analysis may result in further refinement of some of the land use values linked to timber harvest levels.

Comment 2-11:

- *Page 20, second paragraph* – "Although large wood debris was historically abundant…" What historical data supports this statement? See previous discussion about Page 17, first paragraph.
- This section also erroneously suggests that riparian harvesting has resulted in stands characterized by overstocked, small diameter spruce and Douglas fir. This section further states that "These simplified stands will typically lack the capacity to provide the level of bank stability historically associated with mature spruce and cedar habitat types." The author suggests logging activities from the 1950s and 1960s have reduced the volume of large diameter wood available for recruitment to the channel. Again, an on-site field examination will provide otherwise. The author's statement must again be stricken from the document.

Response to Comment 2-11: We agree that there has been significant LWD recruitment and bank stability recovery in this system since the activities that occurred in the 1950s and 1960s, but we also note that more recent riparian harvest has again reduced LWD recruitment (Photos 2 and 8). Riparian harvest can reduce the size and availability of trees for LWD recruitment and bank stabilization, and the removal of all or most of the mature trees completely from riparian area can take decades before trees of a similar size are again available for recruitment to the stream. Language in Section 2.12.3 has been modified to focus on the potential impacts from the riparian harvest activities in the 1950s, 1960s and more recent riparian harvest.

Comment 2-12: *Page 20, third paragraph* – "…have converted large reaches of the channel into braided…" Define large reaches. What percent of the streams are in this condition? What is the range of lengths of stream in this condition? What stream reaches is this occurring in? In fact, wasn't this part of the natural and historical condition of the stream?

Response to Comment 2-12: The existing condition was not part of the historical conditions of the stream as suggested by the comment. 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 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. This situation is discussed in Section E.2.3.2.1 of the document. The braided 'D' channel regimes are 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. These channel reaches that are closer to a 'D' versus 'C' channel are not considered the desired potential even with existing land use constraints. Much of the above language within this comment response has been added to Section 2.12.3 for further clarification.

Comment 2-13: *Page 20, fourth paragraph* – "Classified as a bull trout core area (Montana Bull Trout Scientific Group, 1996b)." There has been no bull trout habitat designated as critical in the State of MT.

Response to Comment 2-13 The document does not use or refer to the term "critical" within the discussion of bull trout core area in Section 2.13 or Appendix D as implied by the comment. The USFWS considers Grave Creek as a local population within the Lake Koocanusa core area. The Montana Bull Trout Scientific Group essentially identified local populations as core areas.

Comment 2-14: *Page 62*, *Macroinvertebrate Date Type I Target* – The text mentions only the Lower Grave Creek macro-samples that were collected post-restoration. It is our understanding that macro-samples were collected prior to restoration. What did these indicate, using the same metric that is now being proposed?

Response to Comment 2-14: We have obtained, reviewed, and further analyzed the macroinvertebrate data referred to in the comment. The analysis shows good macroinvertebrate results in four riffles and one pool prior to restoration and good results in three riffles and one pool after restoration work. One riffle sample did not obtain an adequate population for analysis, possibly due to difficult sampling conditions (personal communication with J. Dunnigan). These results have been added to the document in Appendix D and incorporated into the Section 5.4 water quality impairment status update.

Comment 2-15: *Page 24, second paragraph* – "…including significant timber harvest…" Define significant timber harvest. See previous discussion regarding Page 16, last paragraph. The words significant and significantly are regularly used without definitions throughout this document. They do not define, and in fact tend to exaggerate, the situation they describe. Therefore, they are inappropriate. Generally they are not supported by science or data. They also appear to be value-laden.

Response to Comment 2-15: The term "significant" has been removed in the referenced sentence and in most locations throughout the document. We have been careful in the use of this term, although we do not feel like we should be prohibited from using common and useful terms. Where this term remains within the document, apply the definition from Webster's Dictionary.

Comment 2-16: Section 4.0 Stream Condition and Data Summaries - This section discusses LWD, channel morphology, surface fines and percent surface fines in pool tail outs. Again, as mentioned above a field survey would demonstrate the presence of large woody debris in the riparian areas as a direct result of avalanches and mortality over time. Very little logging activities occur in the riparian areas due to adherence to the Montana Streamside Management Zone regulations, with strict implementation of BMPs.

Response to Comment 2-16: We agree that current management and forest practices in the watershed are protective of water quality and facilitate recovery to the stream's potential as discussed in the Executive Summary. The Montana Streamside Management Zone regulations and widespread applications of BMPs unfortunately did not occur until the 1990s, after timber harvest within riparian areas occurred in the Grave Creek Watershed, thus reducing LWD recruitment. Refer to comments and responses in Section K.3 for further discussion concerning historical impacts from riparian harvest.

Comment 2-17:
- With 13% harvest in the watershed we are well within the historic range of variability for PFI in the watershed.
- *Page 64, first paragraph* – peak flows aren't high at all. What is this discussion trying to say or to infer?

Response to Comment 2-17: The language in Section 6.5, Appendix C and elsewhere has been modified to note that values are not currently considered high at this time although during the 1950s and 1960s PFI would have been higher and would have had more potential impacts given a lack of BMPs during this period. We acknowledge that the historic PFIs may have been within a range that could occur naturally from fire or other disturbance, but again point out that the increased sensitivity of the stream corridor is not considered part of the natural variability.

K.3 Comments and Responses Primarily Linked to Sediment Loading Source Assessment (Section 6.0) and Related Appendices (Appendices I and J)

Comment 3-1: "Bedload" is probably not the word to use to describe the situation throughout the document, since it includes all sediment including fine sediment. Coarse sediment is a more accurate description.

Response to Comment 3-1: Actually, bedload is defined as the material that generally remains in contact with the streambed and is transported via siltation. Depending on the type of stream system, the bedload may or may not include some or all of the fine sediment as implied in the comment. The fine sediment can be part of the suspended load in a system like the Grave Creek Watershed. The excess loading from human activities includes both coarse and fine sediment. The potential lack of excess fine sediment problems in the upper watershed, coupled with the fact that most loading is more than 10 years old and the fact that fine sediment should transport through the system more efficiently suggest that coarse is a more accurate description of the sediment size of concern above the Glen Lake Irrigation Diversion (GLID). High rates of bank erosion in lower Grave Creek include both fine and coarse sediment, and geomorphic conditions may hinder transport of both the fine and coarse sediment sizes that can then remain as excess total load in lower Grave Creek. Therefore, it appears that coarse sediment is a more accurate description of the size class of concern in the watershed above GLID, whereas the concern in the lower watershed is linked to total sediment that includes both the fine and coarse material that can remain in the system as bed material and interfere with cold water fish habitat. We have made updates to the document to be consistent with the sediment terminology within this response.

Comment 3-2: *Page 91, first paragraph* – Road sediment is not necessarily a function of road density. It is a function of road condition and location. Quantify which roads do not meet BMPs. This is especially important since the Forest Service has done quite a bit of BMP work in the watershed.

