Sediment, Nutrients, and Temperature TMDLs and Water Quality Improvement Plans for the Boulder-Elkhorn Planning Area

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Steve Bullock, Governor
Tracy Stone-Manning, Director DEQ

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Prepared by:
Water Quality Planning Bureau
Watershed Management Section

Contributors:
Water Quality Planning Bureau
Watershed Management Section
Christina Staten, Project Coordinator
Jim Bond, Sediment & Temperature Projects Manager
Lou Volpe, Nutrient Project Manager
Eric Sivers, Field and Technical Analysis Assistance

Montana Department of Environmental Quality
Water Quality Planning Bureau
1520 E. Sixth Avenue
P.O. Box 200901
Helena, MT 59620-0901

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ACRONYM LIST

Acronym	Definition
AFDW	Ash Free Dry Weight
AFO	Animal Feeding Operation
AGNPS	Agricultural Nonpoint Source Model
AML	Abandoned Mine Lands
ANFO	Ammonium Nitrate and Fuel Oil
ARARS	Applicable or Relevant and Appropriate Requirements and Standards
ARM	Administrative Rules of Montana
ARRA	American Recovery and Reinvestment Act
BDNF	Beaverhead - Deerlodge National Forest
BEHI	Bank Erosion Hazard Index
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practices
CAFO	Concentrated (or Confined) Animal Feeding Operations
CALA	Controlled Allocation of Liability Act
CECRA	[Montana] Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CNMP	Comprehensive Nutrient Management Plans
CTM	Critical Thermal Maximum
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DMR	Discharge Monitoring Report
DNRC	Department of Natural Resources & Conservation (Montana)
DRP	dissolved reactive phosphorus
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (U.S.)
EPIC	Erosion Productivity Impact Calculator
EQIP	Environmental Quality Initiatives Program
FWP	Fish, Wildlife & Parks (Montana)
GIS	Geographic Information System
GWLF	Generalized Watershed Loading Functions
HBI	Hilsenhoff Biotic Index
HDPE	high-density polyethylene
INFISH	Inland Native Fish Strategy
IR	Integrated Report
ITL	Instantaneous Thermal Load
LA	Load Allocation
LULC	Land Use and Land Cover
LWD	Large Woody Debris
kcal/s	kilocalories per second (s)
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MDT	Montana Department of Transportation
MFISH	Montana Fisheries Information System

Acronym	Definition
MGD	Million Gallons Per Day
MGWPCS	Montana Ground Water Pollution Control System
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MRIS	Montana Rivers Information System
MRLC	Multi-Resolution Land Characterization Consortium
MSU	Montana State University
MWCB	Mine Waste Cleanup Bureau (DEQ)
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPS	Nonpoint Source
NRCS	National Resources Conservation Service
NRIS	Natural Resource Information System (Montana)
NWIS	National Water Information System
PIBO	PACFISH/INFISH Biological Opinion
QA	Quality Assurance
QC	Quality Control
RIT/RDG	Resource Indemnity Trust/Reclamation and Development Grants Program
SAP	Sampling and Analysis Plan
SDR	Sediment Delivery Ratio
SEP	Septic Pumper Fees
SIC	Standard Industrial Classification
SMCRA	Surface Mining Control & Reclamation Act
SMZ	Streamside Management Zone
SOP	Standard Operating Procedure
STORET	EPA STOrage and RETrieval database
SWAT	Soil & Water Assessment Tool
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TPN	Total Persulfate Nitrogen
TSS	Total Suspended Solids
UILT	Upper Incipient Lethal Temperature
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
VCRA	Voluntary Cleanup and Redevelopment Act
VFS	Vegetated Filter Strips
WLA	Wasteload Allocation
WQPB	Water Quality Planning Bureau (DEQ)
WRP	Watershed Restoration Plan

Acronym	Definition
WWTF	Wastewater Treatment Facility
WWTL	Waste Water Treatment Lagoon
WWTP	Wastewater Treatment Plant

DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) and water quality improvement plan for 11 impaired waterbodies in the Boulder River watershed, including the Boulder River (see **Figures A-2, A-3, and A-4** found in **Appendix A**).

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. TMDLs provide an approach to improve water quality so that streams and lakes can support and maintain their state-designated beneficial uses.

The project area for the TMDLs in the document is called the Boulder-Elkhorn TMDL Planning Area (TPA), which is in the Missouri Headwaters Basin (Hydrologic Accounting Unit 100200) of southwestern Montana. The boundaries of the project area and the Boulder River watershed are the same. The TPA and watershed is bounded by the continental divide to the west, Boulder Hill to the north, the Elkhorn Mountains to the northeast, and Bull Mountain to the southwest. The Boulder River flows into the Jefferson Slough, which then joins the Jefferson River. The total planning area is 487,142 acres, or approximately 760 square miles. The TPA is located entirely within Jefferson County.

DEQ determined that eleven waterbodies do not meet their applicable water quality standards. The scope of the TMDLs in this document addresses problems with sediment, temperature and nutrients (see **Table DS-1**). There are also waterbodies in this planning area with metals impairments; however they are addressed in the "Boulder-Elkhorn Metals TMDLs and Framework Water Quality Improvement Plan" published December 2012.

Sediment

Sediment was identified as impairing aquatic life in the Boulder River, Basin Creek, Bison Creek, Cataract Creek, Elkhorn Creek, High Ore Creek, McCarty Creek, Muskrat Creek, N.F. Little Boulder River, Nursery Creek, and Uncle Sam Gulch. Sediment is affecting designated uses in these streams by altering aquatic insect communities, reducing fish spawning success, and increasing turbidity. Water quality restoration goals for sediment were established on the basis of fine sediment levels in trout spawning areas and aquatic insect habitat, stream morphology and available instream habitat as it related to the effects of sediment, and the stability of streambanks. DEQ believes that once these water quality goals are met, all water uses currently affected by sediment will be restored given all reasonable land, soil, and water conservation practices.

Sediment loads are quantified for natural background conditions and for the following sources: bank erosion, hillslope erosion, roads, and permitted discharges. The Boulder-Elkhorn sediment TMDLs indicate that reductions in watershed sediment loads ranging from 29% to 46% will satisfy the water quality restoration goals.

General strategies for achieving the sediment reduction goals are also presented in this plan. They include best management practices (BMPs) for building and maintaining roads, for harvesting timber, and for management of agricultural land. In addition, they includes BMPs for expanding riparian buffer areas and using other land, soil, and water conservation practices that improve stream channel conditions and associated riparian vegetation.

Nutrients

Nutrients were identified as impairing aquatic life in Bison Creek, Uncle Sam Gulch, Nursery Creek, and McCarty Creek. Increased nutrient concentrations in a waterbody accelerate a process known as eutrophication. Eutrophication can cause increased algal and aquatic plant growth and subsequently reduce oxygen concentrations in the affected waterbody. Some further effects of nutrients to designated uses may include increasing algal plants to aesthetic nuisance levels, and depletion of oxygen levels that can harm aquatic life and in some cases hinder human health.

Water quality restoration goals for nutrients were established by quantifying the nutrient loads to each impaired stream during the summer growing season. Nutrient loads were quantified for natural background conditions and for the following sources: agricultural (primarily related to cattle grazing), mining, septic systems, and water storage impoundments. The Boulder-Elkhorn nutrient TMDLs indicate that reductions in watershed nutrient loads ranging from 39% to 85% will satisfy the water quality restoration goals. DEQ believes that once water quality goals are met, water uses currently affected by nutrients will be restored given all reasonable land, soil, and water conservation practices.

General strategies for achieving the nutrient reduction goals are also presented in this plan. They include BMPs for management of agricultural land and historical mining operations. In addition, they include BMPs for expanding riparian buffer areas and using other land, soil, and water conservation practices that improve overall stream health.

Temperature

Temperature was identified as impairing aquatic life in the Boulder River and High Ore Creek. Temperature is affecting aquatic life (coldwater fish) through periodic increases of instream water temperature values to conditions that may impair metabolic functions. Water quality restoration goals for temperature were established through the development of a water quality model, and are centered in improvement to riparian shade potential, restoration of stable stream channel morphology, and the prospect of increasing instream flow conditions during the hottest months of the summer. DEQ believes that once these water quality goals are met, all water uses currently affected by temperature will be restored given all reasonable land, soil, and water conservation practices.

Instream temperature conditions are quantified for natural background conditions and conditions under improved riparian vegetation, and instream flow. The Boulder-Elkhorn temperature TMDLs indicate that reductions in water temperatures ranging from 0.7 to 3.6 F can be achieved.

General strategies for achieving the instream water temperature reduction goals are also presented in this plan. They include BMPs for managing riparian areas and agricultural land, and investigation into water use practices that could improve instream flow.

Water Quality Improvement Measures

Implementation of most water quality improvement measures described in this plan is based on voluntary actions of watershed stakeholders. Ideally, local watershed groups and/or other watershed stakeholders will use this TMDL document, and associated information, as a tool to guide local water quality improvement activities. Such activities can be documented within a watershed restoration plan consistent with DEQ and EPA recommendations.

A flexible approach to most nonpoint source TMDL implementation activities may be necessary as more knowledge is gained through implementation and future monitoring. The plan includes a monitoring strategy designed to track progress in meeting TMDL objectives and goals and to help refine the plan during its implementation.

Although most water quality improvement measures are based on voluntary measures, federal law specifies permit requirements developed to protect narrative water quality criterion, a numeric water quality criterion, or both, to be consistent with the assumptions and requirements of wasteload allocations (WLAs) on streams were TMDLs have been developed and approved by EPA. The Boulder-Elkhorn TPA has permitted dischargers requiring the incorporation of WLAs into permit conditions on the Boulder River, Cataract Creek, Basin Creek, and Elkhorn Creek.

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Boulder-Elkhorn TPA with Completed Nutrient, Sediment and Temperature TMDLs Contained in this Document

<table>
<tr><th>Waterbody & Location Description</th><th>TMDL Prepared</th><th>Pollutant Category</th><th>Impaired Uses</th></tr>
<tr><td rowspan="2">BOULDER RIVER, Town of Boulder to Cottonwood Creek</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>Temperature</td><td>Temperature</td><td>Aquatic Life</td></tr>
<tr><td rowspan="2">BOULDER RIVER, Cottonwood Creek to the mouth (Jefferson Slough), T1N R3W S2</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>Temperature</td><td>Temperature</td><td>Aquatic Life</td></tr>
<tr><td>BASIN CREEK, headwaters to mouth (Boulder River)</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td rowspan="3">BISON CREEK, headwaters to mouth (Boulder River)</td><td>Total Nitrogen</td><td>Nutrients</td><td>Aquatic Life
Primary Contact Recreation</td></tr>
<tr><td>Total Phosphorus</td><td>Nutrients</td><td>Aquatic Life
Primary Contact Recreation</td></tr>
<tr><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>CATARACT CREEK, headwaters to mouth (Boulder River)</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>ELKHORN CREEK, headwaters to Wood Gulch</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>ELKHORN CREEK, Wood Gulch to the mouth (Unnamed Canal/Ditch), T5N R3W S21</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td rowspan="2">HIGH ORE CREEK, headwaters to mouth (Boulder River)</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>Temperature</td><td>Temperature</td><td>Aquatic Life</td></tr>
<tr><td rowspan="2">MCCARTY CREEK, headwaters to mouth (Boulder River)</td><td>Total Phosphorous</td><td>Nutrients</td><td>Aquatic Life
Primary Contact Recreation</td></tr>
<tr><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>MUSKRAT CREEK, headwaters to mouth (Boulder River)</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
<tr><td>NORTH FORK OF THE LITTLE BOULDER RIVER, headwaters to mouth (Little Boulder River)</td><td>Sediment</td><td>Sediment</td><td>Aquatic Life</td></tr>
</table>

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Boulder-Elkhorn TPA with Completed Nutrient, Sediment and Temperature TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	Pollutant Category	Impaired Uses
NURSERY CREEK, headwaters (east branch) to mouth (Muskrat Creek)	Total Nitrogen	Nutrients	Aquatic Life Primary Contact Recreation
	Total Phosphorous	Nutrients	Aquatic Life Primary Contact Recreation
	Nitrate + Nitrite	Nutrients	Aquatic Life Primary Contact Recreation
	Sediment	Sediment	Aquatic Life
UNCLE SAM GULCH, headwaters to mouth(Cataract Creek)	Nitrate + Nitrite	Nutrients	Aquatic Life Primary Contact Recreation
	Sediment	Sediment	Aquatic Life

1.0 Project Overview

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for sediment, nutrient, and temperature problems in the Boulder-Elkhorn TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Figures A-2 and A-3**, found in **Appendix A**, show maps of waterbodies in the Boulder-Elkhorn TPA with sediment, nutrient, and temperature pollutant listings.

1.1 Why We Write TMDLs

In 1972, the U.S. Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act (CWA). The CWA's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA requires each state to designate uses of their waters and to develop water quality standards to protect those uses.

Montana's water quality designated use classification system includes the following:

- fish and aquatic life
- wildlife
- recreation
- agriculture
- industry
- drinking water

Each waterbody in Montana has a set of designated uses from the list above. Montana has established water quality standards to protect these uses, and a waterbody that does not meet one or more standards is called an impaired water. Each state must monitor their waters to track if they are supporting their designated uses, and every two years the Montana Department of Environmental Quality (DEQ) prepares a Water Quality Integrated Report (IR) which lists all impaired waterbodies and their identified impairment causes. Impairment causes fall within two main categories: pollutant and non-pollutant.

Montana's biennial IR identifies all the state's impaired waterbody segments. The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL, whereas TMDLs are not required for non-pollutant causes of impairment. **Table A-1** in **Appendix A** identifies all impaired waters for the Boulder-Elkhorn TPA from Montana's 2012 303(d) List, and includes non-pollutant impairment causes included in Montana's "2012 Water Quality Integrated Report." **Table A-1** provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of total maximum daily loads for all impaired waterbodies when water quality is impaired by a pollutant. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Developing TMDLs and water quality improvement strategies includes the following components, which are further defined in **Section 4.0**:

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards
- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (the TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation (see **Sections 8**, **9**, and **10** of this document).

Basically, developing a TMDL for an impaired waterbody is a problem-solving exercise: The problem is excess pollutant loading that impairs a designated use. The solution is developed by identifying the total acceptable pollutant load (the TMDL), identifying all the significant pollutant-contributing sources, and identifying where pollutant loading reductions should be applied to achieve the acceptable load.

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists all of the impairment causes from the "2012 Water Quality Integrated Report" that are addressed in this document (also see **Figures A-2 and A-3** in **Appendix A**). Each pollutant impairment falls within a TMDL pollutant category (e.g., nutrients, sediment, or temperature), and this document is organized by those categories.

Data assessed during this project identified new sediment impairment causes for two waterbodies (Bison Creek and Muskrat Creek), and three new nutrient impairment causes for two waterbodies (Bison Creek and Nursery Creek). These impairment causes are identified in **Table 1-1** and noted as not being on the 2012 303(d) List (within the integrated report). Instead, these waters will be documented within DEQ assessment files and incorporated into the 2014 IR.

TMDLs are completed for each waterbody – pollutant combination, and this document contains thirteen sediment, seven nutrient, and three temperature TMDLs (**Table 1-1**). There are several non-pollutant types of impairment contained in **Table 1-1** that are also addressed in this document. As noted above, TMDLs are not required for non-pollutants, although in many situations the solution to one or more pollutant problems will be consistent with, or equivalent to, the solution for one or more non-pollutant problems. The overlap between the pollutant TMDLs and non-pollutant impairment causes is discussed in **Section 8.0**. **Section 9.0** provides some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

There are also metals causes of impairments for waterbodies in the Boulder-Elkhorn TMDL planning area (**Table A-1, Appendix A**) that have been addressed in a separate document. The "Boulder-Elkhorn Metals TMDLs and Framework Water Quality Improvement Plan" contains the metals TMDLs and was published December 2012.

Table 1-1. Water Quality Impairment Causes for the Boulder-Elkhorn TPA Addressed within this Document

Waterbody & Location Description [1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status [2]	Included in 2012 Integrated Report [3]
BASIN CREEK, headwaters to mouth (Boulder River)	MT41E002_030	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
BISON CREEK, headwaters to mouth (Boulder River)	MT41E002_070	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Nitrates	Nutrients	Not impaired based on updated assessment	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	No
		Total Nitrogen	Nutrients	TN TMDL contained in this document	No
		Total Phosphorous	Nutrients	TP TMDL contained in this document	No
BOULDER RIVER, Basin Creek to Town of Boulder	MT41E001_021	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
BOULDER RIVER, Town of Boulder to Cottonwood Creek	MT41E001_022	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed via Temperature TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Temperature , water	Temperature	Temperature TMDL contained in this document	Yes
BOULDER RIVER, Cottonwood Creek to the mouth (Jefferson Slough), T1N R3W S2	MT41E001_030	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed via Temperature TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Temperature , water	Temperature	Temperature TMDL contained in this document	Yes
Cataract Creek, headwaters to mouth (Boulder River)	MT41E002_020	Nitrogen, Nitrate	Nutrients	Not impaired based on updated assessment	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes

Table 1-1. Water Quality Impairment Causes for the Boulder-Elkhorn TPA Addressed within this Document

Waterbody & Location Description [1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status [2]	Included in 2012 Integrated Report [3]
Elkhorn Creek, headwaters to Wood Gulch	MT41E002_061	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
Elkhorn Creek, Wood Gulch to the mouth (Unnamed canal/ditch T5N R3W S21	MT41E002_062	Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
High Ore Creek, headwaters to mouth (Boulder River)	MT41E002_040	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Total Suspended Solids	Sediment	Addressed via Sediment TMDL	Yes
		Temperature , water	Temperature	Temperature TMDL contained in this document	Yes
Little Boulder River, headwaters to mouth (Boulder River)	MT41E002_080	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
Lowland Creek, headwaters to mouth (Boulder River)	MT41E002_050	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
McCarty Creek, headwaters to mouth (Boulder River)	MT41E002_110	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Fish Passage Barrier	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Total Phosphorous	Nutrients	TP TMDL contained in this document	Yes

Table 1-1. Water Quality Impairment Causes for the Boulder-Elkhorn TPA Addressed within this Document

Waterbody & Location Description [1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status [2]	Included in 2012 Integrated Report [3]
Muskrat Creek, headwaters to mouth (Boulder River)	MT41E002_100	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	No
North Fork Little Boulder River, headwaters to mouth (Little Boulder River)	MT41E002_090	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Nitrogen (Total)	Nutrients	Not impaired based on updated assessment	Yes
Nursery Creek, headwaters (east branch) to mouth (Muskrat Creek)	MT41E002_130	Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Total Nitrogen	Nutrients	TN TMDL contained in this document	Yes
		Total Phosphorous	Nutrients	TP TMDL contained in this document	No
		Nitrate/Nitrite (Nitrate + Nitrite as N)	Nutrients	NO_3+NO_2 TMDL contained in this document	Yes
Uncle Sam Gulch, headwaters to mouth (Cataract Creek)	MT41E002_010	Alteration in streamside or littoral vegetation covers	Not Applicable; Non-Pollutant	Addressed via Sediment TMDL	Yes
		Nitrogen, Nitrate	Nutrients	NO_3+NO_2 TMDL contained in this document	Yes
		Other flow regime alterations	Not Applicable; Non-Pollutant	Addressed within document (**Sections 8** and **9**); not linked to a TMDL	Yes
		Sediment/Siltation	Sediment	Sediment TMDL contained in this document	Yes
		Turbidity	Sediment	Addressed via Sediment TMDL	Yes

[1]. All waterbody segments within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD)
[2]. TN = Total Nitrogen, TP = Total Phosphorus, NO_3 + NO_2 = Nitrate + Nitrite
[3]. Impairment causes not in the "2012 Water Quality Integrated Report" were recently identified and will be included in the 2014 Integrated Report.

1.3 What This Document Contains

This document addresses all of the required components of a TMDL and includes an implementation and monitoring strategy. The TMDL components are summarized within the main body of the document; additional technical details are contained in the appendices and attachments. In addition to this introductory section, this document includes:

Section 2.0 Boulder River Watershed Description:
Describes the physical characteristics and social profile of the watershed.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the Boulder-Elkhorn TMDL Planning Area.

Section 4.0 Defining TMDLs and Their Components
Defines the components of TMDLs and how each is developed.