Response to Comment 3-2: As suggested, the text had been modified to identify road sediment loading from erosion is also a function of road condition and location. The fact that many roads are now meeting BMPs is reflected in the modeling results from Appendix I, the use of road sediment loading information from 2002 for the allocation in Section 7.1.3.2, and in Section 8.2.1 of the Implementation Strategy. The Kootenai National Forest personnel responsible for the model consulted with experts on road conditions and improvement activities that had occurred in the basin, in particular the headwater tributaries that had not been recently surveyed. The additional BMP quantification requested is not necessary for this document, although it would be a desirable pursuit for landowners consistent with the suggestions in Section 8.2.2.3.

Comment 3-3: Section 6.0 Sediment Loading Source Assessment Summary - The lead statement that the "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 system segment", is misleading and not supported in fact. Currently, the lower reaches of Grave Creek contain heavy equipment that is causing consideration sedimentation disturbance downstream. Also, there has been some bank disturbance due to cattle grazing on private property; however, field observation demonstrates stable bank conditions all along the upper and lower reaches. Again, we have to question the absence of credible data in this section. What sediment loading that has occurred from natural disturbances is not proved to be detrimental to water quality in the Grave Creek Watershed and therefore, a TMDL for sediment is not required under the law.

Response to Comment 3-3: The loading values are linked to human causes in Section 6.0 (Section 6.1, 6.2 and Appendix J) based on a peer-reviewed approach for determining sediment loading. The accelerated bank erosion is linked to channel geomorphic changes caused by human manipulation in addition to near bank activities such as grazing, as defined in Appendix J. These represent preventable sources that may take many years, even with grazing BMPs, to fully recover. Active restoration, along with riparian and bank protection BMPs after restoration, may help with recovery in places. The heavy equipment used to pursue active restoration is consistent with all legal permits to help remedy the accelerated bank erosion concerns. Heavy equipment used for private non-sanctioned uses such as attempts to improve flow for flood protection typically cause more flooding problems in the future and are harmful to the stream and aquatic life. The loading impacts from these types of non-sanctioned activities would generally be captured the bank erosion assessment.

Other sources of sediment not modeled, both naturally occurring and human induced, are discussed in the introduction portion of Section 6.0 and in Section 6.2. We acknowledge the fact that many landowners are cooperatively working toward riparian protection and solutions to habitat limitations in lower Grave Creek. We further acknowledge that there are risks and short-term sediment disturbances involved with any active restoration effort, but the consensus among many water quality professionals supports this type of effort on a case-by-case basis.

The Section K.5 comment responses further address the concern about impairment determinations and the need for a sediment TMDL also brought up in this comment.

Comment 3-4: *Page 91, Section 6.2.5* – "Erosion from existing timber harvest locations is not believed to be a significant source of sediment loading except via mass wasting and roads as discussed above." Where and how much is the mass wasting from timber harvest contributed? Again all fine sediment targets are met in every segment, 36 of 41 segments (88%) meet the percent surface fines <6.35 mm in riffles target, and every segment met the percent fines <6.35 in pool tail outs (grid toss) target.

Response 3-4: We disagree with the implied suggestion that meeting fine sediment targets should imply that all sediment target conditions, including those linked to coarse sediment, are satisfied (refer to Response to Comment 5-1). Section 6.0 identifies existing loading estimates from mass wasting and provides and example of the very high loads from the initial mass wasting event (historical load to the system of 30,000 tons from Williams Creek drainage alone). Based on the Table 6-2 information, human caused mass wasting likely contributed as much as 115,000 tons of sediment from the initial mass wasting events to the Grave Creek Watershed. Much of this would have been fine sediment that appears to have either flushed through the system or at least made it down below GLID. Pool frequency limitations are linked in part to the coarser portion of this mass wasting load.

Comment 3-5: *Page 92* – "These past PFI increases would have contributed extra bedload to the system via channel scour." Isn't this the process that scours pools which is shown in this document to be lacking? If there is a concern that there is excess bedload material it could be easily detected in permanent bench marked cross sections. Why wasn't this proposed?

Response to Comment 3-5: Increased peak flows do not just potentially scour more pools; it can result in scour of the entire channel resulting in increased bedload/sediment load and an increase in pool filling. Research documents the effects of increased water yield/peak flows on channel scour and sediment load. Nevertheless, the words "would have contributed extra bedload" have been changed to "could have contributed extra bedload." Adding benchmarks to track system recovery is an option added to the monitoring section, although we disagree on the implication that cross section benchmarks alone would adequately identify and characterize impacts from excess bedload.

Comment 3-6: (there were several similar comments that suggested that there was no source of sediment loading, particularly the upper reaches, and that existence of mass wasting sites were not adequately identified based on the public meeting):

- The headwaters of the tributary drainages have not deviated from their form due to stable bed forming features. The primary and natural sources of sediment and debris to these reaches are colluvial draws and avalanche chutes. These sources have periodically provided large volumes of trees and other organic material to the system, oftentimes causing extensive debris jams to form, channel avulsions, and bank cutting. Due to glacial moraines on both sides of the channel in the lower reaches of the tributary, this portion of the watershed may be more susceptible to disturbance. However, to state that when disturbed through road construction or logging, these landforms may respond with accelerated soil creek and slope failure, and can become significant sources of sediment intentionally omits Best Management Practices (BMP's), lacks credible data to support, is biased and must be stricken from this document.
- *Page 102, Table 7-1* – Statement under Load Allocation for "Historic Sediment Loads Remaining in the System" makes no sense. What does this mean? Where are these areas?

- *Page 100, third paragraph* – "Based on historical harvest statistics, elevated sediment loading attributed to elevated historical PFI values may still be part of the excess sediment load in the system." There is no data to support this statement. Historical PFI values are not provided and neither are historic sediment loads. It is unknown if there is an elevated sediment load, but data suggests there is not. Since the only sediment identified as a potential issue is bedload and coarse material, it is highly unlikely it was result of past timber harvest. See previous discussions above about the same topic.

  Response to Comment 3-6: The data in Section 6.0 and the photos all identify sources of sediment, which include mass wasting sites and bank erosion. Natural sources are also identified in this section. This source assessment and results are consistent with a large number of watershed evaluations and existing TMDLs, both in Montana and other states. The documented sources include both fine and coarse sediment and have been substantiated within other assessments of the Grave Creek Watershed (USFS, 2000; USFS, 2002). Many of the sediment loads were preventable had BMPs and other measures commonly applied today have been applied in the past, thus making them elevated loads from historical versus current activities. It is well documented that sediment loads within watersheds can take a very long time to transport through the stream network, particularly coarse or bedload size material. These points are made throughout the document. It is probable that some of this elevated sediment load, particularly the coarser bedload size material, is still working through the system.

Comment 3-7: (Refer to Table E-1 of Executive Summary) In the portion of the table titled "Major Pollutant Source Categories" timber harvest is listed. Yet the data and the document fail to identify where pollutants are being introduced into the streams because of these activities. The chart does not disclose that most of these activities are 25-50 years old and through revegetation, implementing BMPs, and closing roads are having no measurable effects on the streams in Upper and Middle Grave and the tributaries.