Sections 5.0 – 7.0 Sediment, Temperature, and Nutrient TMDL Components (sequentially):
Each section includes (a) a discussion of the affected waterbodies and the pollutant's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 8.0 Other Identified Issues or Concerns:
Describes other problems that could potentially be contributing to water quality impairment and how the TMDLs in the plan might address some of these concerns. This section also provides recommendations for combating these problems.

Section 9.0 Framework Water Quality Restoration Strategy:
Discusses water quality restoration objectives and presents a framework for implementing a strategy to meet the identified objectives and TMDLs.

Section 10.0 Monitoring Strategy and Adaptive Management:
Describes a water quality monitoring plan for evaluating the long-term effectiveness of the "Boulder-Elkhorn TMDL Planning Area Sediment, Nutrient, and Temperature TMDLs and Framework Water Quality Improvement Plan."

Section 11.0 Public Participation & Public Comments:
Describes other agencies and stakeholder groups who were involved with the development of this plan and the public participation process used to review the draft document. Addresses comments received during the public review period.

2.0 BOULDER RIVER WATERSHED DESCRIPTION

This section includes a summary of the physical characteristics and social profile of the Boulder River watershed and the Boulder-Elkhorn TMDL Planning Area (TPA). The boundaries of the Boulder River watershed are the same as the Boulder Elkhorn TPA. This summary has been excerpted from a somewhat more detailed version of the Boulder River watershed description, which is contained in **Appendix B**. This figures that are referenced in this section relate to the sequence that they appear in **Appendix B**.

2.1 PHYSICAL CHARACTERISTICS

The following information describes the physical characteristics of the Boulder River watershed.

2.1.1 Location

The Boulder-Elkhorn TPA is within Jefferson County. The total extent is 487,142 acres, or approximately 760 square miles. The TPA is located in the Missouri Headwaters Basin (Accounting Unit 100200) of southwestern Montana, and the Boulder River is a tributary to the Jefferson Slough, which flows into the Jefferson River. The TPA is located in the Middle Rockies Level III Ecoregion. Three Level IV Ecoregions are mapped within the TPA (Woods et al., 2002). These include: Elkhorn Mountains-Boulder Batholith (17ai), Townsend Basin (17w), and Townsend-Horseshoe-London Sedimentary Hills (17y) (**Appendix A**, **Figure A-5**). The planning area is bounded by the continental divide to the west, Boulder Hill to the north, the Elkhorn Mountains to the northeast, and Bull Mountain to the southwest.

2.1.2 Climate

Climate in the area is typical of mid-elevation intermontane valleys in western Montana. Precipitation is most abundant in May and June. Annual average precipitation ranges from 11 to 45 inches in the Boulder River watershed. The mountains receive most of the moisture, and the Boulder Valley below Elkhorn Creek receives the least. Average snowfall in the Boulder Valley is approximately 31 inches a year. May and June are the wettest months of the year and winter precipitation is dominated by snowfall. Temperature patterns reveal that July is the hottest month and January is the coldest throughout the watershed. Summertime highs are typically in the high seventies to low eighties (degrees F), and winter lows are typically in the single digits to ten degrees above (degrees F). **Table 2-1** summarizes climate data for the watershed.

Table 2-1. Climate Summary: Boulder, Montana Period of Record: 7/1/1948 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Max. Temp (F)	33.2	38.6	44.7	54.9	64.2	72.7	82.5	82.0	71.1	59.4	42.9	34.9	56.7
Ave. Min. Temp. (F)	9.3	14.1	19.0	27.1	35.2	42.5	47.7	45.9	36.9	28.2	18.3	11.5	28.0
Ave Tot. Precip. (in.)	0.46	0.32	0.50	0.79	1.78	2.05	1.37	1.24	1.02	0.56	0.51	0.44	11.03
Ave. Snowfall (in.)	7.3	3.6	6.3	3.8	0.4	0.1	0.0	0.0	0.1	0.4	3.9	5.3	31.2
Ave Snow Depth (in.)	3	1	1	0	0	0	0	0	0	0	1	2	1

2.1.3 Hydrology

The Boulder River flows a distance of approximately 80 miles. Hydrography of the Boulder River watershed is illustrated on **Figure A-10** in **Appendix A**. The United States Geological Survey (USGS) maintains two gaging stations within the watershed (**Table 2-2**). Streamflow data are based on records from the stream gage on the Boulder River near Boulder, and is available from the USGS NWIS website (United States Department of Interior, Geological Survey, 2008).

Table 2-2. Stream Gages

Name	Number	Drainage Area	Agency	Period of Record
Cataract Creek near Basin, MT	06031950	30.6 miles2	USGS	1973-2008*
Boulder River near Boulder, MT	06033000	381 miles2	USGS	1929-1972; 1985-2008

* Annual peak data

Flows in the Boulder River vary considerably over a calendar year. **Figure 2-1** shows a hydrograph summarizing flows at this station, based on monthly mean flows. Flow is also variable from year to year, but on average (based on a 75-year period of record), peak flows occur in May. The highest recorded flow occurred in May 1981 at 7,000 cubic feet per second (cfs). Mean low flow occurs in January (26 cfs). Late summer (August and September) mean flows are nearly as low as mean flow in winter (December – February). Mean flows in October and November have been slightly higher (35-36 cfs). During the period of record, annual peaks have ranged from 7,000 cfs (May 22, 1981) to 267 cfs (May 3, 2000). Peak annual flows have not occurred earlier than April 23, nor later than July 7.

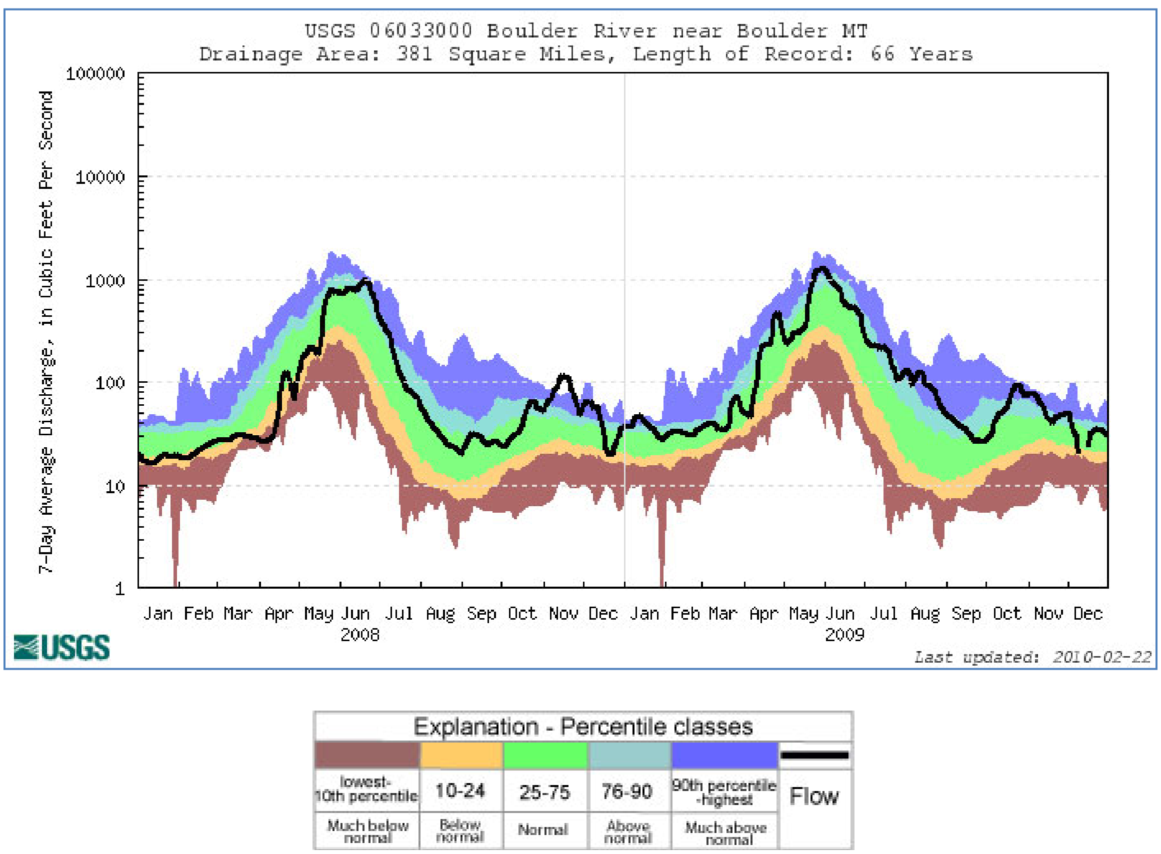

Figure 2-1 Boulder River Hydrograph

2.1.4 Geology, Soils, and Stream Morphology

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier and Smith, 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Soil units assigned to the following ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of greater than 0.4 are considered highly susceptible to erosion. No values greater than 0.34 are mapped in this watershed (**Appendix A, Figure A-8**). The majority of the watershed (57%) has moderate-low susceptibility soils. Roughly similar percentages have moderate-high susceptibility (19.5%) and low susceptibility (23.5%) soils.

The bedrock of the watershed includes Precambrian (Belt Series), Paleozoic and Mesozoic sedimentary rocks; granitoid rocks of the Boulder batholith; and Cretaceous to Tertiary volcanic rocks (**Appendix A, Figure A-7**). The sedimentary rocks are mainly present north of the Boulder River and east of Elkhorn Creek, and at the mouth of the Boulder River. These rocks are deformed into a series of folds related to the Helena Structural Salient. Intrusive and volcanic rocks are widely distributed through the Boulder, Elkhorn and Bull mountains.

Tertiary and Quaternary sedimentary deposits are concentrated in the valleys. The Tertiary sediments are commonly fine-grained with isolated bodies of coarser material. Tertiary sediments commonly occur in benches or dry terraces. Quaternary sediments include fluvial, colluvial, glacial and proglacial deposits.

Many tributary streams in the Boulder River watershed have been historically straightened, or channelized, to accommodate a variety of land uses and/or transportation networks. These alterations can significantly affect sediment transport dynamics of streams and may affect streambank stability.

2.1.5 Vegetation

The primary cover in the uplands is conifer forest. Conifers are dominated by Lodgepole pine, giving way to Douglas fir at lower elevations, with lesser amounts of White pine, Western larch, and juniper. The valleys are characterized by grassland and irrigated agricultural land, with minor shrublands. Landcover is shown in **Table 2-4**. Data sources include the University of Montana's Satellite Imagery land Cover (SILC) project (University of Montana, 2002), and National Land Cover Dataset (NLCD) mapping (Natural Resource Information System, 2003).

2.1.6 Aquatic Life

Native fish species present in the watershed include: westslope cutthroat trout, mountain whitefish, mottled scuplin, longnose dace and longnose sucker (**Appendix A, Figure A-14**). Westslope cutthroat trout are designated "Species of Concern" by Montana Department of Fish, Wildlife and Parks (FWP). Introduced species are also present in streams, including: brook, rainbow, brown and Yellowstone cutthroat trout.

2.1.7 Fires

The United States Forest Service (USFS) Region 1 office and the USFS remote sensing applications center provide data on fire locations from 1940 to the present. Two fires are identified for this period, both of which burned in 2000 (**Appendix A, Figure A-15**). The High Ore fire burned 7,824 acres north of Boulder. The Boulder Hill fire burned 1,830 acres northeast of Boulder.

2.2 Social Profile

The following information describes the social profile of the Boulder River watershed.

2.2.1 Population

An estimated 2,300 persons lived within the watershed in 2010 (**Figure A-16** in **Appendix A**). Population estimates are derived from census data (United States Census Bureau, 2000), based upon the populations reported from census blocks within and intersecting the planning area boundary. The town of Boulder and Basin had reported populations of 1,183 and 212 in the 2010 census, respectively; the remainder of the population is sparsely distributed.

2.2.2 Transportation Networks

The principal transportation routes in the watershed are Interstate 15 and State Route 69. Route 69 follows the Boulder River between the Town of Boulder and Cardwell, MT. Interstate 15 runs through the headwaters portion of the watershed, including the towns of Boulder and Basin, and the area known as Elk Park.

2.2.3 Land Ownership

Land ownership data are provided by the State of Montana CAMA database via the NRIS website (Montana Department of Natural Resources and Conservation, 2008b). Slightly more than one-half of the watershed is under private ownership. The dominant landholder is the USFS, which administers 37% of the watershed. Montana State Trust Lands occupy 6% of the watershed. Land ownership is shown in **Table 2-3** and **Figure A-17** in **Appendix A**.

Table 2-3. Land ownership in the Boulder-Elkhorn TMDL Planning Area

Owner	Acres	Square Miles	% of Total
Private	148,413	231.9	56%
USFS	98,016	153.1	37%
BLM	2,723	4.3	1%
State Trust Land	14,971	23.4	6%
Total	264,124	412.7	100%

2.2.4 Land Use and Cover

Land use within the watershed is dominated by forest and agriculture. Agriculture in the lowlands is primarily related to the cattle industry: irrigated hay and dry grazing. Information on land use is based on National Land Cover Dataset (NLCD) mapping completed by the Multi-Resolution Land Characterization Consortium (MRLC) in 2001 (Homer et al., 2007). The data are at 30-meter resolution, and are based upon interpretation of aerial photographs. Potential sources of human impacts and their spacial extent are illustrated in **Table 2-4** and **Figure A-13** in **Appendix A**.

Table 2-4. Land Use and Cover

Land Use	Acres	Square Miles	% of Total
Evergreen Forest	241,384.2	377.2	54.01
Shrub/Scrub	91,835.4	143.5	20.55
Grassland/Herbaceous	84,012.6	131.3	18.8
Pasture/Hay	13,108.0	20.5	2.93
Transitional	6,979.7	10.9	1.56
Developed, Open Space	3,764.6	5.9	0.84
Woody Wetlands	2,373.6	3.7	0.53
Cultivated Crops	1,378.0	2.2	0.31
Developed, Low Intensity	1,530.8	2.4	0.34
Developed, Medium Intensity	261.6	0.4	0.06

Table 2-4. Land Use and Cover

Land Use	Acres	Square Miles	% of Total
Barren Land	142.5	0.2	0.03
Mixed Forest	79.4	0.1	0.02
Deciduous Forest	32.6	0.05	0.001
Developed, High Intensity	4.5	0.01	0.001
Emergent Herbaceous Wetlands	4.0	0.01	0.001
Totals	446,891.3	698.4	100

Berkas (2005) reported that roughly 3,500 acres upstream of the Boulder River near Boulder gage are irrigated with surface water diversions. A total of 6,754 acres of irrigated land is reported in the watershed. The dominant designated agricultural use is grazing, corresponding to 152,508 acres (238 square miles) or 31% of the watershed (Montana Department of Natural Resources and Conservation, 2008b).

2.2.5 Mining

Mining remains an important economic activity within Jefferson County. Mining and ore processing occurred widely within the watershed but were focused in the communities of Basin and Elkhorn. Waste rock and tailings deposits from historic mining, milling, and smelting operations persist in many locations. Like many Montana mining districts, much of the metal production began in the 1860s with gold-bearing placers. Later, significant lode deposits of lead, zinc, gold and silver were developed. Iron-bearing ore was mined in the Elkhorn district to provide flux to the East Helena smelter.

The environmental impacts of abandoned and inactive mines in the watershed have been widely studied (Madison et al., 1998; Metesh et al., 1995; Metesh et al., 1994). The influences of historic mining are most concentrated in the Basin and Cataract Creek drainages. The Environmental Protection Agency (EPA) added the Basin Mining Area to the Superfund National Priorities List (NPL) in 1999. Pollutant exposure risks are caused by mine waste accumulations in the town of Basin and surrounding watersheds. The NPL site includes the watersheds of Basin, Cataract, and High Ore creeks and portions of the Boulder River below the confluence with these heavily impacted streams. Listing makes the site eligible for federal cleanup funds. The EPA seeks to recover costs from the parties responsible for the contamination, or proceeds to complete reclamation work if no parties are found. The NPL designation also allows EPA to cooperate with other agencies (such as the U.S. Forest Service) in the cleanup. Under Superfund, affected communities are eligible to receive Technical Assistance Grants from EPA to provide a technical advisor for independent review of the proposed work. The Basin Creek Mine property, located on the Continental Divide between Basin and Tenmile Creeks, is now owned by Montana DEQ, and is operated as the Luttrell Depository. This facility provides encapsulated disposal for mine and mill waste from former mining sites in the region.

2.2.6 Permitted Wastewater Discharges

DEQ is required to administer permits for discharges of pollutants to surface and groundwater. The Montana Pollutant Discharge Elimination System (MPDES) program issues permits for discharges to surface water. Dischargers may operate under an individual permit tailored for a specific process, or operate under one of several general permits applied to broader discharge categories. There are 12 facilities in the Boulder River watershed that hold MPDES discharge permits. The town of Boulder and Boulder Hot Springs hold individual permits for discharges of domestic wastewater. Four general permits are held by portable suction dredge operators. Five general permits are issued for stormwater discharges from construction activity (building sites and gravel pits). In addition to a mine operating permit, Elkhorn Goldfields, Inc. holds a general stormwater discharge permit for mining activity. The MPDES permits in the planning area are summarized in **Table 2-5** and **Figure A-18** in **Appendix A**.

Table 2-5. Active MPDES Permits Issued in the Boulder-Elkhorn TPA

Facility Name	Facility Type	Permit Number	Permit Type	Receiving Stream
TOWN OF BOULDER WWTF	Municipal	MT0023078	NPDES Individual Permit	BOULDER RIVER
BOULDER HOT SPRINGS WWTP	Private Facility	MT0023639	NPDES Individual Permit	LITTLE BOULDER RIVER
PARKER SUCTION DRDGE	Private Facility	MTG370269	General Permit, Suction Dredge	LOWLAND CREEK
CARLSON RANCH SUCTION DREDGE	Private Facility	MTG370313	General Permit, Suction Dredge	LOWLAND CREEK
SNOWDRIFT DREDGE MINING	Private Facility	MTG370320	General Permit, Suction Dredge	SNOWDRIFT CREEK
BOULDER RIVER MIDSUMMER DREAM	Private Facility	MTG370322	General Permit, Suction Dredge	BOULDER RIVER
GILMAN EXCAVATING - CARLSON PIT	Private Facility	MTR103333	General Permit, Construction Stormwater	RED ROCK CREEK
MDOT ELKHORN ROAD SOUTH	State Government	MTR103698	General Permit, Construction Stormwater	BOULDER RIVER, LITTLE BOULDER RIVER
AM WELLES - COMPTON SITE	Private Facility	MTR103724	General Permit, Construction Stormwater	BOULDER RIVER
PUMCO - MDT CAREY BORROW	State Government	MTR103727	General Permit, Construction Stormwater	MURPHY IRRIGATION DITCH
MCALVAIN CONSTRUCTION	Private Facility	MTR103757	General Permit, Construction Stormwater	BOULDER RIVER
ELKHORN GOLDFIELDS INC	Private Facility	MTR300264	General Permit, Mining Stormwater	ELKHORN CREEK

Discharges of pollutants to groundwater are permitted by the Montana Groundwater Pollution Control System (MGWPCS) program at DEQ. The town of Basin is sewered and discharges domestic wastewater to groundwater for infiltration cells located south of Highway I-15. O.T. Mining, Inc. holds a MGWPCS permit number MTX000014 for discharges to groundwater from its custom mill tailings pond near the town of Basin.

Wastewater treatment for other communities and rural residences is provided by on-site septic tanks and drainfields. These types of systems are unpermitted systems and do not need MGWPCS permit coverage. Septic system density is estimated from the 2000 census block data, based on the assumption of one septic tank and drainfield for each 2.5 persons (Montana Department of Natural Resources and Conservation, 2008b). Septic system density is classified as low (less than 50 per square mile), moderate (51 to 300 per square mile) or high (greater than 300 per square mile). Nearly the entire watershed is mapped as having low density. Moderate density occurs on 215 acres; high density occurs on 47 acres. The high and moderate density locations are around the towns of Boulder and Basin. The community sewer system s at Boulder is mapped on 727 acres. The Basin system is unmapped. Septic system density is illustrated on **Figure A-18** in **Appendix A.**

There are no permitted Confined Animal Feeding Operations (CAFOs) currently reported in the watershed through the MPDES program. Aerial photo interpretation was conducted by TMDL program to identify potential locations where livestock appear to be focused for extended periods of time, within close proximity to a state waterbody. Although such locations may not meet CAFO definition criteria and thus not require and MPDES permit, they can still represent areas where significant pollutant loading can originate in the absence of BMPs. One facility that may be livestock feeding areas with potential for discharges to surface waters has been identified from aerial imagery (**Appendix A, Figure A-18**).

3.0 MONTANA WATER QUALITY STANDARDS

The federal Clean Water Act provides for the restoration and maintenance of the chemical, physical, and biological integrity of the nation's surface waters so that they support all designated uses. Water quality standards are used to determine impairment, establish water quality targets, and to formulate the TMDLs and allocations.

Montana's water quality standards and water quality standards in general include three main parts:

1. Stream classifications and designated uses
2. Numeric and narrative water quality criteria designed to protect designated uses
3. Nondegradation provisions for existing high-quality waters

Montana's water quality standards also incorporate prohibitions against water quality degradation as well as point source permitting and other water quality protection requirements.

Nondegradation provisions are not applicable to the TMDLs developed within this document because of the impaired nature of the streams addressed. Those water quality standards that apply to this document are reviewed briefly below. More detailed descriptions of Montana's water quality standards may be found in the Montana Water Quality Act (75-5-301,302 MCA) and Montana's Surface Water Quality Standards and Procedures (ARM 17.30.601-670).

3.1 STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Waterbodies are classified based on their designated uses. All Montana waters are classified for multiple uses. All streams in the Boulder River watershed are classified as B-1, (except for Basin Creek, which is A-1). A-1 and B-1 classifications specify that the water must be maintained suitable to support all of the following uses (Administrative Rules of Montana (ARM) (17.30.623(1)):

- Drinking, culinary, and food processing purposes, after conventional treatment (Drinking Water)
- Bathing, swimming, and recreation (Primary Contact Recreation)
- Growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers (Aquatic Life)
- Agricultural and industrial water supply

While some of the waterbodies might not actually be used for a designated use (e.g., drinking water supply), their water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana's surface water classifications and designated uses are provided in **Appendix C**. DEQ's water quality assessment methods are designed to evaluate the most sensitive uses for each pollutant group addressed within this document, thus ensuring protection of all designated uses (Montana Department of Environmental Quality, 2011). For streams in Western Montana, the most sensitive use assessed for sediment is aquatic life; for temperature is aquatic life; for metals are drinking water and/or aquatic life; and for nutrients is aquatic life and primary contact recreation. DEQ determined that thirteen waterbody segments in the Boulder River watershed do not meet the nutrient, sediment, and/or temperature water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and their Impaired Designated Uses in the Boulder-Elkhorn TPA

Waterbody & Location Description	Waterbody ID	Impairment Cause*	Impaired Use(s)
Basin Creek, headwaters to mouth (Boulder River)	MT41E002_030	Sediment / Siltation	Aquatic Life
Bison Creek, headwaters to mouth (Boulder River)	MT41E002_070	Total Nitrogen	Aquatic Life Primary Contact Recreation
		Total Phosphorus	Aquatic Life Primary Contact Recreation
		Sediment / Siltation	Aquatic Life
Boulder River, Town of Boulder to Cottonwood Creek	MT41E001_022	Sediment / Siltation	Aquatic Life
		Temperature	Aquatic Life
Boulder River, Cottonwood Creek to the mouth (Jefferson Slough), T1N R3W S2	MT41E001_030	Sediment / Siltation	Aquatic Life
		Temperature	Aquatic life
Cataract Creek, headwaters to mouth (Boulder River)	MT41E002_020	Sediment / Siltation	Aquatic Life
Elkhorn Creek, headwaters to Wood Gulch	MT41E002_061	Sediment / Siltation	Aquatic Life
Elkhorn Creek, Wood Gulch to mouth (Unnamed Canal/Ditch), T5N R3W S21	MT41E002_062	Sediment / Siltation	Aquatic Life
High Ore Creek, headwaters to mouth (Boulder River)	MT41E002_040	Sediment / Siltation	Aquatic life
		Temperature	Aquatic Life
McCarty Creek, headwaters to mouth (Boulder River)	MT41E002_110	Total Phosphorus	Aquatic Life Primary Contact Recreation
		Sediment / Siltation	Aquatic Life
Muskrat Creek, headwaters to mouth (Boulder River)	MT41E002_100	Sediment / Siltation	Aquatic Life
North Fork Little Boulder River, headwaters to mouth (Little Boulder)	MT41E002_090	Sediment / Siltation	Aquatic Life
Nursery Creek, headwaters (east branch) to mouth (Muskrat Creek)	MT41E002_130	Total Nitrogen	Aquatic Life Primary Contact Recreation
		Total Phosphorus	Aquatic Life Primary Contact Recreation
		Nitrate + Nitrite	Aquatic Life Primary Contact Recreation
		Sediment / Siltation	Aquatic Life
Uncle Sam Gulch, headwaters to mouth (Cataract Creek)	MT41E002_010	Nitrate + Nitrite	Aquatic Life Primary Contact Recreation
		Sediment / Siltation	Aquatic Life

* Only includes those pollutant impairments addressed by TMDLs in this document

3.2 Numeric and Narrative Water Quality Standards

In addition to the use classifications described above, Montana's water quality standards are include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations of specific pollutants so as not to impair designated uses. They apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, organic chemicals, and other toxic constituents).

Narrative standards are developed when there is insufficient information to develop numeric standards and/or the natural variability makes it impractical to develop numeric standards. Narrative standards describe the allowable or desired condition. This condition is often defined as an allowable increase above "naturally occurring." DEQ often uses the naturally occurring condition, called a "reference condition," to help determine whether or not narrative standards are being met (see **Appendix C**). For nutrient, sediment, and temperature TMDL development in the Boulder-Elkhorn TMDL Planning Area, only narrative standards are applicable; they are summarized in **Appendix C**.

4.0 Defining TMDLs and Their Components

A total maximum daily load (TMDL) is a tool for implementing water quality standards and is based on the relationship between pollutant sources and water quality conditions. More specifically, a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive from all sources and still meet water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are discernible, confined and discrete conveyances, such as pipes, ditches, wells, containers, or concentrated animal feeding operations, from which pollutants are being, or may be, discharged. Some sources such as return flows from irrigated agriculture are not included in this definition. All other pollutant loading sources are considered nonpoint sources. Nonpoint sources are diffuse and are typically associated with runoff, streambank erosion, most agricultural activities, atmospheric deposition, and groundwater seepage. Natural background loading is a type of nonpoint source.

As part of TMDL development, the allowable load is divided among all significant contributing point and nonpoint sources. For point sources, the allocated loads are called “wasteload allocations” (WLAs). For nonpoint sources, the allocated loads are called “load allocations” (LAs).

A TMDL is expressed by the equation: $TMDL = \Sigma WLA + \Sigma LA$, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation. Alternatively, the MOS can be implicit in the TMDL. A TMDL must also ensure that the waterbody will be able to meet and maintain water quality standards for all applicable seasonal variations (e.g., pollutant loading or use protection).

Development of each TMDL has four major components:
- Determining water quality targets
- Quantifying pollutant sources
- Establishing the total allowable pollutant load
- Allocating the total allowable pollutant load to their sources

Although the way a TMDL is expressed can vary by pollutant, these four components are common to all TMDLs, regardless of pollutant. Each component is described in further detail in the following subsections.

Figure 4-1 illustrates how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

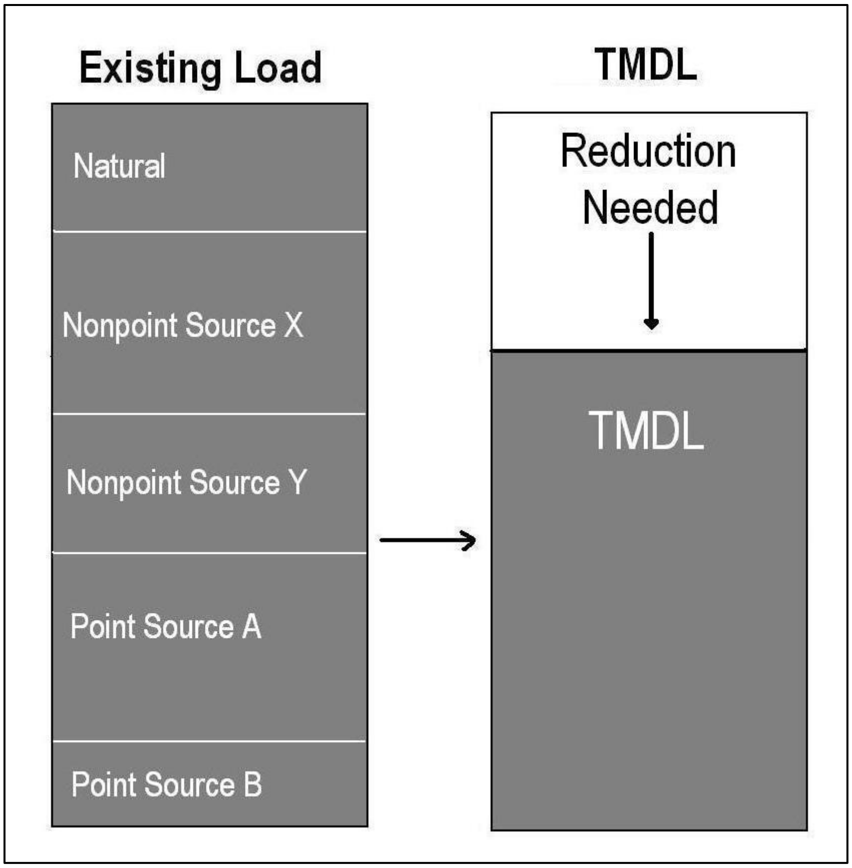

Figure 4-1. Schematic Example of TMDL Development

4.1 Developing Water Quality Targets

TMDL water quality targets are a translation of the applicable numeric or narrative water quality standard(s) for each pollutant. For pollutants with established numeric water quality standards, the numeric value(s) are used as the TMDL targets. For pollutants with narrative water quality standard(s), the targets provide a waterbody-specific interpretation of the narrative standard(s).

Water quality targets are typically developed for multiple parameters that link directly to the impaired beneficial use(s) and applicable water quality standard(s). Therefore, the targets provide a benchmark by which to evaluate attainment of water quality standards. Furthermore, comparing existing stream conditions to target values allows for a better understanding of the extent and severity of the problem.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Because the effects of pollutants on water quality can vary throughout the year, assessing pollutant sources must include an evaluation of the seasonal variability of the pollutant loading. The source assessment helps to define the extent of the problem by linking the pollutant load to specific sources in the watershed.

A pollutant load is usually quantified for each point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Nonpoint sources are quantified by source categories (e.g., unpaved roads) and/or by land uses (e.g., grazing or forestry). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, pollutant sources in a sub-watershed or source area can be combined for quantification purposes.

Because all potentially significant sources of the water quality problems must be evaluated, source assessments are conducted on a watershed scale. The source quantification approach may produce reasonably accurate estimates or gross allotments, depending on the data available and the techniques used for predicting the loading (40 CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate time period necessary to comply with the applicable water quality standard(s). Although "TMDL" implies "daily load," determining a daily loading may not be consistent with the applicable water quality standard(s), or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading during a time period that is appropriate for applying the water quality standard(s) and which is consistent with established approaches to properly characterize, quantify, and manage pollutant sources in a given watershed. For example, sediment TMDLs may be expressed as an allowable annual load.

If a stream is impaired by a pollutant for which numeric water quality criteria exist, the TMDL, or allowable load, is typically calculated as a function of streamflow and the numeric criteria. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

Some narrative standards, such as those for sediment, often have a suite of targets. In many of these situations it is difficult to link the desired target values to highly variable, and often episodic, instream loading conditions. In such cases the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the federal Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period, as noted above.

4.4 Determining Pollutant Allocations

Once the allowable load (the TMDL) is determined, that total must be divided among the contributing sources. The allocations are often determined by quantifying feasible and achievable load reductions through application of a variety of best management practices and other reasonable conservation practices.

Under the current regulatory framework (40 CFR 130.2) for developing TMDLs, flexibility is allowed in allocations in that "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure (e.g., a percent increase in canopy density for temperature TMDLs).

Figure 4-2 illustrates how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

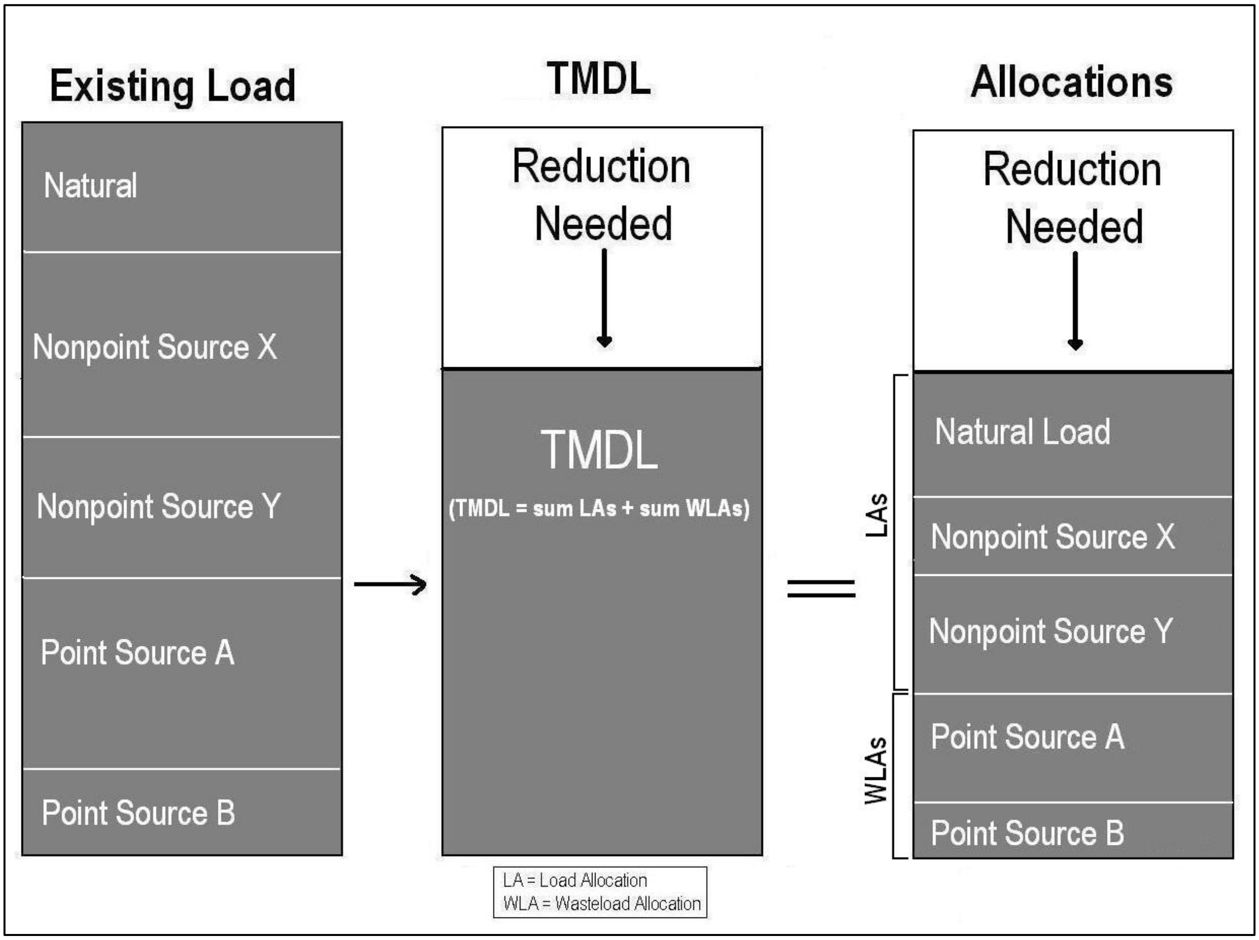

Figure 4-2. Schematic Diagram of a TMDL and its Allocations

TMDLs must also incorporate a margin of safety. The margin of safety accounts for the uncertainty, or any lack of knowledge, about the relationship between the pollutant loads and the quality of the receiving waterbody. The margin of safety may be applied implicitly by using conservative assumptions in the TMDL development process, or explicitly by setting aside a portion of the allowable loading (i.e., a TMDL = WLA + LA + MOS) (U.S. Environmental Protection Agency, 1999). The margin of safety is a required component to help ensure that water quality standards will be met when all allocations are achieved. In Montana, TMDLs typically incorporate implicit margins of safety.

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. For TMDLs in this document where there is a combination of nonpoint sources and one or more permitted point sources discharging into an impaired stream reach, the permitted point source WLAs are not dependent on implementation of the LAs. Instead, DEQ sets the WLAs and LAs at levels necessary to achieve water quality standards throughout the watershed. Under these conditions, the LAs are developed independently of the permitted point source WLA such that they would satisfy the TMDL target concentration within the stream reach immediately above the point source. In order to ensure that the water quality standard or target concentration is achieved below the point source discharge, the WLA is based on the point source's discharge concentration set equal to the standard or target concentration for each pollutant.

4.5 Implementing TMDL Allocations

The Clean Water Act (CWA) and Montana state law (Section 75-5-703 of the Montana Water Quality Act) require wasteload allocations to be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Nonpoint source reductions linked to load allocations are not required by the CWA or Montana statute, and are primarily implemented through voluntary measures. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 9.0** discusses a restoration and implementation strategy by pollutant group and source category, and provides recommended best management practices (BMPs) per source category (e.g., grazing, cropland, urban, etc.). **Section 9.0** also discusses potential funding sources that stakeholders can use to implement BMPs for nonpoint sources. Other site-specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. DEQ's Watershed Protection Section helps to coordinate nonpoint implementation throughout the state and provides resources to stakeholders to assist in nonpoint source BMPs. Montana's Nonpoint Source Management Plan (available at http://www.deq.mt.gov/ wqinfo/nonpoint/nonpointsourceprogram.mcpx) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 10.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute. TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 Sediment TMDL Components

This portion of the document focuses on sediment as an identified cause of water quality impairment in the Boulder-Elkhorn TPA. It includes: 1) the mechanisms by which sediment can impair beneficial uses, 2) the specific stream segments of concern, 3) the presently available data pertaining to sediment impairment characterization in the watershed, including target development and a comparison of existing water quality to targets, 4) quantification of the various contributing sources of sediment based on recent data and studies, and 5) identification of and justification for the sediment TMDLs and the TMDL allocations. An overview of the watershed is presented in **Figure 5-1**.