> **Response to Comment 3-7:** We disagree with the statement about not identifying where pollutants are being introduced into the stream and disagree with the implication that roads are having no measurable effects on the streams. Identification of pollutant loading and loading locations are covered in Section 6.0 of both the public review and existing documents. We agree that many of the roads are having limited impacts from surface erosion processes and that the impacts would not be measurable from many of these roads. We also agree that many road impacts have been mitigated through revegetation and have noted that within the text in Appendix I. On the other hand, there are several locations where roads encroach on streams and are still eroding and contribute to fine sediment loading (Appendix I, Photo 6) that may be causing percent surface fines values above preferred reference values in a few reaches such as upper Grave Creek. There are also locations where roads have contributed to the mass wasting and associated continued sediment loading, which is cumulatively linked to the habitat conditions in Grave Creek. We have changed "major pollutant source categories" to "pollutant

source categories" in the table since some loading categories contribute much more modeled sediment loading of concern than others.

K.4 Comments and Responses Primarily Linked to Reference and Target Development (Sections 5.1 and 5.2 and Appendix H)

Comment 4-1: Plans to engage in more adaptive management practices may be commendable, but "Adaptive Management," to many, has become a synonym for experimentation."

Response to Comment 4-1: Adaptive management is the accepted approach to deal with uncertainty at all levels of the water quality planning process, including target and TMDL/allocation development. Adaptive management provides a framework to protect water quality while still allowing the continuation of many activities within a watershed under the assumption that the activities will be protective in a manner consistent with the allocations, even when there is some uncertainty about how the activities may ultimately impact water quality.

Comment 4-2: (there were several similar comments, below is the most comprehensive)

- The 1987 Forest Plan for this forest was amended by the Inland Native Fish strategy (INFS) in 1995. INFS included Riparian Management Objectives (RMOs) including one relating to pools per mile to the channel wetted width. These were part of the PACFISH/INFISH Biological Opinion rendered by the US Fish and Wildlife Service. Three of the primary targets for pools per mile in the in the Draft Grave Creek TMDL exceed INFS objectives. Therefore, they also exceed the standards in the Forest Plan. I am quite concerned about the state setting a precedent by setting TMDL targets that invalidate current Forest Plans.

  This is especially concerning since it is well known that the pool measurements in the reference streams were done counting pools that were 1/3 the width of the stream. The measurements in Grave Creek counted pools that were ½ the width of the stream. This invalidates the comparison between the reference streams and Graves Creek. In addition, pool counts are subjective at best, have only been done in Grave during a series of drought years, and science relating to how many pools/mile are natural is not well defined. Because of this we maintain that the pools/mile targets are not applicable in these systems, especially since they are naturally poor pools/mile systems.

Response to Comment 4-2: The MDEQ has agreed to modify the reference and pool target ranges (Sections H.1 and 5.2.1.2.1) so they are consistent with the Forest Service Riparian Management Objectives. The decision to make this change was due to the both the concern about pool measures methods and the fact that the RMOs are nearly identical to the values presented in the public review draft as discussed in Section H.1.

We have not seen evidence that either the public document or this final version from MDEQ invalidate any forest plans. The comment implies that pool frequency goals are an important part of the forest plan and yet the comment goes on to imply that pool frequency goals are not at all relevant to water quality, beneficial use support, and fisheries habitat.

The variable methods that the Forest Service and others use to measure pools as well as other target parameters is always of concern, as discussed within the section where pool target values are developed, specifically on page H-5 and within the adaptive management section. This variability is not as extensive as implied by the comment since, according to the methodologies provided by the Forest Service, the reference condition widths were based on bankfull measures and the Grave Creek measures were based on wetted width. Bankfull widths are greater than wetted widths. It is possible that these differences compensate for the implied variability, and it is even possible that a pool that is not even 1/3 bankfull width could actually be 1/2 of the wetted width, implying a variability opposite from what is suggested in the comment. Furthermore, the development of new pool targets based on new reference data is discussed in the pool target applicability considerations section (Section 5.2.1.2.1) to also provide an approach to deal with measurement variations within the context of adaptive management.

We disagree with the implication that the data does not apply because of drought conditions since we do not feel that the pool filling in the watershed is linked to such conditions, although adaptive management allows for continued evaluation and modification in response to these types of concerns. We also disagree about the suggestion that the science on the pools per mile not being well defined. This document provided substantial reference data that supports the target values as well as other targets in this document. More rationale was provided for the development of the targets in this document than most other TMDLs given the large amount of reference data. Furthermore, pool frequency is an established value used by the Forest Service as one of their RMOs and key indicator of stream health.

It is interesting to note that the comment suggests that “the science relating to how many pools/mile are natural is not well defined”, and yet goes on to suggest that the science is defined well enough defined to conclude that “the pools/mile targets are not applicable in these systems, especially since they are naturally poor pools/mile systems”. The data and reports evaluated for development of this document do not provide sufficient justification to conclude that pool frequency in the Grave Creek Watershed is naturally low, although the adaptive management approach in this document does acknowledge and incorporate this as a possibility.

Comment 4-3:

- *Page 40, third paragraph* – Why are targets being arbitrarily established on the 25th percentile of the reference data? If the range was found in the reference streams why is that same range then not acceptable in the Grave Creek watershed? Also somewhat discerning is that the resultant number of pools targets are in some cases higher that the PACFISH/INFISH targets which were later determined (5 yr monitoring) to be simply unattainable in many unmanaged streams. If values used as targets have no high degree of attainability then, again, there is no scientific justification in their use.

Response to Comment 4-3: The use of the 25th percentile value is discussed in detail in Section E.2.3.2.2 as a method to address the expected range of natural variability within systems and the MDEQ does not consider this arbitrary. In fact, the following language has been added to Section E.2.3.2.2:

> "The use of a non-parametric statistical distribution for interpreting narrative water quality standards or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (EPA, 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing MDEQ guidance development for interpreting narrative water quality standards where it is determined that there is "good" confidence in the quality of the reference sites and resulting information (MDEQ, 2004e). If it is determined that there is only a "fair" confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is "very high" confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be "fair" to "good" quality. This is primarily due to a the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set."

The goal is to ensure that the stream is functioning within the range of its natural variability under conditions where all reasonable land, soil, and water conservation practices are applied. The use of multiple targets and/or supplemental indicators assists with this effort, and can eventually lead to a situation where a target is not met but it is determined that the stream is functioning within an acceptable range of its natural variability. Using the total range of variability for setting target values would result in an unacceptable risk of missing major impacts from human activities, and is not consistent with MDEQ interpretation of narrative water quality standards. The approach used in this document is protective of water quality and allows for flexibility through adaptive management.

Comment 4-4:

- *Page 39, fourth paragraph* – The rationale contradicts the pool frequency target for Lower Grave. If dewatering is a cause of impairment and decreased pool frequency makes dewatering even more detrimental to fish, then why aren't the pool targets for Lower Grave higher than anywhere else?

- It also makes no sense since low pool frequency cannot impact fish in a stream that is dewatered. The fish either aren't there or they are dead. In that case pools or lack of them makes no difference.

  Response to Comment 4-4: The pool target derivation is based on reference condition for lower Grave Creek as clearly defined in Section H.1.4, following the process defined in Section 3.0. Pools in lower Grave Creek provide important habitat during most of the year, even with dewatering during part of the year. These comments miss the point in that a major goal of this plan is to identify the limiting factors causing impairment and identify solutions, with focus on those impacts/solutions that can be linked to pollutants and TMDL development as well as solutions that are consistent with standard BMP applications.

Comment 4-5: *Page 40, third paragraph*: Why would the median value of a stream need to be greater than the median value of the reference streams to meet target?

  Response to Comment 4-5: The median value condition in the third sentence of the third paragraph on Page 40 was intended as an example of additional target application flexibility. We agree that this sentence is confusing and have deleted it from the document.

Comment 4-6: *Page 40, last paragraph* – Using the method suggested by Riggers does not accomplish what is intended here. To detect changes in pools, you do not multiply the pool length by the average pool depth. Instead you compare maximum and residual pool depths over time. Pool length does not really matter when determining impairment.

  Response to Comment 4-6: The Riggers example has been removed since there are also other methods to evaluate pools that may work better, as noted in the comment. We do not agree or disagree with the pool length statement in the comment; it is no longer relevant to this document.

Comment 4-7:

- Some segments are at the 10% target level for percent fines < 6.35 mm in pool tail outs (grid toss) as shown on Table 5-10 on page 55. There is no scientific rationale for the 10% target that was adopted for this analysis. See Page 44.
- There is no scientific rationale for the Type 1 target of 18% for percent surface fines <2 mm in riffles. Page 41, second paragraph states that research indicates that these fines need to be between 20-40% to decrease macroinvertebrate richness. Yet because the streams in Grave Creek watershed all meet this target it was then arbitrarily lowered to 18%.

  Response to Comment 4-7: The target development process is based on a scientific approach using comparisons to reference conditions and/or literature values. The 10% supplemental indicator and 18% target ranges are derived in Section H.4 using the process outlined in Section 3.0 and Appendix E. Several published reference data sets were used to develop these target values, although the fact that Grave Creek and tributaries to Grave Creek currently meet the 10% and 18% values was a major consideration consistent with the primary reference development approach. As was discussed in Section 5.2.1.2.2, the percent fines value of 18% was applied as a margin of safety since all streams currently meet this value, although this value has been changed to 20% for consistency with other TMDLs.

Comment 4-8: *Page 41, third paragraph* – "Where the target value is exceeded in a representative riffle…" Does this mean it would only take one sample to consider a stream impaired? This is not scientifically or statistically sound. How do you verify the accuracy of the sample?

Response to Comment 4-8: Flexibility is added to suggest that re-sampling to validate the result is acceptable, and where there are multiple representative spatial samples in a reach, meeting the target value with 75% of the pebble count results may be acceptable as long as there are acceptable macroinvertebrate results also. Nevertheless, given the already low values that tend to be well below the target everywhere in the watershed (Table 5-8), pebble count results for less than 2 mm above 20% should be a cause for concern.

Comment 4-9: *Page 42, first paragraph* – "If the lower end is exceeded…" What does this mean? The 15% target appears arbitrary. Bimodal distribution of channel substrate is very common on the Kootenai.

Response to Comment 4-9: It is not arbitrary and is developed using reference data from the Kootenai National Forest as defined in Section H.4.2, perhaps reflecting the bimodal distribution identified, but in a way that suggests an average result of less than 15% is not so common. Nevertheless, in reviewing this section of the document, the MDEQ feels that values less than 15% should not be used as a TMDL target implying impairment from excess fine sediment. Such values may be more of an indicator of habitat or another type of problem. The document has been edited to reflect this.

Comment 4-10: *Page 41, fifth paragraph* – "…average or median…" These are not the same thing. Clarify.

Response to Comment 4-10: These words are unnecessary and confusing as used in this location and have been removed.

Comment 4-11: "…macroinvertebrate samples are a more direct measure of beneficial use based on developed reference approaches." If this is the case then why weren't these samples taken? It appears they were only taken in a portion of Lower Grave and even then not enough samples were taken to provide sufficient data. Why were more questionable measures used as a means to determine impairment?

Response to Comment 4-11: Additional macroinvertebrate data would have been useful and is noted for future TMDL development planning in other areas. Nevertheless, the process of using multiple targets and indicators is consistent with TMDL methodology used in Montana and elsewhere (EPA, 1999). The selected indicators for sediment TMDL targets are not considered questionable as implied in the comment. Similar targets and indicators have been successfully applied in other nonpoint source TMDLs in Montana and throughout the country, Their use is consistent with EPA guidance and they can be used instead of or in conjunction with macroinvertebrate data.

Comment 4-12: *Page 42, second paragraph* – this mentions core sampling for cutthroat redds. This appears to be a new requirement that we have not discussed before.

Response to Comment 4-12: It is not meant as a new requirement, but instead to point out that the target is intended as a means to measure support of other cold water fish spawning habitat, whether the spawning is by bull trout or cutthroat trout. Language in this location has been modified to further clarify this and allow for the use of Type II target surrogates.

Comment 4-13: Page 43, third paragraph – "Furthermore, continued high w/d ratios may eventually need to be evaluated from the perspective of a potential temperature impairment in Lower Grave Creek." Why is this here? Why discuss things are not a concern at this time?

Response to Comment 4-13: The potential temperature impacts from high width-to-depth (w/d) ratios as well as other habitat and flow limitations is a concern at this time. Increased temperatures are a typical response to increased w/d ratios. The additional temperature reduction benefits of reduced w/d ratios should be identified within a water quality restoration plan. The language "potential temperature impairment" has been changed to "potential temperature impacts" since no such impairment determination has been noted although temperature could end up being a concern in the Tobacco River. Efforts to reduce water temperatures in Grave Creek are, at a minimum, desirable for Tobacco River aquatic life use support.

Comment 4-14: Where did the 15% target for % fines< 6.35 mm in riffles (pebble count) come from? Why doesn't it represent the range (15-28%) found in the reference streams? It appears arbitrary. Why was median value used? Did you intend to use the mean value?

Response to Comment 4-14: The target value is not arbitrary and it is derived in Section H.4.3 using the process outlined in Section 3.0 and Appendix E. The 15 to 28% target range in the public review draft, now presented as less than 28%, is for substrate fines based on McNeil core data, whereas the 15% target applies to surface fines from pebble counts and is used as an indicator that the substrate target is satisfied. Therefore, it would not be appropriate to apply the 15 to 28% reference range values from substrate sampling to surface fines values. The median value is applied as a preferred option for larger data sets versus the mean since the use of non-parametric statistics (median vs. means) is typically preferred for environmental data (reference Section 2.3.2.2).

Comment 4-15: *Page 45, last paragraph, and Page 46, first through third paragraphs* – Where did the sinuosity targets come from? They appear arbitrary. Rosgen shows 1.2 ± 0.2. 1.2 or below is not a considered a problem. What's more Rosgen (1996) states, "Sinuosity, however, carries the least weight of all criteria used to delineate Level II morphology." Based on that, width to depth ratio should be the target and the sinuosity target should be dropped entirely.

Response to Comment 4-15: Sinuosity is only applied as a supplemental indicator, with the derivation of the 1.2 to 1.6 reference range explained in Section H.7 of both the public review document and this document. There is a high level of confidence in this reference range and subsequent supplemental indicator range given the fact that there are both historic aerial photos and an internal reference reach used to derive the values. This is perhaps one of the more important supplemental indicators for Lower Grave Creek. MDEQ does not agree with the use of values below 1.2, particularly all the way down to 1.0, which would imply that a straight stream in an alluvial valley is an acceptable stream potential.