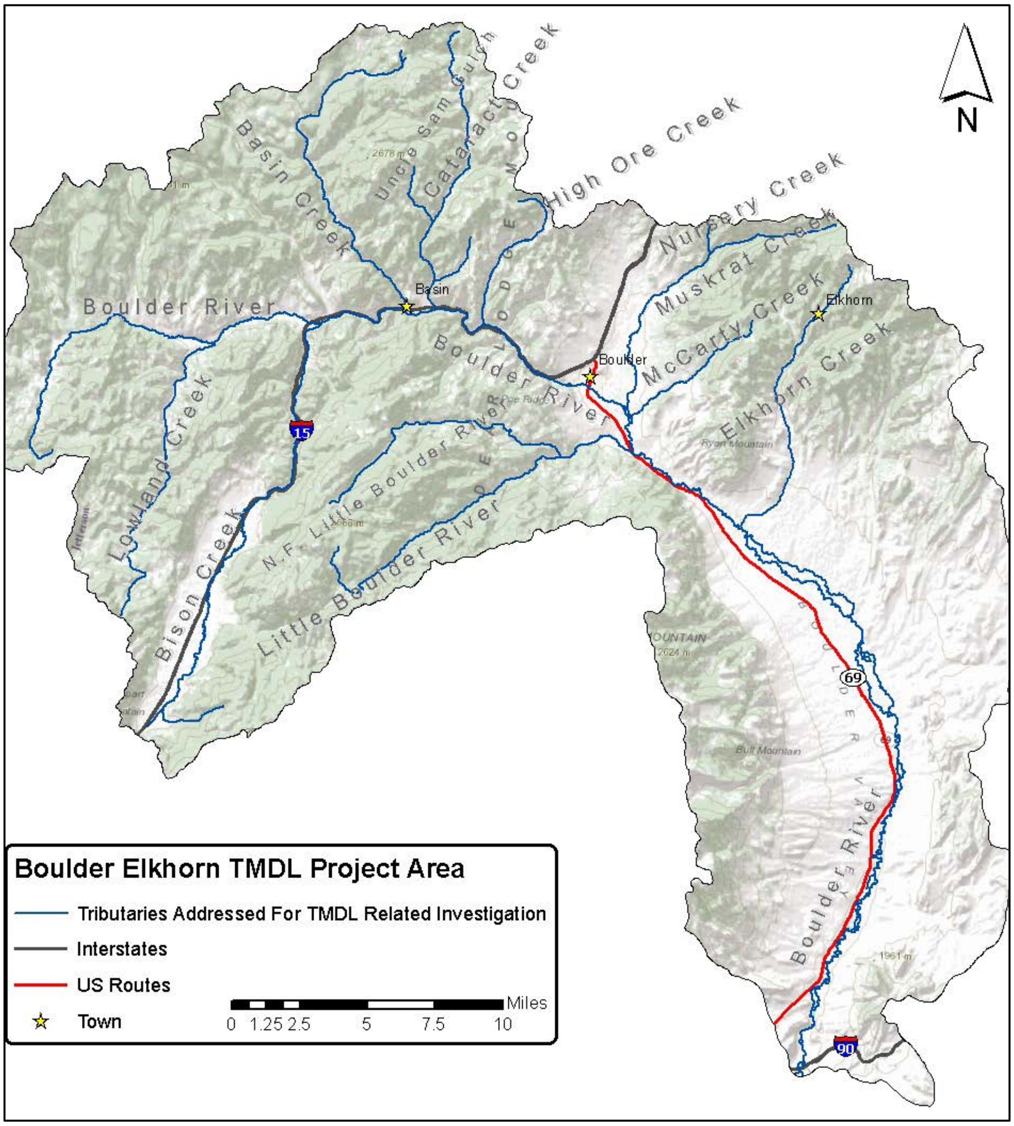

Figure 5-1. Boulder Elkhorn Watershed

The term sediment is used in this document to refer collectively to several closely-related factors associated with the sediment pollutant, including suspended sediment, turbidity, or alterations to habitat or channel shape and character that may affect sediment delivery and transport, and sediment deposition on the stream bottom.

5.1 Effects of Excess Sediment on Beneficial Uses

Sediment is a naturally occurring component of healthy and stable stream and lake ecosystems. Erosion through natural processes such as wind, water, or ice constantly supplies our waters with some amounts of sediment. Regular flooding allows sediment deposition to build floodplain soils and point bars, and it prevents excess scour of the stream channel. Riparian vegetation and natural instream barriers such as large woody debris, beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features. When these barriers are absent, or human causes create excessive sediment loads from bank erosion or other sources on the landscape, it may alter channel form and function. These alterations may affect fish and other aquatic life by increasing turbidity and causing excess sediment to accumulate in critical aquatic habitat areas not naturally characterized by high levels of fine sediment.

More specifically, sediment may block light and cause a decline in primary production, and it may also interfere with fish and macroinvertebrate survival and reproduction. Fine sediment deposition reduces availability of suitable spawning habitat for salmonid fishes and can smother eggs or hatchlings. Effects from excess sediment are not limited to suspended or fine sediment; an accumulation of larger sediment (e.g. cobbles) can fill pools, reduce the percentage of desirable particle sizes for fish spawning, and cause channel overwidening (which may lead to additional sediment loading and/or increased temperatures). This larger sediment can also reduce or eliminate flow in some stream reaches where sediment aggrades within the channel, causing flow to go subsurface (May and Lee, 2004). Although fish and aquatic life are typically the most sensitive beneficial uses regarding sediment, excess sediment may also affect other uses. For instance, high concentrations of suspended sediment in streams can also cause water to appear murky and discolored, negatively impacting recreational use, and excessive sediment can increase filtration costs for water treatment facilities that provide safe drinking water.

5.2 Stream Segments of Concern

A total of eleven waterbody segments in the Boulder-Elkhorn TPA appeared on the 2012 Montana 303(d) List due to sediment impairments (**Table 5-1**). These streams include: Basin Creek, Boulder River, Cataract Creek, Elkhorn Creek, High Ore Creek, McCarty Creek, North Fork Little Boulder River, Nursery Creek, and Uncle Sam Gulch. As shown in **Table 5-1 and Figure 5-1**, many of the waterbodies with sediment impairments are also listed for habitat alterations, which are non-pollutant causes of impairment frequently associated with sediment. TMDLs are developed for pollutants, but implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some non-pollutant impairment causes.

Table 5-1. Waterbody Segments in the Boulder-Elkhorn TPA with Sediment Related Pollutant and/or Non-pollutant (Pollution) Listings on the 2012 303(d) List

Waterbody ID	Stream Segment	2012 Probable Causes of Impairment
MT41E002_030	**BASIN CREEK**, headwaters to mouth (Boulder River)	**Sedimentation/siltation,** *Alteration in streamside or littoral vegetation covers*
MT41E002_070	**BISON CREEK,** headwaters to mouth (Boulder River)	*Alteration in streamside or littoral vegetative covers*
MT41E001_021	**BOULDER RIVER**, Basin Creek to Town of Boulder	*Alteration in streamside or littoral vegetation covers*
MT41E001_022	**BOULDER RIVER,** Town of Boulder to Cottonwood Creek	**Sedimentation/Siltation,** *Alteration in streamside or littoral vegetation covers*

Table 5-1. Waterbody Segments in the Boulder-Elkhorn TPA with Sediment Related Pollutant and/or Non-pollutant (Pollution) Listings on the 2012 303(d) List

Waterbody ID	Stream Segment	2012 Probable Causes of Impairment
MT41E001_030	**BOULDER RIVER**, Cottonwood Creek to the mouth (Jefferson Slough), T9N R3W S2	**Sedimentation/siltation**, *Alteration in streamside or littoral vegetation covers*
MT41E002_020	**CATARACT CREEK,** headwaters to mouth (Boulder River)	**Sedimentation/Siltation**
MT41E002_061	**ELKHORN CREEK,** headwaters to Wood Gulch	**Sedimentation/Siltation,** *Alteration in streamside or littoral vegetation covers, Low flow alterations*
MT41E002_062	**ELKHORN CREEK,** Wood Gulch to mouth (Unnamed Canal/Ditch), T5N R3W S21	**Sedimentation/Siltation,** *Low flow alterations*
MT41E002_040	**HIGH ORE CREEK,** headwaters to mouth (Boulder River)	**Sedimentation/Siltation, Total Suspended Solids (TSS)*,** *Alteration in streamside or littoral vegetation covers*
MT41E002_080	**LITTLE BOULDER RIVER,** North Fork to mouth (Boulder River)	*Alteration in streamside or littoral vegetative covers, Physical substrate habitat alterations*
MT41E002_050	**LOWLAND CREEK,** headwaters to mouth (Boulder River)	*Alteration in streamside or littoral vegetative covers, Physical substrate habitat alterations*
MT41E002_110	**McCARTY CREEK,** headwaters to mouth (Boulder River)	**Sedimentation/siltation,** *Alteration in streamside or littoral vegetative covers, Low flow alterations*
MT41E002_100	**MUSKRAT CREEK,** headwaters to mouth (Boulder River)	*Alteration in streamside or littoral vegetative covers*
MT41E002_090	**NORTH FORK LITTLE BOULDER RIVER,** headwaters to mouth (Little Boulder River)	**Sedimentation/siltation,** *Alteration in streamside or littoral vegetative covers*
MT41E002_130	**NURSERY CREEK,** headwaters to mouth (Muskrat Creek)	**Sedimentation/Siltation**
MT41E002_010	**UNCLE SAM GULCH,** headwaters to mouth (Cataract Creek)	**Sedimentation/Siltation, Turbidity*,** *Alteration in streamside or littoral vegetative covers*

*TSS and Turbidity are pollutants that fall within the Sediment pollutant category
Non-pollutant (pollution) listings are presented in *italics*

All streams in **Table 5-1** were included for data collection and analysis as a result of their appearance on the state's list of impaired waters for sediment and/or non-pollutant impairment causes frequently associated with sediment. These sites within the Boulder-Elkhorn TPA helped provide the foundation for target development, and give a broader representation of sediment issues throughout the watershed. Data and reporting from the 2010 field effort for these streams is included in **Attachment A**.

Data from the streams in **Table 5-1** were reviewed relative to sediment targets. TMDLs were developed for all streams with sediment pollutant listings. Data from two of the streams listed for only non-pollutant listings showed a strong indication of excess sediment (Bison Creek, Muskrat Creek) and consequently TMDL s were developed for those streams as well. Although TMDLs were not developed for every stream in **Table 5-1**, the sediment reduction strategies discussed for the TMDL streams are applicable to all streams in **Table 5-1** due to the strong relationship between habitat and sediment impairments, and consideration that all sediment sources to the Boulder River must be taken into account. Sediment reduction strategies in effect, apply to all streams in the watershed where excess sediment may be affecting state beneficial uses, and where opportunity exists to improve management practices and reduce sediment from human caused sources.

5.3 Information Sources and Assessment Methods

The information sources used to develop the TMDL components include information used during the initial impairment determination (**See Section 3.0**), in addition to data obtained during the recent TMDL development process. The following data was considered in preparing the TMDL components:

The data collected by DEQ, its contractors, and other agencies, was catalogued within DEQ's centralized water quality database and archives. The data considered in preparing the assessments include a wide range of:

- chemical, physical, and biological water quality monitoring results;
- fisheries inventories;
- streamflow data;
- GIS data layers;
- agency and university documents; and
- land use information

The data was used to evaluate sediment sources and compare existing conditions to waterbody restoration goals. It was also used to provide a framework restoration strategy that, if implemented, will reduce pollutant contributions so that beneficial uses can be supported.

For TMDL development, information sources and assessment methods fall within two general categories. The first category, discussed within this section and **Section 5.4**, is focused on characterizing overall stream health with focus on sediment and related water quality conditions. The second category, discussed within **Section 5.5**, is focused on quantifying sources of sediment loading within the watershed.

5.3.1 Summary of Information Sources

To characterize sediment conditions for TMDL development purposes, a sediment data compilation was completed and additional monitoring was performed during 2010. The below listed data sources represent the primary information used to characterize water quality and/or develop TMDL targets.

- DEQ Assessment Files
- DEQ 2010 Sediment and Habitat Assessments
- USFS Beaverhead-Deerlodge National Forest Stream Condition and Habitat Data
- USFS Pacfish/Infish Biological Opinion (PIBO) Data
- USFS Beaverhead-Deerlodge National Forest Road Assessment Data
- USGS Water Quality and Quantity Data
- Montana Department of Transportation Road Sanding Data
- Montana Fish Wildlife & Parks Fish Data
- BLM Reclamation Evaluation Report (High Ore Creek)

5.3.2 DEQ Assessment Files

The DEQ assessment files contain information used to make the existing sediment impairment determinations. The files include a summary of physical, biological, and habitat data collected by DEQ on most waterbodies between 1999 and 2008 as well as other historical information collected or obtained by DEQ. The files also include information on sediment water quality characterization and potentially significant sources of sediment, as well as information on non-pollutant impairment determinations and associated rationale.

5.3.3 DEQ's 2010 Sediment and Habitat Assessments

Field measurements of channel morphology and riparian and instream habitat parameters were collected in 2010 from 23 sites on 13 waterbodies to aid in TMDL development. (Detailed locations and further information included in **Attachment A**.)

Initially, all streams of interest underwent an aerial assessment by which reaches were characterized by four main attributes: stream order, valley gradient, valley confinement, and ecoregion. These four attributes represent main factors influencing stream morphology, which in turn influence sediment transport and deposition. These four attributes are also assumed to be unaffected by human influence.

The next step in the aerial assessment involved identification of near-stream land uses since land management practices can have a significant influence on stream morphology and sediment characteristics. The resulting product was a stratification of streams into reaches that allow for comparisons among those reaches of the same natural morphological characteristics, while also indicating stream reaches where land management practices may further influence stream morphology. The stream stratification, along with field reconnaissance, provided the basis for selecting the above-referenced monitoring reaches. Stream stratification results are included in **Appendix B**.

Monitoring sites were chosen with the goal of being representative of various reach characteristics, land use categories, and anthropogenic influence. However, there was a preference to ensure sampling of some sites where anthropogenic influences would likely be apparent since it is a primary goal of sediment TMDL development to characterize sediment impairment conditions. Thus, it is not a random sampling design intended to sample stream reaches representing all potential impairment and non-impairment conditions. Instead, it is a targeted sampling design that aims to assess a representative subset of reach types while ensuring that reaches within each of the streams of interest are incorporated into the overall evaluation. Typically, the effects of excess sediment are most apparent in low gradient, unconfined streams larger than 1st order (i.e. having at least one tributary); therefore, this stream type was the focus of the field effort. Although the TMDL development process necessitates this targeted sampling design, it is acknowledged that this approach results in less certainty regarding conditions in 1st order streams and higher gradient reaches, and that conditions at sites within reaches are not necessarily representative of conditions throughout the entire stream.

The field parameters assessed in 2010 include standard measures of stream channel morphology, fine sediment, stream habitat, riparian vegetation, and streambank erosion. Although the sampling areas are frequently referred to as "sites" within this document, to help increase sample sizes and capture variability within assessed streams, they were actually sampling distances ranging from 500 to 2000 feet (depending on the channel bankfull width) that were broken into five cells. Generally, channel morphology and fine sediment measures were performed in four of the cells, and stream habitat, riparian, and bank erosion measures were performed in all cells. Field parameters are briefly described in **Section 5.4**, and summaries of all field data are contained in the 2010 monitoring summary report (**Attachment A**).

5.3.4 Relevant Local and Regional Reference Data

Reference data refers to data that may be used to determine a reference condition; in other words, a condition meeting naturally occurring conditions (including all reasonable land, soil, and water conservation practices). Relevant local and regional reference data was reviewed from Beaverhead - Deerlodge National Forest (BDNF) reference sites and sites of the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO) in the BDNF. The PIBO reference dataset includes USFS and BLM sites throughout the Pacific Northwest, but to increase the comparability of the data to conditions in the Boulder River watershed, only data collected from watersheds within or adjacent to the Boulder-Elkhorn TPA were evaluated.

5.3.5 Other Relevant Local and Regional Data

Including the information described above, water quality data from USGS, data from the BLM on High Ore Creek, road data from the BDNF and MDT, MT FWP fish data, and other various sources were used to evaluate and describe existing conditions.

5.4 Water Quality Targets

The following sections describe the water quality targets used to evaluate stream conditions in the Boulder-Elkhorn TPA as they relate to sediment impairment and a comparison of those targets to available data for sediment for streams of interest.

5.4.1 Targets

DEQ uses multiple parameters related to stream habitat and morphology to determine the relative effect of sediment on a stream’s beneficial uses. These parameters provide a quantitative translation of a narrative standard. The values for these parameters are referred to as targets and they represent the instream conditions that would likely be found when all TMDL allocations are met. Usually, not one single water quality target is sufficient for determining the condition of a stream; however, when viewed in combination, measures of instream siltation, the presence and quality of certain habitat features, and biological response to increased sediment provide a good representation of the effects from sediment. When assessing stream condition it is also crucial to take into account the degree to which one or more targets are exceeded.

In developing these targets, consideration must be made to account for natural variation throughout the river. Specifically, some reaches have a natural tendency for storage of sediment and others are prone to sediment transport. In addition, stream size and power factor into the response of a stream to increased sediment. Therefore, targets may be broken into sub-categories, such that they can be applied appropriately.

The water quality targets presented in this section (**Table 5-2**) are based on the best science and information available at the time this document was written. However, targets may be assessed during future TMDL reviews for their appropriateness and can be modified if new information provides a better understanding of reference conditions. In addition, it is noted that evaluation of a stream relies not only on a comparison to targets, but a combination of target analysis, qualitative observations, and sound, scientific professional judgment. A brief description and justification of the target parameters used in the analysis is included in the sections that follow, and rationale and development of target values is included in **Appendix D**.

Table 5-2. Boulder-Elkhorn TPA Morphology, Substrate, and Habitat Targets

TARGET PARAMETER	TARGET VALUE
Morphology	
Width/Depth Ratio	
B streams (Rosgen classification)	≤13
C streams (Rosgen classification)	≤18
Boulder River mainstem	≥30
Entrenchment Values correspond to Rosgen stream type delineative criteria	A,F,G types - <1.4; B type – 1.4-2.2; C, E types - >2.2; D type – n/a; Da type – >4.0
Substrate Composition	
Wolman Riffle Pebble Count, % <2mm	≤10
Wolman Riffle Pebble Count, % <6mm	≤16
Pool Tail Grid Pebble Count, % <6mm	≤13
Pool Habitat	
Pool Frequency (#/mile)	
Bankfull Width <15 feet	≥120
Bankfull Width 15-40 feet	≥90
Bankfull Width >40 feet	≥50
Boulder River mainstem	≥30
Residual Pool Depth (feet)	
Bankfull Width <15 feet	≥0.8
Bankfull Width 20-40 feet	≥1.4
Bankfull Width >40 feet	≥1.9
Riparian Indicators	
Percent Streamside Shrub Cover	≥65%
Percent Streamside Bare Ground	0%
Biological Indicators	
O/E Model value	≥ 0.80

5.4.1.1 Morphology

Parameters related to stream morphology describe channel shape and dimension, and thereby indicate the ability of the stream to store and transport sediment. Stream gradient and valley confinement are two significant controlling factors that determine stream form and function, however alterations to the landscape, and sediment input beyond naturally occurring amounts can affect stream morphology. Numerous scientific studies have found trends and common relationships between channel dimensions in properly functioning stream systems and those with a sediment imbalance. Two of those relationships are used as targets in the Boulder-Elkhorn TPA and are described below.

Width/Depth Ratio and Entrenchment Ratio

The width/depth ratio and the entrenchment ratio are fundamental aspects of channel morphology; each provides a measure of channel stability and indicates a stream's ability to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e., riffles, pools, and near-bank zones). Changes in both the width/depth ratio and entrenchment ratio can be used to indicate change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess coarse sediment load (MacDonald et al., 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in channel width as the stream attempts to regain a balance between sediment load and transport capacity. Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios signify that stream energy is concentrated in-channel during flood events rather than dissipating energy to the floodplain. Accelerated bank erosion and an increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Knighton, 1998; Rosgen, 1996; Rowe et al., 2003).

5.4.1.2 Substrate Composition

Percent surface fines provide a good measure of the siltation occurring in a river system and serve as an indicator of the ability of stream bottom habitat to support aquatic life. Cover et al (2008) observed a correlation between sediment supply and instream measurements of fine sediment in riffles and pools. Although it is difficult to correlate percent surface fines with sediment loads in mass per time directly, the Clean Water Act allows "other applicable measures" for the development of TMDL water quality restoration plans. Percent surface fine measures have been used successfully in other sediment TMDLs in western Montana to address stream bottom deposits, siltation, and aquatic life uses.

Percent Fines <2mm

Surface fine sediment measured using the Wolman (1954) pebble count method can indicate excessive sediment loading. Studies have shown that increased substrate fine materials less than 2mm can adversely affect embryo development success by limiting the amount of oxygen needed for development (Meehan, 1991). In addition, as described in the Flathead Headwaters TMDL (Montana Department of Environmental Quality, 2004), work completed in the Boise National Forest in Idaho showed a strong correlation between the health of macroinvertebrate communities and percent surface fine particles less than two millimeters.

Percent Fines <6mm

As with surface fine sediment smaller than 2mm diameter, an accumulation of surface fine sediment less than 6mm diameter may also indicate excess sedimentation, and may have detrimental impacts on aquatic habitat. Size distribution of substrate material in the streambed is also indicative of habitat quality for salmonid spawning and egg development. Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material less than 6.35 mm and the emergence success of westslope cutthroat trout and bull trout.

5.4.1.3 Pool Features

Pools are stream features characterized by slow moving, deep sections of the stream. These important components aid the balance between flow and sediment load by reducing stream velocity and storing water and sediment. The measure and comparison of pool features can have direct links to sediment load increases and its effect on stream form and function, as well as biological integrity (Cover et al., 2008). Pool features play an important role for aquatic life and fisheries by providing refuge from warm water, high velocity, and terrestrial predators. However, when sediment loads are excessive, pool habitat quality and frequency is often diminished as pools fill with sediment. When this happens, velocities increase, stream channels widen, and sediment is transported to other areas of the stream where it may be deposited into areas that have an additional impact on fisheries and aquatic life.