Comment 4-16: *Page 46, last paragraph* – "Ideally future values should be as high or higher over most years." What if the stream has already reached or exceeded its maximum potential? What science or data indicates the statement is a realistic expectation?

Response to Comment 4-16: The referred-to sentence is not necessary and will be removed since so many factors can influence the redd counts.

Comment 4-17: *Page 52 and 53, third paragraph and Table 5-8* – If the target is met, it is met. Statements such as "…suggested elevated levels of fines", "Low End of Type II Range" or "High End of Type II Range" are readily apparent by reading the chart. These appear to be trying to highlight problems that in fact may not exist. This is inflammatory and unnecessary.

Response to Comment 4-17: Some Type II targets are used in the context of a supplemental indicator, making it appropriate to note where the value is relative to the reference range. We do not consider this inflammatory and unnecessary.

It is noted here that the MDEQ has determined that the use of the 9 – 12% range as a Type II Target for percent fines < 2 mm is not necessary. This target has been removed from the document.

Comment 4-18:

- We question the scientific basis for the large woody debris targets. Again we know how variable this is in natural situations. We also know large woody debris counts are very subjective. It appears that the targets were derived from areas with mainly old growth character. This gives no variation for stand types or age which are naturally variable.

- It is interesting to note that to gain large woody debris in the stream frequently requires some type of disturbance such as fires, slumps, etc. These same events can also introduce sediment into the stream. Such things are portrayed in the document as negative if they are potentially caused by timber harvest but as positive if they occur from natural events.

Response to Comment 4-18: Reference streams from which LWD values were derived had undergone many of the natural cycles referred to in the comments. Under the application of reasonable land, soil, and water conservation practices, there would be more old growth character along Grave Creek and several tributaries. The application of the 25^{th} to 75^{th} percentile for setting LWD objectives, takes much of this natural variability into consideration, and is an acceptable approach to a supplemental indicator for sediment TMDL development.

We acknowledge that natural events such as fire and slumps can have positive impacts, as was witnessed from the snowslide that added significant LWD to Grave Creek without adding significant sediment load (personally witnessed by MDEQ water quality specialist). Excess sediment loading associated with human causes such as mass wasting/landslides or road erosion where BMPs are or have been lacking is not considered a desirable imitation of natural events as implied by the comment. As noted by the assessment results and photos in this document, the human caused slumps in the Grave Creek Watershed are typically linked to tree removal and actually provide little if any LWD recruitment. No changes were determined to be necessary based on these comments.

Comment 4-19: *Page 118, first paragraph* – At last meeting we agreed LWD would be an indicator but not a reason to make an impairment determination.

Response to Comment 4-19: At the meeting LWD was presented as both a supplemental indicator for the TMDL sediment targets and as a “use support objective” for potential impairments linked to habitat alterations outside the context of TMDL development. This is reflected within the document. This document no longer uses the conditions where the LWD “use support objective” is not met to justify impairment determinations as was done in the public review draft.

Comment 4-20: *Page 68, second paragraph* – There is no data that shows a clear statistical link between large woody debris and pools in Grave Creek. See previous discussions regarding pools and LWD targets. There is also no statistical data to link lack of LWD in these systems to low fish populations.

Response to Comment 4-20: As noted in the Response to Comment 4-19, LWD is no longer used as a separate impairment justification, although it is used as a supplemental indicator linked to habitat or lack of pools impairment, and still retained as an additional “use support objective” as defined in Section 5.2.2.1. We agree that there is a lack of a statistical linkage as noted in this data set and in the Libby reference data set. Nevertheless, 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 in-stream cover is provided by logs, rocks, undercut banks, and overhanging vegetation and root wads. Also, the Grave Creek EAWS (USFS, 2002) notes that for Grave Creek below Blue Sky that most of the pools are greater than three feet in depth and are associated with large woody debris, although it is presumed that these are not residual pool depth values given the results reported in Table G-12. The fact that the existing data do not show a clear relationship between LWD and pools in Grave Greek indicates that there may be other factors that confound the statistical analysis. It does not mean that there is no relationship between LWD and pools in Grave Creek. The physics of water flowing over and around wood and causing scour is no different in Grave Creek from those very same physics in other streams with LWD. Research supports the fact LWD plays a major role in pool formation in many systems.

For the above reasons and based on general cover provided by LWD, we consider it appropriate to use of LWD as both a supplemental indicator for pool formation and as a separate use support objective for cold water fish use support. Ideally, future monitoring and data assessment will record pools as well as information linking pool formation and depth to LWD, recognizing that past observations have noted apparent positive contributions to pool habitat due to LWD within portions of the watershed.

K.5 Comments and Responses Primarily Linked to the Impairment Status Update (Section 5.4)

Comment 5-1:

- Throughout the document there are similar references to sediment issues caused by past harvest practices and yet no data indicates such a fine sediment problem. The only sediment issue identified is for 5 of the 41 segments, which are above the target levels for surface fines <6.35 mm in riffles. See the next paragraph for the discussion regarding that target. Purge the document of references and inferences to sediment issues caused by past timber harvest and roads, since data fails to support these statements. Studies show that sediment introduced through timber harvest and roads is fine sediment, not bed load, and larger size materials.
- Page 1, first paragraph of the documents states, “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.” What pollutant budget is exceeded in the Grave Creek watershed? All fine sediment targets were met in every segment, 36 of 41 segments (88%) met the percent surface fines <6.35 mm in riffles target, and every segment met the percent fines <6.35 in pool tail outs (grid toss) target. In addition, there is no data presented in the document with regards to coarse sediment levels. This concerns us since the

document repeatedly uses coarse sediment levels (referred to as bedload in the document) as rationale for an impairment determination.

Response to Comment 5-1: We disagree with the overall premise of these comments. As discussed throughout the document and summarized in the Executive Summary, it appears that fine sediment may not be a problem in most if not all stream segments in the Grave Creek Watershed, although we may be lacking important data for some reaches. The pool data and problems in the lower watershed suggest an impairment linked to excess total sediment loading, with a significant portion of the sediment of concern in the streams being of a coarser material size. As discussed in detail in Section 6.0 of the public review document and in the final version of this document, coarse sediment loading has been linked to timber harvest activities. This coarser material can take decades or more to work through a stream system, as identified in several references that are added to the document. Even Forest Service documentation identifies bedload, pool filling and aggradation as apparent impacts in various locations associated with past timber management in the watershed (USFS 1998 and USFS 2002). The process by which excess fine and/or coarse sediment can lead to pool filling or loss of pool habitat was not invented by this document as implied by the comments, but is instead referred to within USFS publications for Grave Creek as well as other studies throughout the Western United States.

Comment 5-2:

- We continue to request a clear definition of impairment to measure against. These discussions have often led to answers that danced around “not meeting potential,” “can be improved”, “not what it could be”, and “not meeting reference conditions”. However, in our minds these situations do not necessarily indicate impairment. Completely unmanaged streams go through cycles of disturbance. Therefore, there is a range of the various factors that would be natural, not impaired. We have requested that the natural range of variability be considered in making these determinations. While it was given some “lip service” on Page 37 of the document, there is no indication the natural range of variability was truly considered in the impairment determinations. We believe that Upper and Middle Grave and it’s tributaries are within the natural range of variability, are fully supporting beneficial uses, and therefore most likely are not impaired.
- I would also doubt upper Grave Creek was meeting pool targets before road building and logging began during the decade of the 50’s.
- We also do not agree that functioning below its maximum potential is necessarily a basis for an impairment determination.

Response to Comment 5-2: Natural variability is incorporated into the derivation of reference values/ranges that are then used to assist with impairment determination consistent with Montana Water Quality Standards as defined in Section 3.0 and Appendix E of the document. Natural variability was considered and used to justify application of a 25th percentile value for pool data, versus the median value from the reference data set. This approach does not require that a stream function at its maximum potential, but instead implies that the stream could be below its potential and still considered not impaired since the true potential could be upwards of the median or even the 75th percentile of the reference range. Natural variability is part of the adaptive management approach as defined within the document (Sections 5.2.1.1, 5.4.3) to ultimately determine what Grave Creek is capable of from a pool and habitat perspective. The reference approach is similar to how several TMDL targets have been developed in Montana. The Response to Comment 5-3 addresses the portions of the comments referring to the impairment determinations.

Comment Set 5-3: (8 of 9 entities or individuals commenting on the document did not agree with the impairment determination, particularly relating to pools, in the upper watershed. Below is a representative subset of these comments)

- Montana State law defines 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 standards. The Grave Creek Planning Area contains one stream segment listed on Montana's 303(d) impaired waters list. Probable causes analyzed were sediment-related pollutants and habitat alteration impairments... When water quality monitoring data reveal changes to natural conditions that exceed those allowed by the State standards, the water is determined impaired or threatened. More specifically, the beneficial uses, which are protected by the exceeded standards, are determined impaired or threatened. Under the requirements of Section 208 and 303(e) of the Clean Water Act, any water found to have one or more threatened or impaired uses must be placed on a list for which "water quality management plans" must be developed. Since there is no sufficient and credible data supporting the assumption that Grave Creek does not meet beneficial uses, by virtue of federal statute, it must be dropped from the 303(d) protected list.
- We continue to question if data supports the impairment determination for Upper and Middle Grave and it's tributaries. Page 36 of the Draft Grave Creek TMDL document states "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." Why then does failure to meet a single Type 1 Target or even possibly a single Type II Target result in an impairment determination, even when all the other targets are met? See page 37 of the document.
- *Page 68, sixth paragraph* – There is no statistical link between sedimentation in these systems and lack of pools. See previous discussions regarding sediment and Page 69, third-fifth paragraphs.

Response to Comment 5-3: MDEQ placed Grave Creek on the 2000 303(d) list using an EPA-approved procedure for determining sufficient credible data that supported an impairment determination as identified in Section E.1.1. Grave Creek has since been on the 2002 and 2004 303(d) lists. This document did not find sufficient evidence to change any impairment conclusions found within the most recent 303(d) list, although the water quality impairment status (Section 5.4) further refines our knowledge of the impairment linkages to sediment. Section 3.0 and Appendix E in both the existing document and public review document provide discussion on the overall approach used to evaluate Montana Water Quality Standards. This includes discussion on the application of statistical ranges for setting target parameters and identifying the linkages between targets and water quality standards.

Section 5.4 includes an improved discussion on the application of targets and supplemental indicators for making an updated sediment impairment determination on Grave Creek consistent with the impairment status in the most recent 2004 303(d) list. The targets and supplemental indicators are more clearly presented to point out that all three primary targets must be met at this time. This is because they each deal with a different way in which sediment can impair fish and/or aquatic life, and because there are sediment loading sources, now included within the supplemental indicators, that can be linked to potential sources of impairment. The pools target in the Grave Creek document is related to a different set of conditions from the percent fines targets, and it would not be appropriate to require an indication of a percent fines problem before concluding that there is a coarse or total sediment problem.

As noted in Section 5.4.2.2 the MDEQ has decided to no longer identify any of the Grave Creek tributaries (Foundation, Lewis, Blue Sky, Clarence and Williams) as being impaired. This is consistent with the most recent 2004 303(d) list since the MDEQ has not made any previous impairment determinations for these tributaries. Nevertheless, the sediment TMDL for Grave Creek includes sediment load allocations for sources throughout the watershed. These sediment load allocations provide a level of protection from excess sediment loading to the tributaries by specifically addressing both fine and coarse sediment loading sources at the watershed scale.

The EPA guidance does not limit the number of targets that must be met, nor require that multiple targets not be met to define impairment. EPA uses several examples where it is implied that all targets must be met for full support (EPA, 1999), and the MDEQ has several EPA- approved TMDLs where this approach was applied. The application of supplemental indicators, including land use indicators from Appendices A, B and C and sediment loading indicators from Section 6.0, provide a reasonable explanation for the lack of pools in comparison to the reference condition. This approach is consistent with the new language regarding interpretation of Montana Water Quality Standards at the beginning Section 5.4.1.3.

As more data is collected in the Grave Creek Watershed, we will obtain a better understanding on the natural condition of Grave Creek and the tributaries, the role of LWD and its linkage to pool formation, and the role of residual coarse sediment on pool formation. This improved understanding is part of the adaptive management process that will be used for future impairment status updates.

Comment 5-4: *Page 82, first paragraph* – "Historically road networks that include skid trail impacts would have had more significance." What is this trying to say? What are the impacts today? Is the author trying to make the case that since the watershed has had past logging, road building, and skid trails it has to be impaired, regardless of what the current data shows? What about MT DEQ statements that reference conditions reflects a waterbody's greatest potential for water quality given historic land use activities?

> **Response to Comment 5-4:** We disagree with what is implied in the comment about impairment determinations. There are a number of streams with significant existing and/or historical harvest that have been considered not impaired for sediment by MDEQ personnel working on this document (Swan TMDL, MDEQ 2004d). The historical activities provide sediment sources and are used in conjunction with the pool frequency and other target criteria. As noted in Section E.2.3.2.1: "for many streams such as those in the upper portions of the Grave Creek Watershed, recovery from historic land use activities that led to elevated sediment loading and removal of riparian vegetation is possible, even though full recovery may take decades. This recovery then represents the greatest potential because existing and future forest activities, including timber harvest, can still be pursued in a way that will allow recovery via the application of BMPs and all reasonable land, soil and water conservation practices." Additional monitoring as part of the adaptive management will help determine what the true potential, given past land uses, will be for Grave Creek as well as the tributaries to Grave Creek.

Comment 5-6: *Page 61, Table 5-14* – listed for each stream "Significant human activity lacking BMPs or other conservation practices" This statement is inflammatory and appears to be value-laden. Define significant human activity. Why does this chart indicate the activity is historical in Lower Grave but not in the other streams? In fact Lower Grave is the one stream segment most apt to see additional current and future human activity because of private ownership. Most of the activities that have occurred were prior to BMPs and current conservation practices being developed.