Residual Pool Depth

Residual pool depth, defined as the difference between the maximum depth and the tail crest depth, is a discharge-independent measure of pool depth and an indicator of pool habitat quality. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods (Baigun, 2003; Bonneau and Scarnecchia, 1998; Nielson et al., 1994). Similar to channel morphology measurements, residual pool depth integrates the effects of several stressors; pool depth can be decreased as a result of filling with excess sediment (fine or coarse), a reduction in channel obstructions (such as large woody debris), and changes in channel form and stability (Bauer and Ralph, 1999). A reduction in pool depth from channel aggradation may not only alter surface flow during the critical low flow periods, but may also harm fish by altering habitat, food availability, and productivity (May and Lee, 2004; Sullivan and Watzin, 2010). Residual pool depth is typically greater in larger systems. During DEQ sampling in 2009, pools were defined as depressions in the streambed bounded by a “head crest” at the upstream end and “tail crest” at the downstream end with a maximum depth that was 1.5 times the pool-tail depth (Kershner et al., 2004).

Pool Frequency

Pool frequency is another indicator of sediment loading that relates to changes in channel geometry and is an important component of a stream’s ability to support the fishery beneficial use (Muhlfeld and Bennett, 2001). Sediment may limit pool habitat by filling in pools with fines. Alternatively, aggradation of larger particles may exceed the stream’s capacity to scour pools, thereby reducing the prevalence of this critical habitat feature. Pool frequency generally decreases as stream size (i.e. watershed area) increases.

5.4.2 Supporting Information/Supplemental Water Quality Parameters

Although the following categories are not a direct measure of sediment, they do provide insight into the overall riparian quality. Riparian condition is often associated with factors that may be leading to increased sediment loads and the reduction of instream habitat.

During the 2010 DEQ sediment and habitat data collection, a riparian assessment method (ie, Greenline) (Montana Department of Environmental Quality, 2010) was used to conduct a coarse survey of the riparian corridor and its general vegetation composition. The results are used here to infer riparian corridor health and bank stability. In addition, large woody debris counts were conducted and results were tallied to develop targets.

Understory Shrub Cover along Green Line

Riparian shrub cover is one of the most important influences on streambank stability. Removal of riparian shrubs can dramatically increase streambank erosion and increase channel width/depth ratios. Shrubs stabilize streambanks by holding soil and armoring lower banks with their roots, and reduce scouring energy of water by slowing flows with their branches.

Good riparian shrub cover is also important for fish habitat. Riparian shrubs provide shade, reducing solar inputs and increases in water temperature. The dense network of fibrous roots of riparian shrubs allows streambanks to remain intact while creating important fish habitat in the form of overhanging banks and lateral scour pools. Overhanging branches of riparian shrubs provide important cover for aquatic species. In addition, riparian shrubs provide critical inputs of food for fish and their feed species. Terrestrial insects falling from riparian shrubs provide one main food source for fish. Organic inputs from shrubs, such as leaves and small twigs, provide food for aquatic macroinvertebrates, which are another important food source for fish.

Bare Ground along Green Line
Percent bare ground is an important indicator of erosion potential, as well as an indicator of land management influences on riparian habitat. Bare ground was noted in the greenline inventory in cases where recent ground disturbance was observed, leaving bare soil exposed. Bare ground is often caused by trampling from livestock or wildlife, fallen trees, recent bank failure, new sediment deposits from overland or overbank flow, or severe disturbance in the riparian area, such as from past mining, road-building, or fire. Ground cover on streambanks is important to prevent sediment recruitment to stream channels. Sediment can wash in from unprotected areas due to snowmelt, storm runoff, or flooding. Bare areas are also much more susceptible to erosion from hoof shear. Most stream reaches have a small amount of naturally-occurring bare ground. As conditions are highly variable, this measurement is most useful when compared to reference values from best available conditions within the study area or literature values.

Large Woody Debris
Large woody debris in the form of branches, trunks, rootwad, and other manner of downed wood within the active stream channel is a vital component of most western Montana stream ecosystems. Large wood in the channel provides multiple benefits for fish and other aquatic life by creating cover and habitat, encouraging scour resulting in pool development and sediment transport, and being a component in the overall foodweb for the various lifeforms in and around the stream. In addition, large woody debris may also be an indicator of riparian community health and maturity, which also has impacts on the overall form and function of a stream ecosystem.

Although large woody debris does not, by itself, suggest impairment from sediment, because of the common linkages that large woody debris has on stream health, it is commonly reviewed in combination with other sediment parameters to provide a better picture of the overall issues affecting a stream. Large woody debris discussion within the context of this document is used for that purpose and is not suggested as a target value per say; but simply to provide a stronger weight of evidence when discussing the condition of streams in the Boulder-Elkhorn TPA.

Macroinvertebrates
Siltation exerts a direct influence on benthic macroinvertebrates assemblages by filling in spaces between gravel and by limiting attachment sites. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessment scores are an assessment of the macroinvertebrate assemblage at a site, and DEQ uses one bioassessment methodology to evaluate stream condition and aquatic life beneficial-use support. Aquatic insect assemblages may be altered as a result of different stressors such as nutrients, metals, flow, and temperature, and the biological index values must be considered along with other parameters that are more closely linked to sediment.

The macroinvertebrate assessment tool used by DEQ is the Observed/Expected model (O/E). The rationale and methodology for the index is presented in the DEQ Benthic Macroinvertebrate Standard Operating Procedure (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2006). The O/E model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled and is expressed as a ratio of the Observed/Expected taxa (O/E value). The O/E community shift point for all Montana streams is any O/E value < 0.80. Therefore, an O/E score of ≥ 0.80 is established as a sediment target in the Boulder-Elkhorn TPA.

An index score greater than the threshold value is desirable, and the result of each sampling event is evaluated separately. Because index scores may be affected by other pollutants or forms of pollution such as habitat disturbance, they will be evaluated in consideration of more direct indicators of excess sediment. In other words, not meeting the biological target does not automatically equate to sediment impairment. Additionally, because the macroinvertebrate sample frequency and spatial coverage is typically low for each watershed and because of the extent of research showing the harm of excess sediment to aquatic life, meeting the biological target does not necessarily indicate a waterbody is fully supporting its aquatic life beneficial use. For this reason, measures that indicate an imbalance in sediment supply and/or transport capacity will also be used for TMDL development determinations.

5.4.3 Existing Conditions and Comparison to Targets

The following sections provide a review of DEQ field data and assessment record information for all stream segments currently listed for sediment impairment or for those segments where sediment impairment is determined based on available data. TMDL development status is described at the end of each stream segment discussion.

5.4.3.1 Basin Creek, headwaters to the mouth (Boulder River); MT41E002_030

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Basin Creek was compiled in 1999. A brief summary review of that information provides the following description:

Past subsurface mining and placer mining have resulted in sediment and metals impairments. In addition, roads were identified as a sediment source. Above Jack Creek, considerable suspended solids were observed at all sampling locations reviewed. Below the town of Basin, habitat was classified as marginal (39% of total possible score) and identified channel alterations, poor riffle development, limited habitat diversity, and poor riparian conditions as problems. Fish habitat was described as ‘poor’. Macroinvertebrate metrics indicates moderate impairment as well (with score 25% to 75% of reference).

2010 Field Investigation

Two sites on Basin Creek were evaluated by the DEQ during the 2010 field effort (**Figure 5-2**). Both sites occur in unconfined valleys, with valley gradients less than 2%. BASI 08-02 is in a second order reach, and BASI 15-02 is in a third order reach. Width/Depth ratios were high at both sites. BASI 08-02 did not meet the residual pool depth target, but pool frequency was good. Conversely, BASI 15-02 met the residual pool depth target, but not pool frequency (**Table 5-3**).

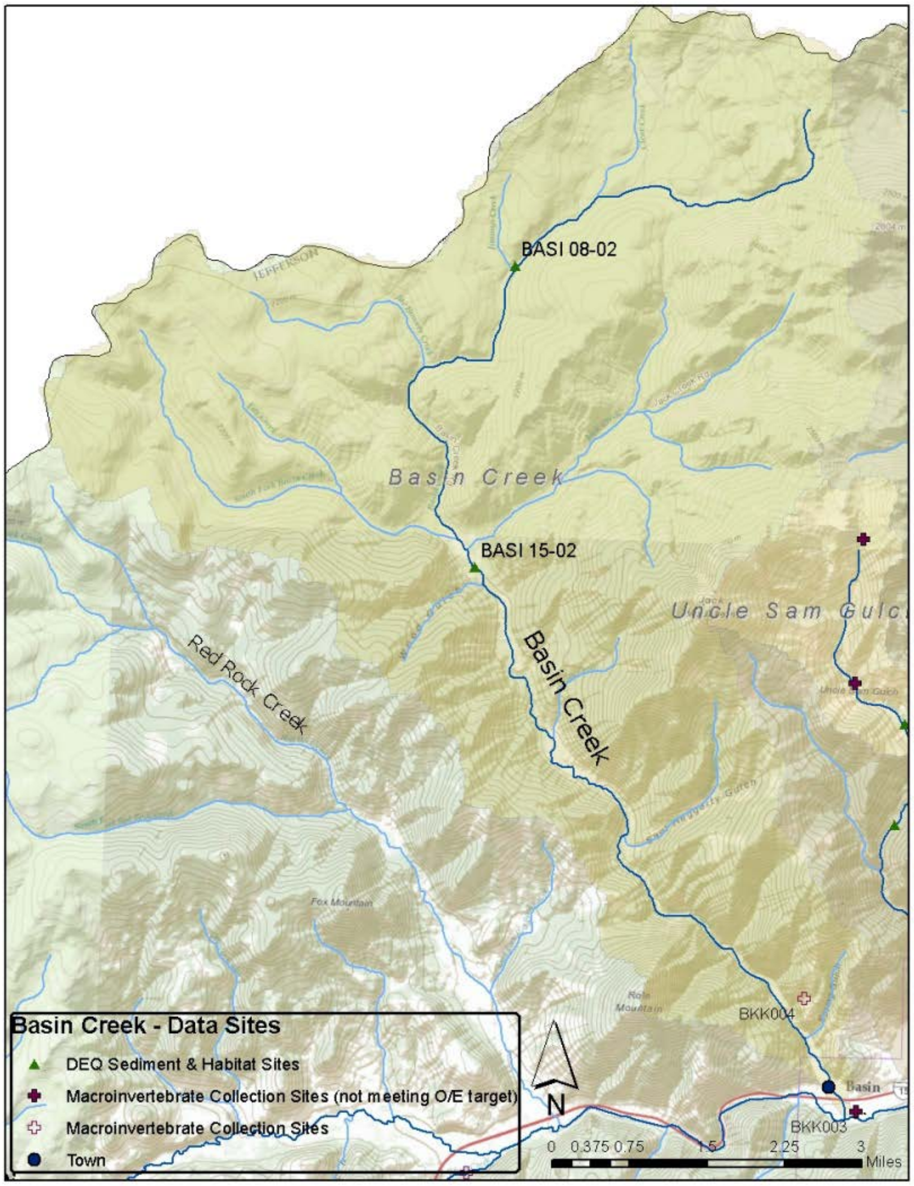

Figure 5-2. Basin Creek Data Locations

Table 5-3. Basin Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
BASI 08-02	17ai	0-2-U	19.5	**30.8**	2.2	**1.0**	106
BASI 15-02	17ai	0-3-U	34.2	**34.6**	4.3	1.9	**63**

Percent fines data met target values at both sites. In addition, percent shrub cover was well below expected values for both sites, particularly at BASI 08-02, suggesting human influence on the riparian corridor (**Table 5-4**).

Table 5-4. Basin Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
BASI 08-02	5	13	0	**8**	0	380
BASI 15-02	5	10	-	**32**	0	206

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- BASI 08-02 field notes document significant human impacts related to a parallel road and remnants of historic placer mining. In general, the stream appears significantly over-widened. Site notes describe a general lack of quality pool formation, although pool formation is influenced by bends and large wood. Appropriate spawning gravel in pool tails is limited (only two locations suitable for measurement were observed in pools; those pools formed by large wood). Active streambank erosion was minimal despite the obvious signs of nearby human influence, however the over-widened stream channel and lack of discernible banks implied the stream has begun to stabilize from disturbance that occurred many years ago.

- The area around BASI 15-02 also appears to have significant influence from human activity. Nearby, there is a residence and landing strip, and the landscape surrounding the stream is dominated by transitional vegetation and young tree classes suggesting past logging, or maybe mining, through here. Multiple transverse bars and deep, large point bars indicate an aggrading system. The substrate is dominated by large cobbles which occur both within the stream, and on point bars, and suggest powerful spring flows capable of moving larger material. Substrate material in pool tails was larger than would be considered appropriate for spawning habitat in this type of system. Width/depth ratios varied throughout the site; often larger than would be expected in this environment. Long eroding banks were influenced by the effects of transverse bars and stream meanders, particularly in areas of poor stabilizing vegetation. Overall, this site appears to have strong channel forming flows and excess sediment loads of large size material from local and upstream sources. These factors result in an actively fluctuating stream channel as the larger sediment is moved and deposited, resulting in both lateral channel migration where stabilizing vegetation is poor, and downcutting and deep pool formation in areas where streamside vegetation is good.

Macroinvertebrate Analysis

Macroinvertebrate data exists for three sampling events on Basin Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Results under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. One sample taken on August 16, 1994 indicated potential impairment with an O/E score of 0.77. Two other samples taken on September 5, 1997 provided O/E scores of 1.14 and 1.26.

Summary/Conclusion

Although percent fines are within target values at the two sites sampled in Basin Creek in 2010, there is other information that indicates potential problems with sediment and known sediment sources exist throughout this watershed. Much of the sediment issues are likely related to human-caused disturbances within the channel and riparian zone which has led to destabilized banks and over-widening of the stream, with subsequent affects to other available habitat (pools, riffles). This, in combination with the excess sediment from known sources (past mining impacts and roads) further supports the development of a sediment TMDL for Basin Creek.

5.4.3.2 Bison Creek, headwaters to the mouth (Boulder River); MT41E002_070

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. In the case of Bison Creek, the stream is listed for habitat alteration; but with likely linkages to sediment related issues. The most recent assessment record for Bison Creek was compiled in 1999. A brief summary review of that information provides the following description:

Bison Creek is most influenced by highway construction, the old railroad grade, and private land activities which have manipulated and affected the valley bottom and stream channel to a large degree. The stream now appears stable, although it is highly altered from its original state. Macroinvertebrate communities indicate moderate impairment due to dominance of pollution tolerant species in the sample (25% to 75% of reference). Moderate impairment to the habitat is also attributed to limited riparian areas due to road and railroad encroachment and channel alteration.

2010 Field Investigation

Two sites on Bison Creek were evaluated by the DEQ during the 2010 field effort (**Figure 5-3**). Both sites occur in unconfined valleys, with valley gradients less than 2%. BISO 04-02 is in a second order reach, and BISO 11-02 is in a third order reach. Width/Depth ratios were within the target range at both sites, but site BISO 11-02 was moderately entrenched. Pool frequency was low at both sites, and BISO 11-02 exhibited average residual pool depths below the target (**Table 5-5**).

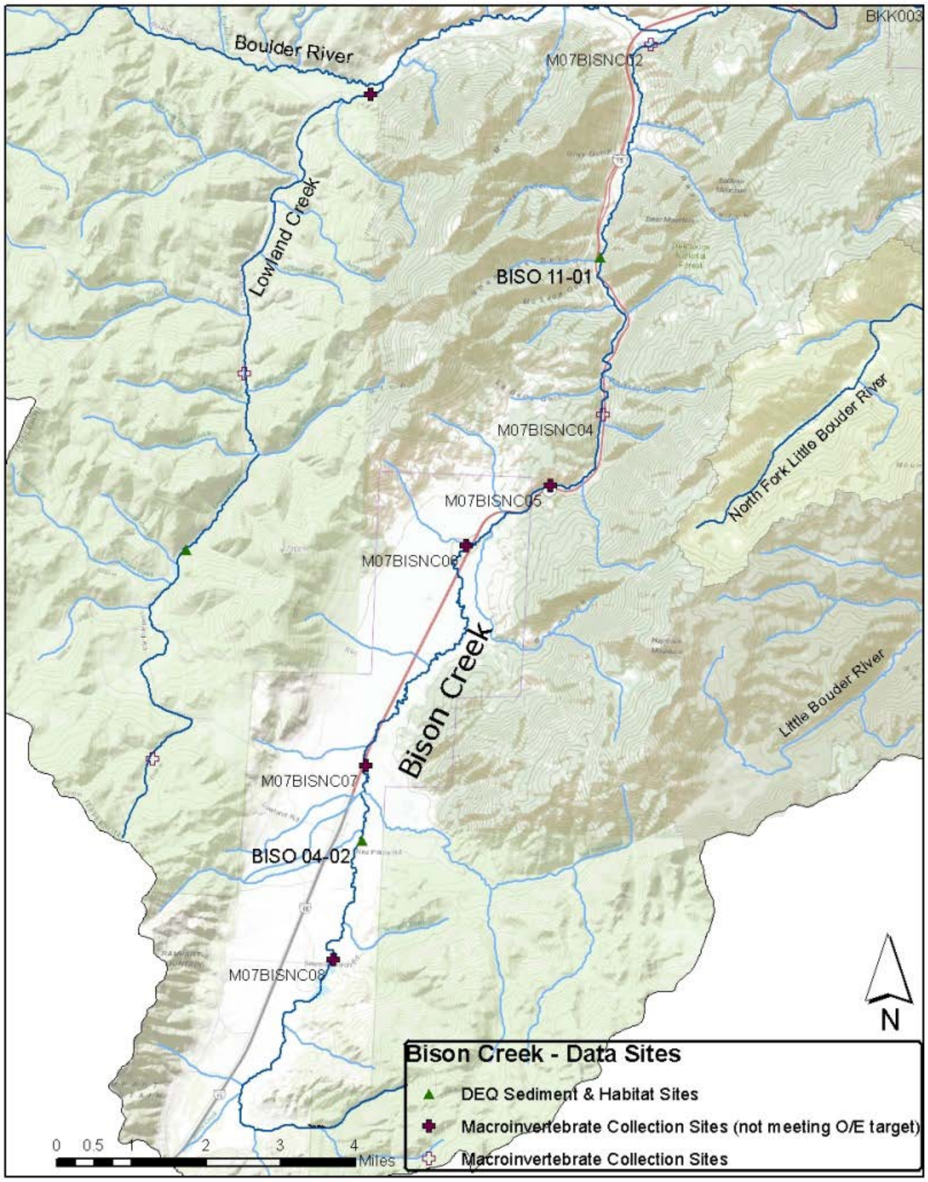

Figure 5-3. Bison Creek Data Locations

Table 5-5. Bison Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
BISO 04-02	17ai	0-2-U	8.0	5.5	22	1.1	74
BISO 11-02	17ai	0-3-U	23.3	16.9	1.6	0.8	69

Percent fines data were extremely high and well exceeded the target value at BISO 04-02, but only slightly above the target values for riffles and pool tail percent fines <6mm at BISO 11-02. In addition, percent shrub cover was well below expected values at BISO 04-02, and somewhat below the target at BISO 11-02. Bare ground was observed to some degree at both sites (**Table 5-6**).

Table 5-6. Bison Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
BISO 04-02	**29**	**96**	-	**14**	**6**	63
BISO 11-02	8	**19**	**16**	**53**	**2**	79

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- BISO 04-02 field notes identify signs of both active and past grazing, in addition to potential influence from roads in the watershed. Logging and past mining is also known to have occurred upstream. This site occurs in what is described as a Rosgen E channel type, which is defined as having low channel width/depth ratios, high entrenchment values, and (typically) low slopes, among other features. E channels often tend to have higher percent fines than other low gradient systems. E channels are generally very stable unless streambanks are disturbed, and significant changes in sediment supply or streamflow occur. BISO 04-02 has very high fine percentages throughout the channel, although much of this is thought to be naturally derived from weathered granite of the Boulder batholiths geology that exists here. Most of the streambanks encountered are stable and slowly eroding and indicative of natural conditions, however the upper end of the site does exhibit some areas where hoof shear and trampling from livestock have resulted in actively eroding banks.