> **Response to Comment 5-6:** We agree that Table 5-14 was lacking information regarding lower Grave Creek as implied in the comment. Table 5-14 has been removed and the newly written Section 5.4 incorporates concerns about higher levels of human activity in lower Grave Creek.

Comment 5-7: *Page 63, ninth paragraph* – As we have discussed before and as data indicates removal of the fish barrier at GLID is not the most notable habitat improvement leading to increased bull trout redd counts. The change in fishing regulations was the most notable improvement.

> **Response to Comment 5-7:** Wording has been changed in Section 5.4 to only note that the fish barrier impairment no longer exists in lower Grave Creek. Wording in Section D.2.1 identifies fishing regulations as one factor, along with GLID removal, contributing to an improved fishery.

<u>Comment 5-8:</u> *Page 65, second paragraph* – Why is this data used when it clearly does not give a representative sample? What were the temperature measurements? This appears inflammatory. Check the bull trout redd counts for that same year. Was there really a problem? Rationale is not consistent with Page 64, fourth paragraph.

> **<u>Response to Comment 5-8:</u>** This comments is no longer relevant given the new wording in Section 5.4 and the removal of the text that this comment is based upon.

<u>Comment 5-9:</u> Page 70, first paragraph – Road density of 1.8 miles is not high. Most research indicates road densities are high between 3-5 miles, depending on soils and precipitation.

> **<u>Response to Comment 5-9:</u>** Language has been changed to avoid this terminology. Some studies suggest road densities above 1.7 miles per square mile are "high" (USFS, 1996), although we have modified the language in Section 5.4.1.1 as follows: "Road density is also not very high, although there appear to be further opportunities for BMP improvements".

<u>Comment 5-10:</u> Page 71, sixth paragraph – Many headwater drainages consist of a combination of A/B or BA stream types. Having indicators that overlap in A/B or B/A type streams are not, by themselves, an indicator of "instability."

> **<u>Response to Comment 5-10:</u>** We agree that the natural condition of the stream can include this overlap, but still note within Section 5.3.6 that these conditions can be used as an indicator of a potential instability type problem consistent with a supplemental indicator approach.

<u>Comment 5-11:</u> *Page 77, third paragraph* – Makes no sense. Large woody debris does not influence pool tail formation.

> **<u>Response to Comment 5-11:</u>** Large woody debris can influence pool formation, such as increasing pool depth, and thus is likely to impact the quality of pool tail (glide) formation.

<u>Comment 5-12:</u> Page 77, second paragraph – Most data does not indicate an impairment determination linked to excess sediment. If there were a coarse material issue, would not the w/d ratio also indicate an issue?

> **<u>Response to Comment 5-12:</u>** The width to depth ratio is used as a Type II target and is an important indicator of stream potential regarding pool formation as noted in the Section 5.4 rewrite. We agree that the fact that generally acceptable w/d (width to depth) ratios in upper Grave Creek and in several tributaries provide one indication of acceptable conditions in this portion of the watershed and this is noted in Section 5.4. Excessive width to depth values in lower Grave Creek is an important indicator of impairment.

Comment 5-13:

- *Page 78-80, discussion on Lewis Creek* – Calling Lewis Creek impaired could not pass even the “prudent person test.” Statements contradict the data. Page 80 hints at excess fine sediment and then a couple of sentences later states percent fines were very low suggesting no percent fines problem. Only 1 in 5 segments don’t meet target for the percent surface fines <6.35 mm in riffles. How does this equate to an impairment?
- In particular, I am surprised at the Lewis Creek designation of impaired. Man has had very little impact except for the road. Historically very little logging was done, which makes me believe the sediment must be from natural causes—mainly the snow slides this drainage suffers every year.

Response to Comment 5-13: As noted in the Response to Comment 5-3, Lewis Creek is no longer identified as being impaired in the newly written Section 5.4. In fact, the following language has been incorporated: “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 pool frequency values in Lewis Creek are about the same amount below reference levels as the other tributaries, and the pool size values are also apparently low similar to the other tributaries. 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, and a prudent person might have uncertainties about whether or not conditions should only be attributed to natural sediment loading. The sediment allocations for Grave Creek include existing and potential future activities in Lewis Creek, as well as other tributaries, since the few existing human related sources, as well as potential future activities, can contribute sediment to Grave Creek.

K.6 Comments and Responses Primarily Linked to Section 7.0 Restoration Objectives, Including TMDL Allocations

Comment 6-1:

- *Page 106, third and fourth paragraph* – 8% water yield is not what we agreed to at our last meeting. We agreed to the standard DEQ recommended 15% water yield increase ceiling. If that is and has been the standard DEQ recommendation we see no reason to change it for Grave Creek.
- *Page 106, fourth paragraph (relates to water yield discussion)* – data does not show increased bank erosions as a result of timber harvest in the Grave Creek watershed. Overall bank stability in the watershed is rated at 96% and for 29 of 32 reaches it is over 90%. Also important to note that bed scour, whether created by natural events or timber harvest, creates pools.

Response to Comment 6-1: Water yield or peak flow is a difficult concept to incorporate into sediment load allocations. We agree that the lower bank erosion rates and higher stability in the upper watershed in comparison to the lower watershed suggest less concern from increased water yield and related peak flows. Therefore, the wording in this section has been modified to note that an 8% water yield level increase is a potential increase of concern, but only for lower Grave Creek due to existing eroding banks and apparent instabilities in this portion of the stream. It is further noted that "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 these values do not represent a water yield increase ceiling, and take increased stability in the upper watershed into concern.

We disagree with the statements about peak flow increases being a likely improvement to pool formation. Increased peak flows can scour the whole bed, including riffles, not just pool areas, and can lead to increased bank erosion. We agree that minor flow changes are probably not of concern, and do agree that floods can play a role in pool formation, but also note that not all flooding results in desirable channel impacts and can negatively impact fish habitat in some situations.

Comment 6-2: *Section 7.0 Restoration Objectives*- This section makes reference to a lack of implemented BMPs during logging activities, which is a completely erroneous and biased statement. As the BI-annual BMP audits report, BMPs are applied and successful 97% to 99% across all land ownerships. To suggest that BMPs are not being implemented during harvest activities is to expose the author's ignorance and/or bias towards logging practices.

Response to Comment 6-2: BMPs were not in place during the majority of logging that occurred in the Grave Creek drainage. Evidence of mass wasting and riparian harvest still exist from the lack of BMPs, from as recent as the late 1980's or early 1990's in the Grave Creek Watershed. We do not consider it a bias against any industry to note instances where BMPs were not in place and sediment loading and potential stream impacts are identified. We acknowledge the fact that the BMP compliance rate is currently very high based on scheduled audit results and compliment the logging industry on this successful effort.

Comment 6-3: *Page 107, third paragraph* – 1 pool = 1% load reduction? Makes no sense. Neither science nor data supports this approach. Arbitrary conclusion.

Response to Comment 6-3: The wording referred to in this comment has been removed since a load allocation is no longer developed for the "Historic Sediment Loads Remaining in the Stream."

K.7 Comments and Responses Primarily Linked to Implementation (Section 8.0)

Comment 7-1: *Page 128, Table 8-1* – Define High, Moderate, and Low Disturbance.