- Transportation appears to be a major influence on BISO 11-02. The interstate highway parallels the stream on one side, and there is evidence of an abandoned railroad grade within the site, as well as a tall berm further confining the stream toward the end of the site. These influencing factors have cramped the stream and reduced its ability to meander, while also increasing the stream slope through this area. In the absence of the highway and other confining features, it is presumed that this site would be more slow and sinuous. Small step pool formation has resulted and few of the pools encountered had suitable spawning gravels. Stream substrate has mostly fine particles and the stream bottom appears highly embedded. Streamside vegetation is limited in its ability to stabilize banks, and tall actively eroding banks often occur at river bends. Non-native floodplain material and modifications from the transportation corridor may be affecting the nature of the banks and increasing the likelihood of erosion.

Macroinvertebrate Analysis

Macroinvertebrate data exists for six sampling events on Bison Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. The six samples were taken in August 2010, at six separate locations throughout Bison Creek, starting at the upper end and moving downstream. Respectively, the O/E values were 1.2, 0.8, 0.5, 0.4, 0.5, and 0.4.

Summary/Conclusion

Percent fines are extremely high in the upper site investigated during the field sampling; however this site is considered an E channel where it is likely that percent fines would typically be higher than the target values. The higher fines in this area are also thought to be largely natural due to the local geology;

however the adjacent road corridor may be supplying additional sediment into the system that is above what would naturally occur. Greenline results and pool frequency are not meeting the target for site BISO 04-02. BISO 11-02 shows considerable effects from the adjacent transportation corridors that have been built through here. The lower part of Bison Creek is confined by roads and historic railroads and may therefore be limited in the amount of restoration that can be expected, but the effects witnessed from the human activities throughout Bison Creek warrant TMDL development for sediment impairment.

5.4.3.3 Boulder River, Town of Boulder to Cottonwood Creek; MT41E001_022

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for the Boulder River was compiled in 1999. A brief summary review of that information provides the following description:

> Fish population numbers indicate severe impairment, relative to numbers upstream of Basin (<25% of reference). Habitat assessments by the DEQ resulted in a value 64%, which equates to a moderate impairment of available habitat. Depressed fish populations may be attributed to metals and metals in sediment, excessive sedimentation, severe dewatering, and removal of streambank cover. Among other causes described in the assessment records, upstream channelization from mining, mill tailings, and highway construction has led to excessive sedimentation. Dewatering has led to reduced riparian vegetation and impacts to the fishery – nearly 30 miles of river contain less than adequate flow volumes to sustain an optimal fishery. Agriculture use is extensive; hayfields encroach upon streambanks, grazing impacts are moderate to severe, irrigation severely depletes instream flows, the habitat trend is listed as deteriorating, and channel alterations may be attributed to agriculture, floods and ice.

2010 Field Investigation

Two sites on this segment of the Boulder River were evaluated by the DEQ during the 2010 field effort (**Figure 5-4**). Both sites occur in fourth order reaches, in unconfined valleys, with valley gradients less than 2%. Width/Depth ratios were well above the target value for the Boulder River at both sites. Pool frequency was just below the target at both sites. Residual pool depths were slightly below the expected target value at site BLDR 13-04, but within the desired range at BLDR 13-10 (**Table 5-7**).

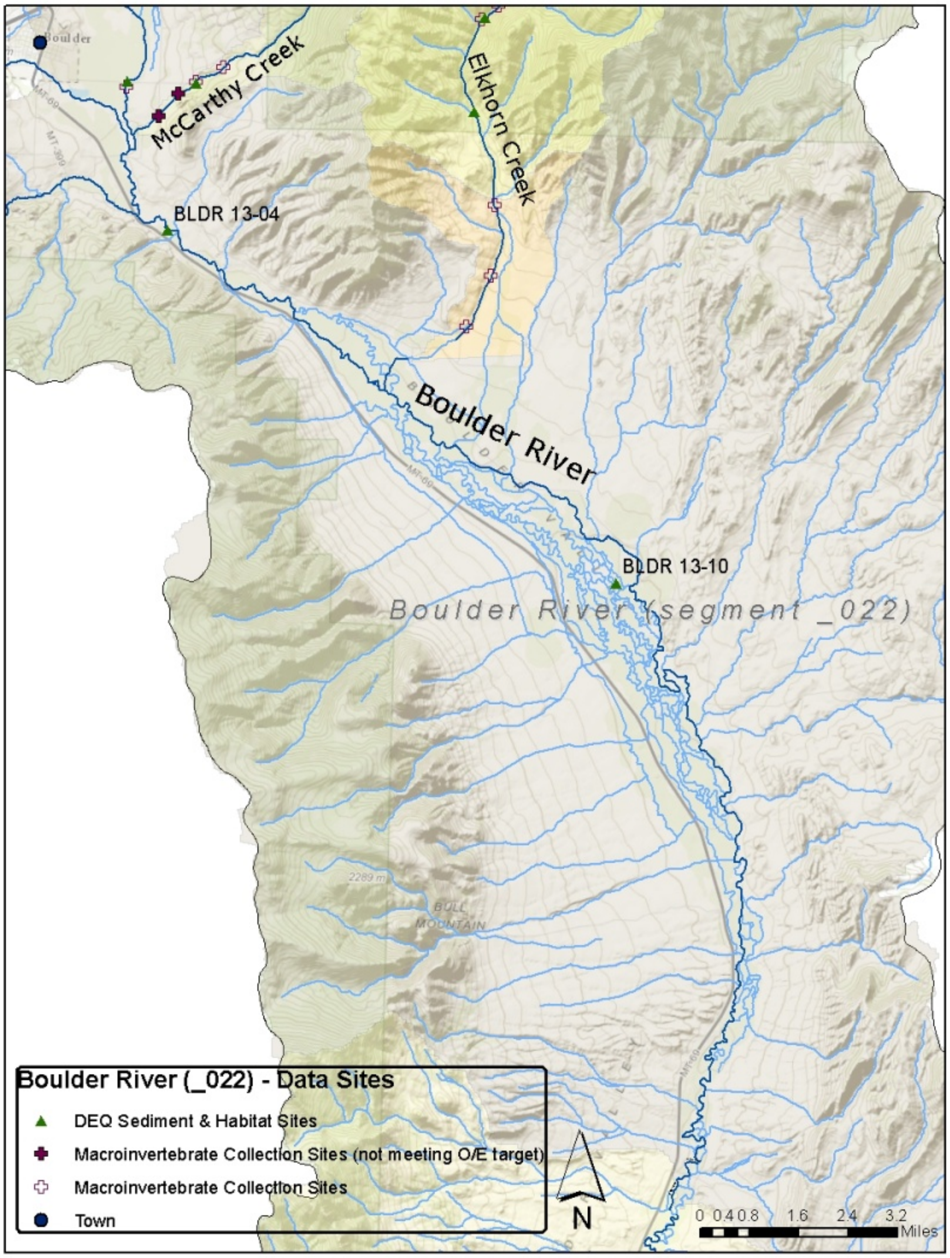

Figure 5-4. Boulder River (Segment _022) Data Locations

Table 5-7. Boulder River (Segment _022) Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
BLDR 13-04	17w	0-4-U	63.9	**40.5**	4.2	**1.7**	**28**
BLDR 13-10	17w	0-4-U	75.5	**68.1**	5.0	3.0	**25**

Percent fines data were meeting all target values at both sites, however, percent shrub cover and percent bare ground were well beyond expected values at both sites (**Table 5-8**).

Table 5-8. Boulder River (Segment _022) Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
BLDR 13-04	9	17	10	**22**	**17**	44
BLDR 13-10	8	12	3	**4**	**57**	197

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- Irrigated hay ground and active grazing is present along BLDR 13-04. Several long, near vertical actively eroding banks occur throughout this site. A number of banks have been armored with rip-rap, with varying levels of success. In some cases, the river has undercut the rip-rap, causing the rip-rap and the banks to slump off into the stream. This site has a meandering channel through this site with short, poorly developed riffles and long lateral scour pools on outside meander bends. The lower end of the site has pools with poorly developed tails and minimal spawning gravels; however, the upper area has pools with well-developed pool tails and good spawning gravels. Substrate has a higher percentage of fines (although not witnessed in the riffle data and pool tail data), and is moderately embedded. Very little stabilizing vegetation exists along the riparian corridor, and predominantly fine bank material is exacerbating erosion throughout.

- BLDR 13-10 is heavily impacted by grazing. The riparian corridor is almost entirely grasses, with few willow or other desirable woody or wetland species. Irrigation is prevalent throughout the Boulder River watershed and flow fluctuations and changes in stream energy may also be having an effect. This site has a meandering channel with short, poorly developed riffles, and long lateral scour pools on the outside of meander bends. Pool tails generally have good spawning habitat, however many pool tail locations are also used as animal crossings and there is evidence of excess fines from bank trampling. Channel braiding is also apparent in portions of this site. Near vertical eroding banks exist throughout almost the entire length of the site, especially at the outside bends. Riparian fencing exists in the upper cells of the site, but erosion is threatening to remove the fence within a few years, and the riparian area within the fence appears to be more heavily grazed than outside the area. The erosion that occurs here does not appear to be naturally occurring, and is most obviously related to grazing practices.

Summary/Conclusion

Of the two sites assessed during the 2010 field effort, percent fines do not indicate a problem. However, high width/depth values, lower than desired pool frequency and pool depths (in BLDR 13-04), and greenline results indicate significant channel alteration and streambank erosion is prevalent. This information describes areas where adjacent land use could be improved to help stabilize the stream channel, and certainly identifies sources of sediment to the system, regardless if that sediment is accumulating within the site. In addition, the assessment records describe similar conditions throughout much of the listed segment. A TMDL will be completed for this segment of the Boulder River.

5.4.3.4 Boulder River, Cottonwood Creek to the mouth (Jefferson Slough) T9N R3W S2; MT41E001_030

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for the Boulder River was compiled in 1999. A brief summary review of that information provides the following description:

Fish population numbers are less than expected given the size of the river, where numbers are, on average, 65% of those fish numbers upstream of Basin. Habitat indicates severe impairment from severe dewatering, and this site sees excessive sedimentation. Agricultural use is extensive. Dewatering has had effects on riparian vegetation, and livestock concentrated in bottomlands for prolonged periods have influenced bank stability. Extensive reduction of riparian vegetation has occurred with over 69 miles affected. Impacts from I-15 construction, riprapping and overgrazing have resulted in loss of bank cover. During irrigation season, nearly 30 miles of the Boulder River contain less water than necessary to sustain optimal fishery. Cold Spring flows rejuvenate the river and improve habitat, however, sedimentation impacts are still seen here.

2010 Field Investigation

Two sites on the lowest segment of the Boulder River were evaluated by the DEQ during the 2010 field effort (**Figure 5-5**). Both sites occur in fourth order reaches, in unconfined valleys, with valley gradients less than 2%. Width/Depth ratios were not meeting the target value for the Boulder River at both sites. Pool frequency was below the target at both sites; however residual pool depths were good in both locations (**Table 5-9**).

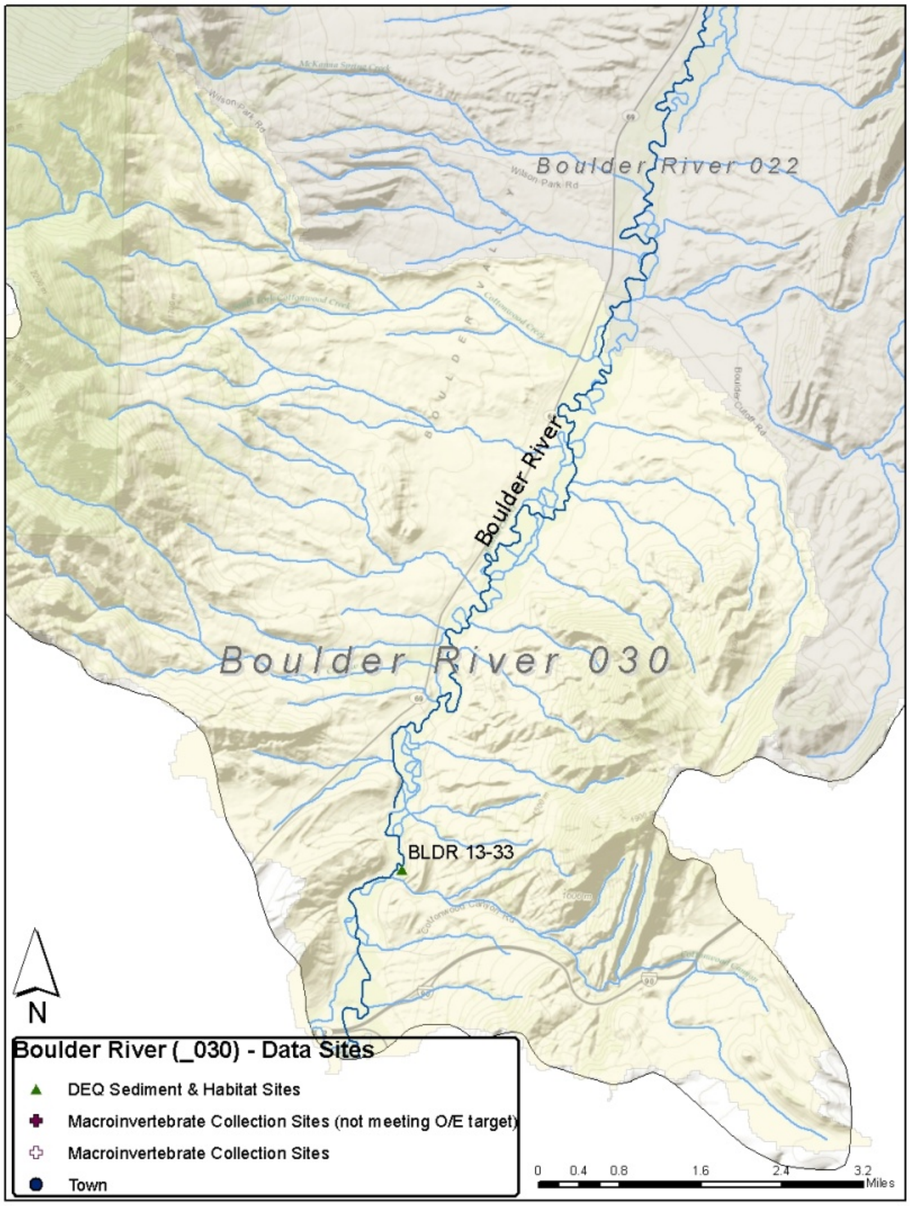

Figure 5-5. Boulder River (Segment _030) Data Locations

Table 5-9. Boulder River (Segment _030) Channel and Pool Quality

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
BLDR 13-23	17w	0-4-U	62.2	**31.9**	6.7	2.6	**21**
BLDR 13-33	17w	0-4-U	70.5	**37.9**	**1.9**	2.5	**24**

Percent fines data were above target values at both sites, particularly for fines <2mm. Percent shrub cover and percent bare ground were not meeting the target values at both sites. Shrub cover was minimal at BLDR 13-23, accompanied by a high percentage of bare ground. Shrub cover was just below the target at BLDR 13-33, but bare ground was extremely high (**Table 5-10**).

Table 5-10. Boulder River (Segment _030) Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
BLDR 13-23	**22**	**28**	2	**20**	**37**	17
BLDR 13-33	**22**	**28**	-	**63**	**44**	71

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- BLDR 13-23 appears to be largely affected by agricultural practices in the area. Irrigated hay production exists directly adjacent to the stream and cattle paths exist in parts of the site with some locations of isolated bank trampling. Substrate is predominantly fine material except for some gravel in riffles and a few pool tails. Large, compound pools exist at outside bends, however limited spawning gravel occurs in pool tails. Most banks are large, near vertical eroding banks that produce fine substrate and have little stabilizing vegetation. One slowly eroding bank was witnessed where willow vegetation was present. Riparian description comments that the site has generally good ground cover dominated by grasses on upper banks with some sedges/rushes present, although understory vegetation has been cleared in lower portions of the site to accommodate agriculture practices.

- A road encroaches the river in several places throughout BLDR 13-33; however, unlike the other Boulder River valley bottom sites that were visited, recent riparian grazing was not apparent. The site is dominated by pool/run features with deep compound pools on meander bends. Pool tails have embedded cobbles and gravels with very little suitable spawning habitat. Streambanks were dominated by long, actively eroding banks on outside meander bends where surface protection was limited; however, slowly eroding banks were noted in areas with significant vegetation and good root density. Riparian vegetation was mostly dominated by dense willow growth however an upper canopy is almost non-existent throughout the site.

Summary/Conclusion

Of the two sites assessed during the 2010 field effort, results indicate sediment issues, and sediment sources were witnessed at both sites. Riparian grazing and agricultural impacts were evident at the upper site (BLDR 13-23) and described in the assessment records as an issue throughout much of the Boulder River, however recent grazing did not appear to be an issue in the lower site (BLDR 13-33). Limited overstory canopy at BLDR 13-33 suggests that grazing or riparian harvest may have occurred in the past. Because both sites display sediment effects, and the assessment record describes prevalent impacts throughout the lower Boulder River, a TMDL will be completed for this segment as well.

5.4.3.5 Cataract Creek, headwaters to the mouth (Boulder River); MT41E002_020

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Cataract Creek was compiled in 1999. A brief summary review of that information provides the following description:

Habitat is severely impacted due to excess sediment, cementation of channel substrate, and depletion of riparian vegetation attributable to mining, timber harvest, and grazing practices. Un-vegetated tailings, dump material, and disturbed areas from the Mantle, Morning Glory, Crescent, and Crystal

Mines contribute metals and sediment to Cataract Creek. In addition, cattle, roads, and recreational use have led to moderate bank instability. Percent fines have been found to be 5% to 50% in riffles. Road encroachment, clearcuts right up to the stream channel, and recreational roads that cut through the stream are additional sources of sediment to Cataract Creek. Despite this, good habitat potential for resident and rearing trout exists.

2010 Field Investigation

Only one site on Cataract Creek was evaluated by the DEQ during the 2010 field effort (**Figure 5-6**). Site CATA 18-01 occurs in an unconfined second order reach, with 2-4% valley gradient. The average width/depth ratio for the site was above the target value. Pool frequency was good but residual pool depths were not meeting the expected target value (**Table 5-11**).

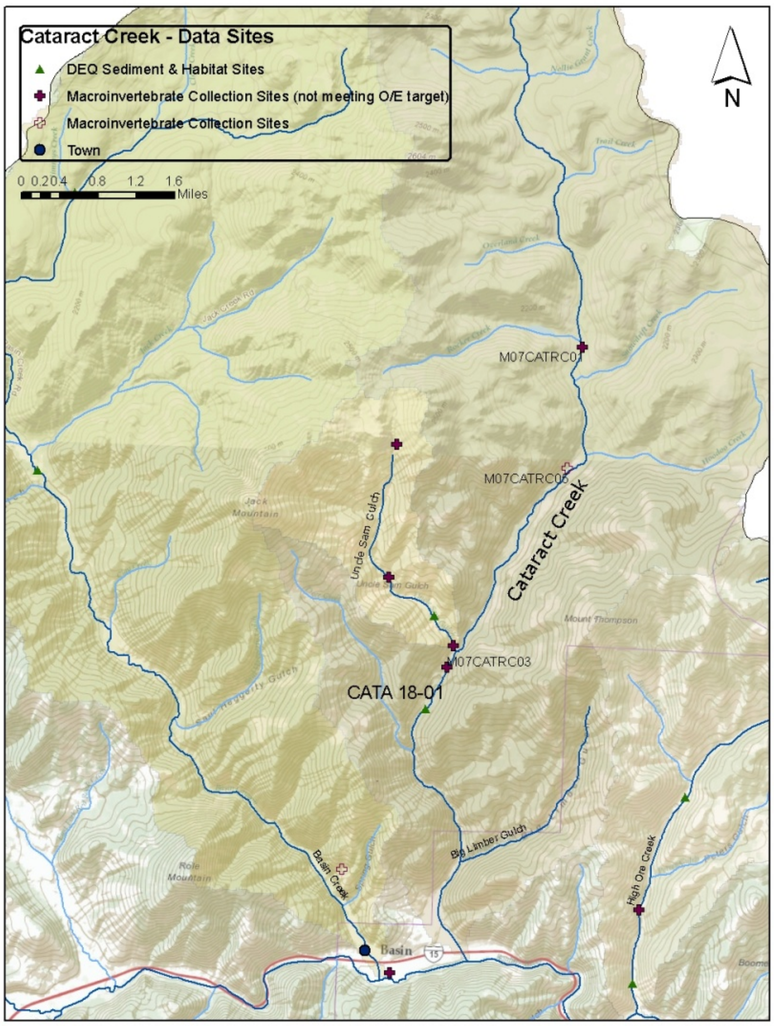

Figure 5-6. Cataract Creek Data Locations

Table 5-11. Cataract Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
CATA 18-01	17ai	2-2-U	31.8	**24.5**	1.5	**1.0**	137

Percent fines exceeded the target in all substrate parameters, particularly pool tails. Percent shrub cover and percent bare ground were also not meeting targets (**Table 5-12**).

Table 5-12. Cataract Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
CATA 18-01	**13**	**24**	**53**	**42**	**5**	158

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled site further:

- Recent disturbances in CATA 18-01 appear relatively minor; however there is ample evidence of past logging and mining throughout the site. The stream is characterized by a step-pool system with large gravel, cobble and boulder substrate. Due to the gradient here, the site is basically one long riffle/run with intermixed pocket pools formed by boulders and LWD. Pools provide good habitat, but little spawning gravels exist. Fine substrate exists in the few slow water areas and is somewhat embedded. Banks at this site were heavily armored and showed little sign of erosion. Bank conditions were typical of a higher gradient, coarse bed stream channel.

Macroinvertebrate Analysis

Macroinvertebrate data exists for three sampling events on Cataract Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. The three samples were taken in September 2010. The O/E values results were 0.8, 0.7, and 1.1.

Summary/Conclusion

Only one site was investigated during the 2010 DEQ field effort, in part due to accessibility issues. However, the one site did show signs of some sediment impact to the substrate; although the site itself had stable banks which did not contribute much sediment load. The shallow pool depths here were below what would be expected for this size stream, although the higher gradient and larger substrate material dominated system would probably lend itself to slightly shallower pocket pools as the stream cascades through this site. Supplemental information from the assessment records however indicate a significant effect from mining and other human caused sources in Cataract Creek; and a TMDL will be completed.

5.4.3.6 Elkhorn Creek, headwaters to Wood Gulch; MT41E002_061

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Elkhorn Creek was compiled in 1999. A brief summary review of that information provides the following description:

- There is severe impairment to habitat from mining and grazing due to bank destabilization, vegetation denudation, dewatering, and excess siltation. Habitat impacts appear to have attenuated downstream. Encroachment of the road and railroad in places also has led to some bank instability. In addition, previous stream dredging as part of historic mining practices have altered the stream channel and resulted in high fines and cemented substrate in places, although the stream has re-stabilized somewhat from those historic activities.

2010 Field Investigation
Two sites on upper Elkhorn Creek were evaluated by the DEQ during the 2010 field effort (**Figure 5-7**). Both sites occur in third order reaches, and in reaches with valley gradients between 2 and 4%. Both sites occur in slightly steeper reaches (Rosgen B type), therefore width/depth ratios would be expected to be somewhat smaller (<13). Results from the assessments show that residual pool depths were slightly under expected values, and pool frequency was slightly below desired values at ELKH 23-01 (**Table 5-13**).

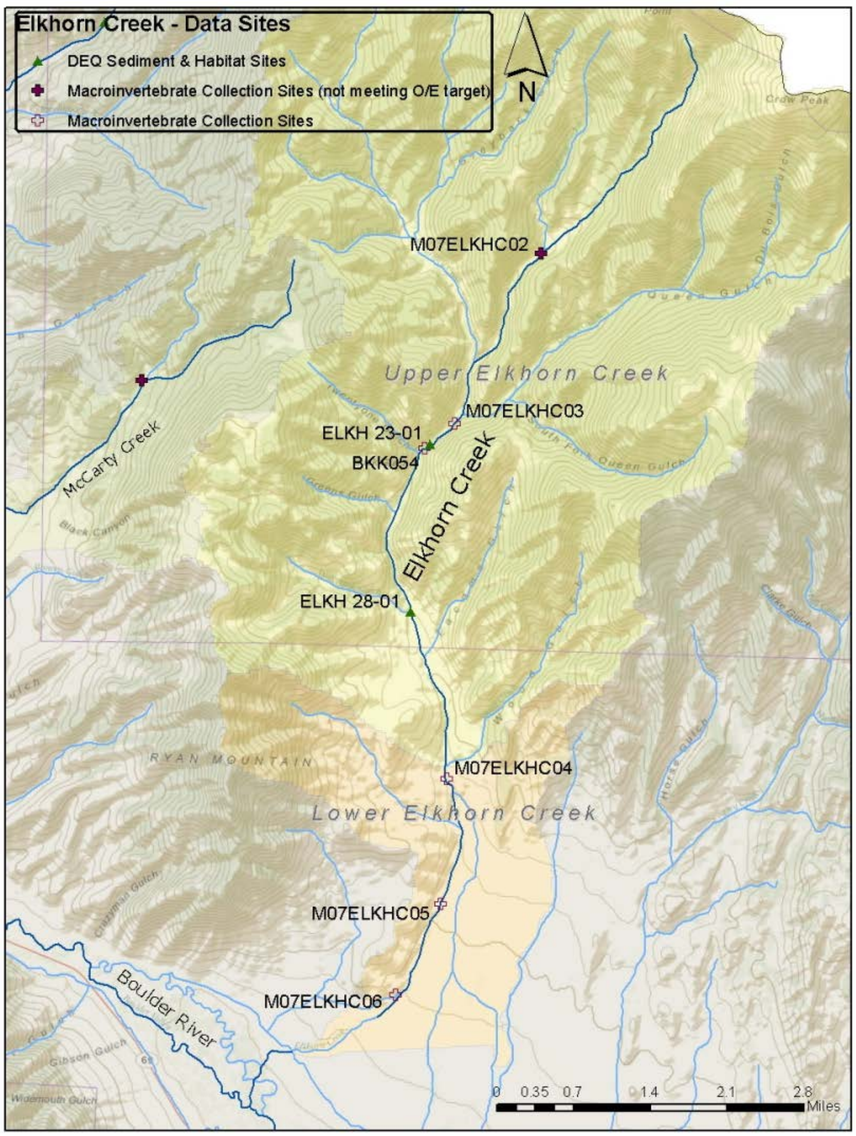

Figure 5-7. Elkhorn Creek (Segment _061) Data Sites

Table 5-13. Elkhorn Creek (Segment _061) Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
ELKH 23-01	17ai	2-3-C	17.4	**17.3**	3.3	**0.9**	**79**
ELKH 28-01	17y	2-3-U	16.3	**16.3**	1.6	**0.8**	111

Percent fines in both sites were considerably far from meeting the target. Greenline results showed some riparian shrub cover was slightly under the target in ELKH 23-01, but fully met the target at ELKH 28-01. Bare ground however was particularly high at the ELKH 28-01 (**Table 5-14**).

Table 5-14. Elkhorn Creek (Segment _061) Substrate and Riparian Condition Data (Water & Environmental Technologies, 2010)

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
ELKH 23-01	**33**	**39**	5	**55**	**6**	512
ELKH 28-01	**25**	**32**	4	82	**48**	1088

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- Human impacts are evident throughout ELKH 23-01; a forest road parallels the stream and a different primitive access road also parallels the stream as close as 5 feet in some places. Fire pits and camp sites are scattered nearby in the adjacent lands, and signs of cattle or animal trampling occur on both sides of the stream. Tree stumps in the riparian and upland area suggest logging or mining activity has previously occurred nearby. The stream appears to have been altered or confined to its present channel, possibly to accommodate the adjacent roads. The stream channel has long riffles and small step-pool features. The channel appears slightly over-widened is several places. Pools however are generally not well developed with only a few good pools behind instream large wood or boulders. Streambank erosion is relatively minor and characterized by small, slowly eroding, undercut banks at boulders, large wood, or tight meander bends. Erosion here is likely influenced by the reduction in riparian vegetation in some places, and at animal crossings, as hoof shear was observed.

- Evidence of cattle grazing occurs throughout ELKH 28-01, with multiple cattle paths crossing the stream. A clearing occurred on river left in the lower portion of the site and a large crib structure was also observed in the upper end of the site that may be related to cattle operations. Roads also parallel the stream nearby. ELKH 28-01 is also less sinuous, slightly steep (2-4% slope) with lateral scour pools and poorly defined riffles. The channel is overwidened in places and shows signs of downcutting. Suitable spawning gravels were limited. Cattle paths and bank trampling influence bank erosion in a number of places, and several tall eroding banks also exist where riparian vegetation has died from loss of connectivity to the stream (likely related to the downcutting channel).

Summary/Conclusion

Both sites assessed on Elkhorn Creek during the 2010 field effort show impacts from sediment. In addition, historic mining has left a lasting impact on the stream, and current land use practices appear to perpetuate those effects. As a result, a TMDL for the upper section of Elkhorn Creek will be completed.

5.4.3.7 Elkhorn Creek, Wood Gulch to the mouth (Unnamed Canal/Ditch) T5N R3W S21; MT41E002_062

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Elkhorn Creek was compiled in 1999. A brief summary review of that information provides the following description:

There is severe impairment to habitat from dewatering and siltation. A field assessment in 1992 showed healthy riparian zones with good species and age class diversification, but the channel was dry, and siltation within the channel was evident. Most of the streamflow in lower Elkhorn Creek is diverted for irrigation or absorbed by pervious gravels in the substrate, and the last two miles of the stream are typically dry. There appear to be moderate impacts from cattle grazing and historical mining, with channel alterations the result of past dredging; but the channel seems to have stabilized since the mining activity.

2010 Field Investigation

No sites were assessed on lower Elkhorn Creek during the 2010 field investigation. Inability to gain access to desired stream sites, and a lack of a discernible channel at other sites prohibited a thorough field assessment of specific locations. However, field notes, information from the upper segment, and assessment record information provide data to review.

Summary/Conclusion

Review of past stream assessments and other information in the assessment record note some visual observations of siltation with signs of influence from past mining and modern grazing practices. More recent observations of lower Elkhorn Creek witnessed much the same conditions as reported in the past. Riparian disturbance, streamside grazing, and lack of flow affect the lower segment of Elkhorn Creek, and compound the effects from sediment loading upstream. Although the full sediment and habitat field assessment was not conducted on any sites in the lower Elkhorn Creek during the 2010 field effort, past information along with recent observations warrant TMDL development for lower Elkhorn Creek.

5.4.3.8 High Ore Creek, headwaters to mouth (Boulder River); MT41E002_040

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for High Ore Creek was compiled in 1999. A brief summary review of that information provides the following description:

High Ore Creek record assessments describe the creek as severely impaired due to grazing, siltation related to roads and timber harvest, and riparian denudation and related bank erosion above the Comet Mine. Channel alterations and riparian denudation related to mining occur below the Comet Mine as well. Mine tailings in and around the channel have impacted the riparian area and heavy browsing from cattle further limit the health of the riparian area. The channel is actively downcutting and hummocks and pugging are present along the streambanks. A very large amount of sediment has been deposited in the upper portion of the stream, and bank encroachment and channel alterations from past mining and dredging occur. Grazing impacts, while significant, may be the lesser source of sediment in comparison to the impacts from past mining practices. In addition, impacts from timber harvest on private lands and lack of drainage structures on road contribute to water quality problems.

2010 Field Investigation
Two sites on High Ore Creek were evaluated by the DEQ during the 2010 field effort (**Figure 5-8**). Both sites occur in second order, unconfined reaches, where valley gradients are greater than 4%. The higher stream slopes suggest that width/depth ratios would be expected to be somewhat smaller (<13). At both sites, width/depth ratios were either very close to the target or within the target range. Residual pool depths are not meeting the target; however the higher slopes for these two sites suggest a result of naturally smaller pools, but with potentially greater numbers of pools (consistent of a step-pool system). Pool frequency is slightly below the target in HIOR 09-01 (**Table 5-15**).

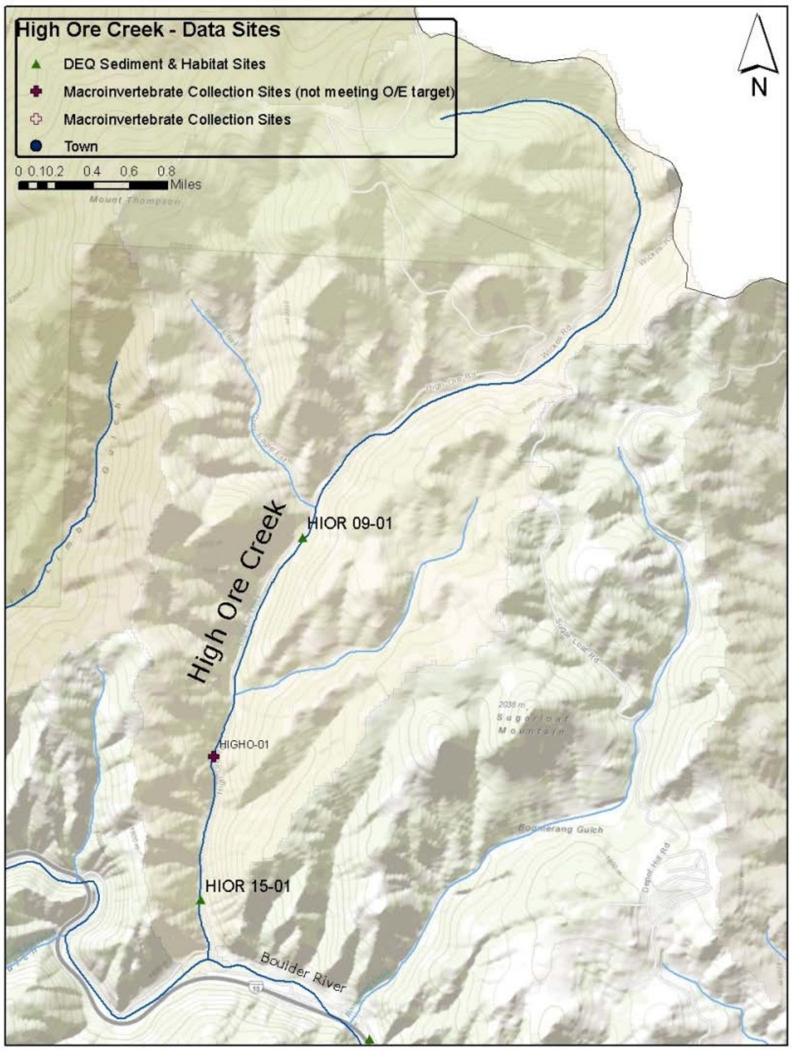

Figure 5-8. High Ore Creek Data Sites

Table 5-15. High Ore Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
HIOR 09-01	17ai	4-2-U	8.6	**14.0**	2.4	**0.6**	**106**
HIOR 15-01	17ai	4-2-U	5.1	7.4	3.6	**0.6**	127

Percent fines values were higher than the target at both sites. A low percentage of shrub cover was also witnessed in both sites, in addition to some bare ground (**Table 5-16**).

Table 5-16. High Ore Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
HIOR 09-01	**28**	**39**	-	**26**	**7**	507
HIOR 15-01	7	**20**	**47**	**21**	**2**	169

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- Human impacts exist throughout HIOR 09-01, including a road parallel to the stream, hoof shear from cattle grazing, fire rings, an outhouse, an old road crossing and various debris. The area adjacent to the site appears to have been cleared at some point, possibly for logging or mining, as there is evidence of past placer mining. Stream clarity was very murky at the time of sampling. Forest fires, mining and reclamation activities upstream may also be affecting this site. The stream is a narrow channel dominated by long, fast riffles, few pools and occasional channel braids. Substrate is a mix of small to mid-size gravel and cobble with a few boulders, although fines were common in areas of slower water. Streambanks were quite stable despite limited riparian vegetation, possibly because the floodplain has been significantly flattened and few true banks exist. Hoof shear and human traffic is evident along the stream, although it doesn't appear to have a significant effect on streambank erosion at this site.

- A road parallels much of site HIOR 15-01, typically within 30 feet. Work on the stream channel occurred here as evidenced by coir fabric and wooden stakes along the stream. The site is fenced on both sides and there is no evidence of current grazing. The site contains a reconstructed channel that is narrow, deep (for its size), and not entrenched with numerous boulders and plunge pools and very little large wood. Most pools were short and shallow and followed by long riffles. Substrate is predominantly large gravels embedded with fines. Very few spawning gravels exist in pool tails. Overall, banks were well vegetated and stable.

Macroinvertebrate Analysis

Macroinvertebrate data exists for one sampling event on High Ore Creek from August 2003. An observed/expected model was run using the results of this event. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. The O/E value was 0.5.

Other Information

A significant source of sediment related problems in High Ore Creek is due to past mine activities at the Comet Mine and related impacts downstream. More recently, major efforts to improve conditions and restore High Ore Creek have been completed through a cooperative effort with the Bureau of Land Management (BLM) and DEQ. Reclamation was conducted from September 1999 through June of 2000. The goal of the remediation was to remove at least 88 percent of the tailings from former tailings deposits and waste rock dumps within the floodplain (from the Comet Mine site to the mouth). The reclamation generally included removal of the mine waste from High Ore Creek's floodplain and streambank, then transferring and consolidating the waste into an off-site repository. Amended coversoil was placed on the new surface and the streambank and floodplain were recontoured and reconstructed. Reconstruction included back-filing the floodplain with amended coversoil and creating "steps, pools, and grade control structures" in the stream channel. In addition, willow cuttings were installed in the streambanks, and floodplain and streambanks were seeded and mulched with appropriate seed mixes. Fencing was placed around the reconstructed stream reach sections (11 sections) to protect reconstruction work and help allow vegetation to establish. Approximately 2.8 miles of stream length was treated (Reclamation Research Group, LLC., 2009).

Evaluation of reclamation efforts conducted in 2009 found mixed success. There are areas of good vegetation on a positive trajectory, and many areas that appear to be deteriorating from low pH soils, erosion, and noxious weed infestations. Fencing has in large part remained intact, and there were no signs of livestock grazing within the reclaimed areas. Erosion from High Ore Creek Road was noted as a major problem along the creek, as well as bare/sparsely vegetated areas where vegetation either never established, or has been degraded by erosive conditions. Improving successful revegetation of the poorly vegetated areas would greatly decrease the sediment load to High Ore Creek, as would constructing barriers to minimize erosion from the roadway (Reclamation Research Group, LLC., 2009).

Summary/Conclusion

Limitations in accessing sites along High Ore Creek and data collection from higher gradient reaches have resulted in data from sites that are not entirely comparable to conditions for which the target values were developed for. Never the less, high fines were witnessed (not expected in reaches of higher gradient), and less than optimal conditions in habitat were seen in the data. In addition, the assessment records detail significant past impacts, particularly from the Comet Mine, as well as grazing and other sources throughout much of High Ore Creek. Although recent reclamation work by the BLM and DEQ has attempted to address a significant portion of the causes and sources for sediment in High Ore Creek, recovery is not complete and sediment sources still exist in many areas. As a result of this, a TMDL for High Ore Creek will be completed.

5.4.3.9 McCarty Creek, headwaters to the mouth (Boulder River); MT41E002_110

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for McCarty Creek was compiled in 2005. A brief summary review of that information provides the following description:

This stream is experiencing impacts from several sources; the influence of cattle is heavy in the upper section where they have unlimited access to the riparian zone. The results include absence of young willows, lack of cottonwood regeneration, and moderate bank erosion from trampling. In the lower portion of the watershed below Upper Valley Road, the stream is channelized and dewatered for irrigation purposes. Woody riparian vegetation and fish habitat are lacking in this part of the stream. McCarty Creek is in very good condition above the road however, and illustrates excellent conditions of riparian health. Aquatic macroinvertebrates are limited by the high percentage of fine sediment in the stream; at the lower site, Wolman pebble count data showed 98% of the substrate surface as <6mm (although much of the high fines are thought to be natural in this stream). Channel alteration is generally minimal along most of the stream length. Shallow pools are more prevalent than deep pools. Banks generally well protected by native vegetation and the width of the riparian zone is generally good.

2010 Field Investigation

Only one site on McCarty Creek was evaluated by the DEQ during the 2010 field effort (**Figure 5-9).** Site MCCA 22-01 occurs in an unconfined second order reach with a valley gradient greater than 4%. This reach was investigated in part to provide some representation of small, high gradient reaches in the Boulder-Elkhorn TMDL planning area. The bankfull width was very small, and the residual pool depths reflect a small stream size. The slope, in addition to the small stream size, was outside of the typical conditions where most target values would apply and therefore the small residual pool depths are not necessarily considered inappropriate here (**Table 5-17**).