> **Response to Comment 7-1:** The table has been removed and this terminology is no longer used.

Comment 7-2: *Page 134, last paragraph* – "Channel restoration is the most optimal method to restore the river to its potential condition." Based on what? This appears to be a justification for the work already being done. It also appears to contradict the idea put forth in this document regarding anthropogenic activities within the watershed.

> **Response to Comment 7-2:** We disagree with the overall implications of this comment and support the following language modification to the document: "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". We have determined that the document provides adequate justification for this conclusion, particularly given the reduced width to depth ratios and increased pool habitat identified as part of the Phase I Restoration Project summary in the document. Active channel restoration can be a preferred and appropriate approach to address anthropogenic (human) impacts where such impacts have significantly altered the geomorphic character of the stream and a very long recovery time is anticipated in absence of the active channel restoration work. We acknowledge that such work introduces some risk of failure, although even when a project is not completely successful there are still often improvements to fish habitat. The MDEQ has not invented this approach to addressing impairment conditions in watersheds, many other agencies, including the United States Forest Service, often promote similar active restoration work.

Comment 7-3: Restoration is an admirable goal, but again, because of the unique characteristics of this stream and the havoc caused by its spring run-off, how do you determine what was its original condition? On what basis do you determine that upon achieving what you believe to be its original condition, that condition will be impervious to the forces of nature, which have continually reshaped the landscape?

> **Response to Comment 7-3:** Channel design dimensions are based on many of the same dimensions used for targets and supplemental indicators for lower Grave Creek. These designs are based on best available science and criteria that will handle yearly spring runoff while still maintaining the overall pattern, dimension and profile of a stream that is in equilibrium with sediment transport and maintains favorable aquatic life habitat. These criteria are discussed within Section 8.0.

Comment 7-4:

- My husband and I still live on a portion of my father-in-law's original homestead, which is located approximately 5 miles from Grave Creek. For over 50 years we have fished in the stream and know it well. We have over the years had opportunity to observe the phenomena to which I have referred. I have grave concern that allegations made to present a case for stream "restoration" could result in restricting water use and stakeholders' ability to utilize their property as has been their custom. Any goals established should be achievable without imposing hardship on adjacent property owners and the water users in North Lincoln County.

- Major consideration must be given to the protection of existing water rights, which in the Grave Creek drainage go back to the early 1900s. Preservation of The Glen Lake Irrigation District is a major concern as its delivery system provides the life blood of the entire Tobacco Valley, as well as recreational opportunities at Glen Lake. Equally important to other stakeholders in the basin is the protection of original domestic, irrigation and stock watering rights.

Response to Comment 7-4: We agree that any goals established should be achievable without imposing hardship on adjacent property owners and the water users. As noted in Section 3.5, State Law directs the MDEQ to support a voluntary program of reasonable land, soil and water conservation practices to achieve compliance with water quality standards. It is also noted in Section E.1.2.2 and again in Section 8.3.2 that the TMDL development section of State Law states that "nothing in this part may be construed to divest, impair, or diminish any water right recognized pursuant to Title 85". Additional language regarding water rights protection has been added to the Section 7.3.3 discussion on Other Restoration Objectives. State lawmakers obviously felt the same way as the reader about trying to avoid imposing unnecessary hardships on property owners and water users. The MDEQ develops water quality restoration plans and TMDLs in a way that is consistent with the above state law.

Projects completed to date along lower Grave Creek have improved diversions points of the affected landowners. These improvements, which are noted in Section 8.0, included improved diversion structures to ensure flows are able to be diverted during low flow periods, fish screens to prevent entrainment of fish and debris into the respective irrigation canals, and in one instance, installation of a center pivot system to improve irrigation efficiency. Addressing landowner concerns with regard to water rights will always be one of the primary objectives of stream restoration planning in lower Grave Creek.

Comment 7-5: No restoration for the problem *(excess sediment loading from historical logging activities)* is identified.

Response to Comment 7-5: The load allocations for existing and future activities developed within Section 7.0, the implementation strategies developed in Section 8.0, and the monitoring strategy developed in Section 9.0 all create a comprehensive program to protect and restore water. These Sections address excess sediment loading from historical and other timber harvest activities as well as other significant or potentially significant sources in the watershed.

<u>Comment 7-6:</u> One commenter was concerned about cattle grazing along the river and within a spring complex that flows into Grave Creek. The commenter felt that this issue needed to be addressed and that the grazing was not consistent with water quality protection, with particular concern about e coli or nutrient loading.

<u>Response to Comment 7-6:</u> The referred to grazing activities along the stream are being pursued as part of a voluntary grazing BMP implementation effort to protect the riparian area. The protection of these riparian areas is an important component to the load allocation and overall solution to excess bank erosion in lower Grave Creek. Grazing BMP strategies can and often do include limited grazing near streams. Nutrient and e coli (pathogens) problems have not been noted in Grave Creek and are probably not a problem, although landowners are always encouraged to reduce pollutant loading and impacts to streams as a voluntary and cooperative effort. Future TMDL development for the Tobacco River may involve nutrient load reductions via allocations, and there may be additional focus on grazing management throughout the whole Tobacco River Watershed. The landowner referred to in this comment has voluntarily implemented extensive riparian fencing in cooperation with the Natural Resources Conservation Service and US Fish and Wildlife Service, and the current water quality protection efforts are likely consistent with or very close to being consistent with any future nutrient reduction goals in the Tobacco River Watershed.

K.8 Comments Based on Minor Wording Corrections or Suggestions

<u>Comment 8-1:</u> *Page 40, first paragraph* – "…typically dry…" when in fact it *(Grave Creek)* has occasionally been documented to dry up in the past. It is not typically dry. Could say "…may dry up completely, providing no habitat."

<u>Response to Comment 8-1:</u> The language has been changed as suggested by the comment.

<u>Comment 8-2:</u> *Page 14, Table 2-7* – shows clearing, tilling, and pasturing under major natural disturbances for agricultural land

<u>Response to Comment 8-2:</u> The information has been deleted from the table.

<u>Comment 8-3:</u> *Page 104, fourth paragraph* – INFS provides guidelines, not requirements.

<u>Response to Comment 8-3:</u> Corrections made per the comment.

<u>Comment 8-4:</u> *Page 72, third paragraph* – Disclose the results of the counts.

<u>Response to Comment 8-4:</u> The redd count results have been added to the new tables in Section 5.4.

K.9 Comments Noted; No Response Necessary

Comment 9-1: I think anyone would agree that lower Grave Creek is impaired. The reasons are of course varied but the log drives when three streams were combined into one creek below Stoken Bridge and then widened by the drive itself. When crawler tractors became common in the 30's this made clearing the forest, channeling the river, and over grazing the riparian area common.

Comment 9-2: The lack of large woody debris can be attributed in large part to the past forest service decision using best science available, to remove logs and log jams from the mainstream Grave Creek.

Comment 9-3: I would also like to comment on our fishery. I believe, and think the biologist would agree, the decline in cutthroat numbers is mostly related to Libby dam.

Comment 9-4: I feel there is consensus the Bull Trout numbers between Libby dam and the international border are greater than they were prior to development in upper Grave Creek.