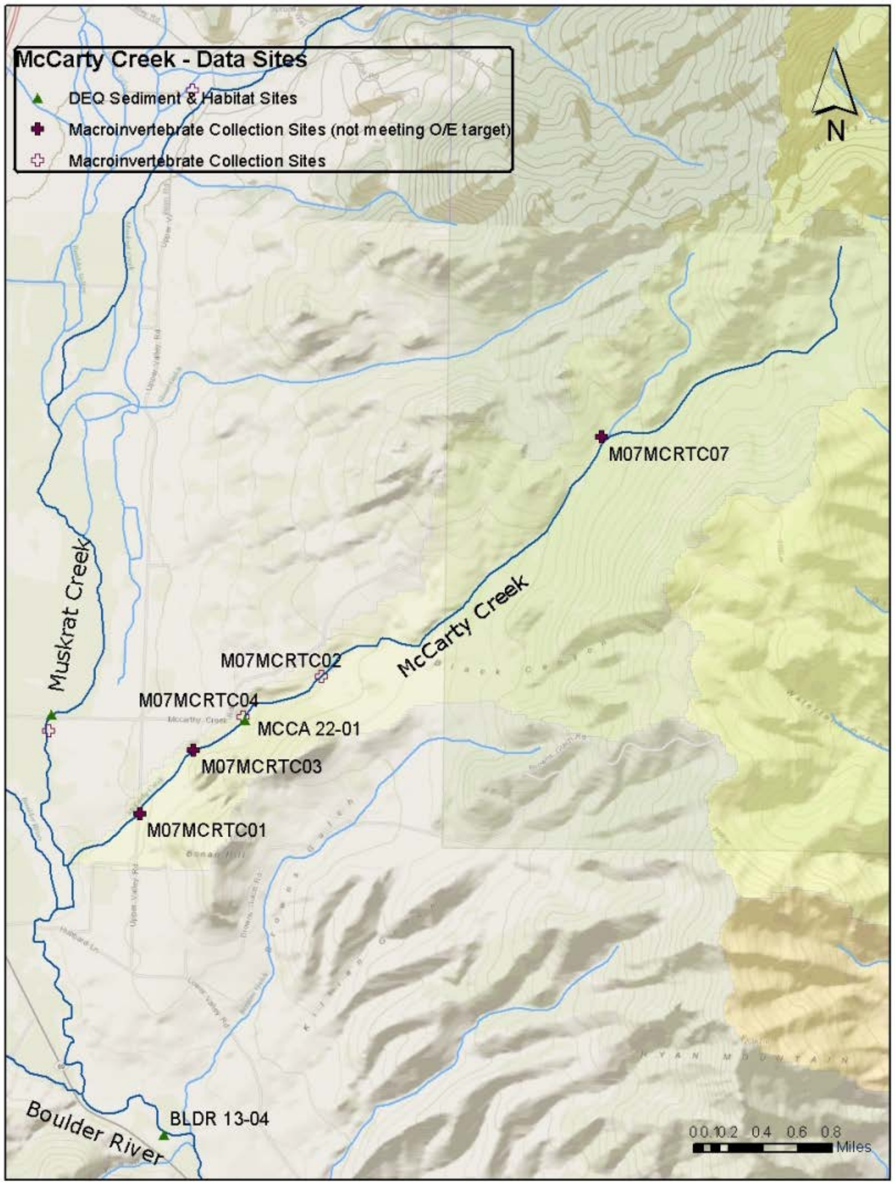

Figure 5-9. McCarty Creek Data Sites

Table 5-17. McCarty Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
MCCA 22-01	17w	4-2-U	3.2	6.4	1.8	0.4	190

Percent fines were considerably beyond the target at this site. This may in part be due to the small size of the stream and lack of stream power to flush sediment; however the high fines values do indicate cause for further investigation. Percent shrub cover appeared good however percent bare ground was above what is desired (**Table 5-18**).

Table 5-18. McCarty Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
MCCA 22-01	**50**	**82**	**83**	74	**11**	1436

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled site further:

- Signs of grazing exist throughout MCCA 22-01, particularly in the lower end. This site may have been influenced by past beaver activity, and a small reservoir exists just upstream of the site which likely resulted instream downcutting and subsequent entrenchment. The stream is a narrow, shallow, steeper gradient system (Rosgen B-type). The stream has decent riffle and pool habitat for its size. It also has good cover from woody vegetation. Eroding banks generally occur where woody vegetation has died, or in tight meander bends. Erosion appears to be partially due to the severe downcutting observed in this site, and the subsequent dying of woody vegetation as the brush becomes hydraulically disconnected from the stream.

Macroinvertebrate Analysis

Macroinvertebrate data exists for six sampling events at five locations on McCarty Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. Two samples were collected in June 2004 and resulted in O/E values of 0.7 and 0.8. Three samples were collected in August 2010 and resulted in O/E values of 0.5, 1.1, and 0.6. One sample was collected in August 2011 and resulted in an O/E value of 1.0.

Summary/Conclusion

Only one site was investigated on McCarty Creek during the 2010 DEQ field effort, in part due to accessibility issues. This site occurred at the upper end of the stream and just below a reservoir where it displayed signs of downcutting and associated entrenchment, most likely as a result of management of the reservoir. Nevertheless, site conditions appeared generally good. Percent fines were high however, although this could be due in part to the modified hydrology from the reservoir and local geology. McCarty Creek assessment records also show high fines throughout the stream, although natural conditions are noted to display naturally high fines as well. Influence from human caused sources related to grazing practices is apparent in some areas of the stream, but there are locations where conditions in McCarty Creek appear to be close to desired. A TMDL will be developed for McCarty Creek as a result of some of the known human caused sediment sources in this stream, however it is noted that relatively less sediment reduction may be needed in this watershed compared to other Boulder-Elkhorn TPA streams.

5.4.3.10 Muskrat Creek, headwaters to the mouth (Boulder River); MT41E002_100

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. In the case of Muskrat Creek, the stream is listed for habitat alteration; but with likely linkages to sediment related issues. The most recent assessment record for Muskrat Creek was compiled in 1999. A brief summary review of that information provides the following description:

Assessment records for Muskrat Creek describe only minimal to moderate impairment, with little to no impairment to the biology. Macroinvertebrate communities scored higher than any other site in the Boulder watershed at one location. Habitat trends appear to be improving, with good spawning and rearing habitat, good stream cover and generally good stream cover and bank condition. Some overuse by stock and bank instability from trampling noted. Over 95% of human caused bare ground is attributed to grazing.

2010 Field Investigation

Two sites on Muskrat Creek were evaluated by the DEQ during the 2010 field effort (**Figure 5-10**). One site occurs in a second order, unconfined reach, with a valley slope of 2-4%. The second site, further downstream, is in a low gradient, third order unconfined reach. Width/depth ratios were either very close to the target or within the target range for the two sites. MUSK 18-01 displayed no entrenchment, whereas MUSK 22-01 was slightly entrenched, (which is the opposite of what would be expected given their slope categories). Residual pool depths were smaller than the target at MUSK 22-01, and pools per mile were well under the target values at both sites, particularly at MUSK 22-01 (**Table 5-19**).

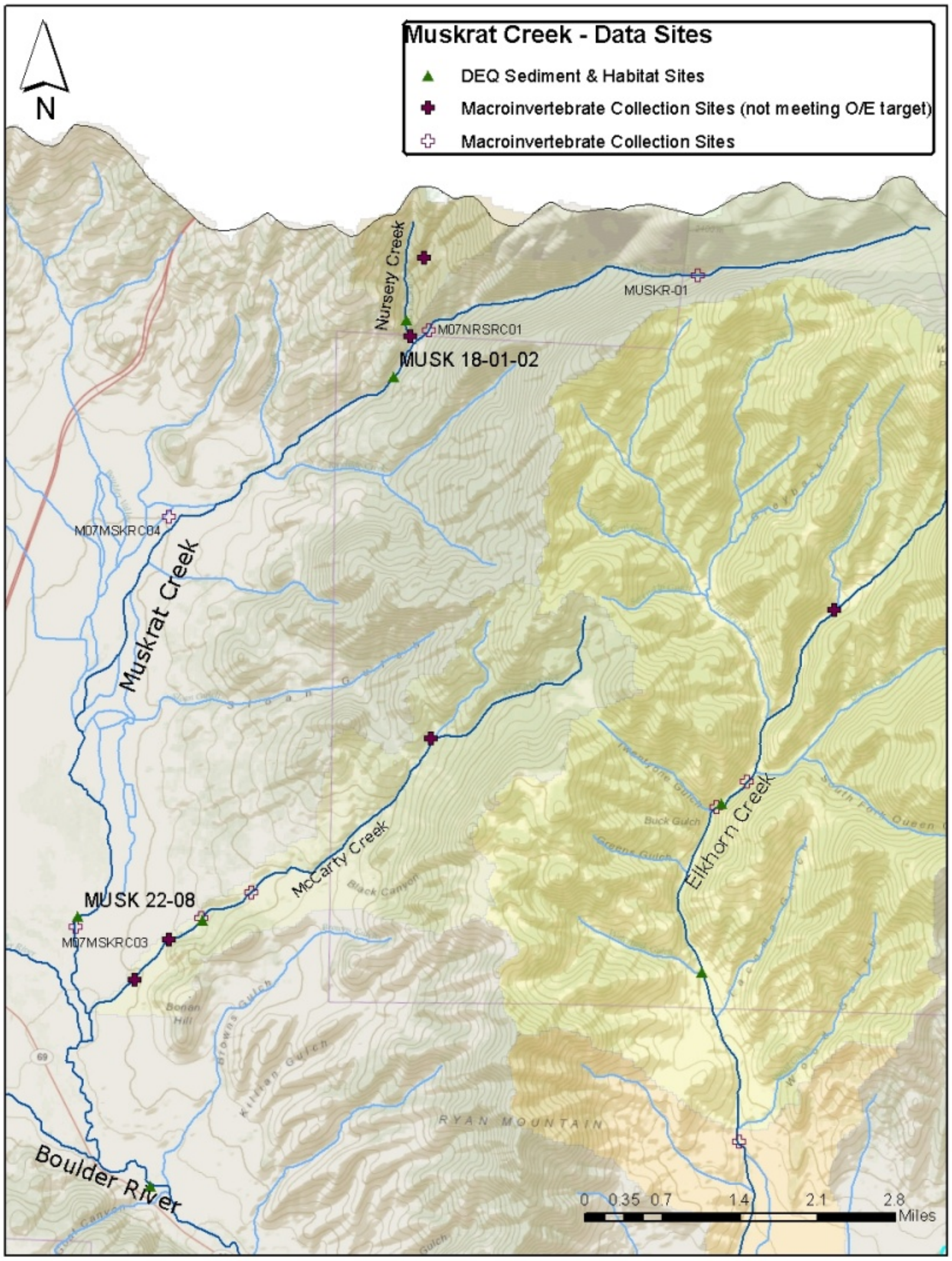

Figure 5-10. Muskrat Creek Data Sites

Table 5-19. Muskrat Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
MUSK 18-01	17w	2-2-U	13.6	**13.5**	**4.2**	0.9	**84**
MUSK 22-01	17w	0-3-U	14.4	14.0	**2.7**	**0.7**	**42**

Percent fines were also quite high and above the target at both sites. No shrub cover was recorded in both MUSK 22-01, and fairly high percentages of bare ground occur at both sites (**Table 5-20**).

Table 5-20. Muskrat Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
MUSK 18-01	**12**	**29**	**60**	72	**17**	539
MUSK 22-01	**44**	**53**	**11**	**0**	**13**	5

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled sites further:

- MUSK 18-01 is located on USFS land with a road paralleling the stream within 100 yards of the site. The site appears to be frequented by people, with established camp sites occurring near the top of the site. Hoof shear was observed in several places along this site, and old stumps on adjacent hillslopes indicate past logging. Cleared or grazed vegetation has left the banks unstable at a few locations in the upper portion of the site, although these are rare. The site occurs in a small, somewhat steep channel, characterized with large boulders and long riffles. Short pools exist with poorly developed tails and minimal spawning gravels that are typically embedded with fines. Some fish habitat is provided by small pocket pools near boulders. Large wood exists throughout the site and appears to influence channel form. Meander bends and large wood influence some actively eroding banks, and the channel splits in the lower portion of the site, also due to large wood.

- The stream through site MUSK 22-01 has been channelized and moved to accommodate the adjacent hay fields. Evidence of the excavated channel exists along river left. A road runs perpendicular to the channel downstream of the site, which may be restricting movement of groundwater and creating seeps along the channel. Several seeps or returns of irrigation water were observed in the lower ends of the site. Due to the channelized nature, the site has poorly developed features, including very few riffles, long runs with some micro-habitat, significant fine substrate, low sinuosity, and very little spawning habitat. The site is characterized by numerous slowly eroding banks with thick vegetation (grasses/sedges), fine substrate, and groundwater seepage throughout.

Macroinvertebrate Analysis

Macroinvertebrate data exists for four sampling events on Muskrat Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. One sample was collected in August 2003 and resulted in an O/E value of 1.1. Three samples were collected in August 2010 and resulted in O/E values of 1.2, 0.8, and 1.2.

Summary/Conclusion

Of the two DEQ assessed sites in 2010, channel form appears stable at the upper site; however percent fines and pool conditions are not meeting targets. The lower site has been considerably altered and affected by human activity, and the measured values reflect that. Assessment record information and the macroinvertebrate analysis results describe a generally healthy stream system that is improving, although it does note some effects from grazing in this watershed. Due to the recent observations in Muskrat Creek during the 2010 Field Investigation, human influences and impacts to Muskrat Creek still exist however, and a TMDL will be developed. However it is noted that conditions in Muskrat Creek overall are not as severe as many other streams in the Boulder Elkhorn TPA.

5.4.3.11 North Fork Little Boulder River, headwaters to the mouth (Little Boulder River); MT41E002_090

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for North Fork of the Little Boulder River was compiled in 2005. A brief summary review of that information provides the following description:

Grazing is a source of disturbance to riparian soils and streambanks in the upper areas, but less so at the lower end. The opposite is the case for the impacts of the forest road, as it plays an increasing role as a source of sediment to the channel in the lower portion of the site. Proximity of the road to the channel generally increases downstream, and channel storage of fine sediment is significant even in areas with steep gradients. Disturbances from grazing have impacted willow and sedge communities in the riparian area. Also, there are destabilized streambanks and altered channel features including the presence of mid-channel bars, expanding point bars and substrates containing high percentages of fine sediment compared to reference condition. The lower reaches are well armored with large rock, woody vegetation and large wood. The upper reaches are more vulnerable to disturbance, due to the vegetation communities and grazing presence there. Slight impairment and partial support of aquatic life due to sedimentation is concluded for the upper site. Monotonous substrate habitats and fairly low overall taxa richness may be attributable to high loads of sand in the substrate. Eroded granitic geology naturally elevates the sand supply to the channel. The channel morphology data indicates a departure from stability in the upper assessed reaches, where elevated sediment supply and in-channel storage is indicated. Sources of sediment include riparian grazing and sediment sources from the forest road.

2010 Field Investigation

Only one site on North Fork Little Boulder River was evaluated during the DEQ 2010 field investigations (**Figure 5-11**), in part due to accessibility issues and rough road conditions. NFLB 42-01 occurs in a second order reach. It has a steeper valley gradient (>4%) than is typically used to evaluate sediment, but was included in part, to represent this type of stream segment. Most channel form and habitat parameters appear good, although the width/depth ratio is slightly above the target (**Table 5-21**).

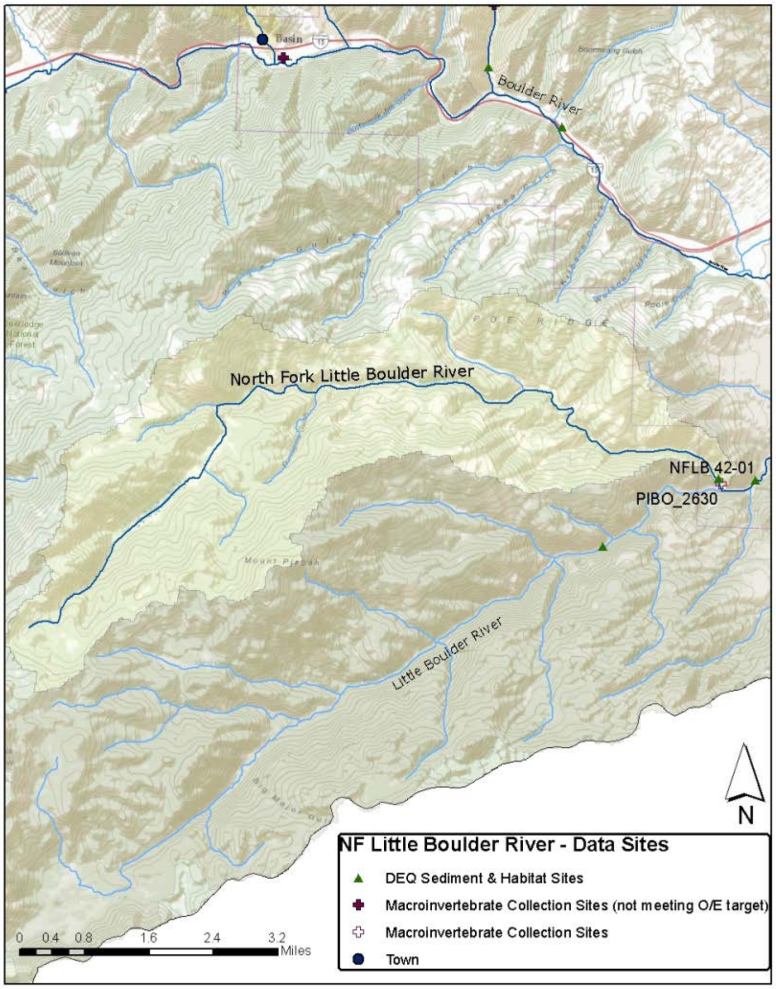

Figure 5-11. North Fork Little Boulder Data Sites

Table 5-21. North Fork Little Boulder River Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
NFLB 42-01	17ai	4-2-C	18.6	**17.1**	2.0	1.4	90

Percent fines were greater than the target values and certainly higher than what is expected for a steeper gradient site, indicating potential sedimentation (**Table 5-22**). A somewhat high percent of bare ground indicates some disturbance as well.

Table 5-22. North Fork Little Boulder River Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
NFLB 42-01	**15**	**30**	**43**	90	**16**	137

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled site further:

- A forest road parallels site NFLB 42-01 closely on river left, and a short access road also parallels the stream on river right. Metal piping was found in the lower portions of the site, and a non-functioning diversion structure or dam was found in the upper portion of the site. Other signs of human activity, in the form of debris and fire rings were observed. The site is naturally confined by the steep valley, but confinement is further exacerbated by the two neighboring roads. The stream is a steep, cascading channel with numerous large boulders. Not many true riffles occur, and pools were often deep with poorly developed tails and minimal spawning gravel. Multiple split channels exist from the influence of boulders and large wood. Fine material occurs in pools and slow water, but may in part be naturally derived from the local granitic geology. Some actively eroding banks exist throughout the site, but they are generally short and near vertical or overhanging. Bare ground through this site is also influenced by the dense canopy shading and steep topography of the site.

Macroinvertebrate Analysis
Macroinvertebrate data exists for one sampling event on the North Fork Little Boulder River. An observed/expected model was run using the results of this event. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. The sample was taken in September 2008. The O/E value result was 1.1.

Summary/Conclusion
Although only one site was investigated on the North Fork Boulder River during the 2010 DEQ field effort, information in the DEQ files provides further information about the stream, particularly regarding areas of the upper watershed. Impacts occur both in the upper watershed (largely from grazing), and in the steeper lower segments (largely from adjacent roads). A TMDL will be developed for North Fork Little Boulder River.

5.4.3.12 Nursery Creek, headwaters to the mouth (Muskrat Creek); MT41E002_130

Assessment Records
DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Nursery Creek was compiled in 2005. A brief summary review of that information provides the following description:

Fishery information is limited to either the presence or absence of fish over a period of years, but with no estimates or statements as to general health. Macroinvertebrate results indicate sediment deposition may have compromised stony substrates. Pebble counts and assessments document the presence of very fine and smaller gravels (90% 6mm or less). The cause is likely natural however, due to the erosion that followed fires in 2000, when almost the entire drainage burned. Habitat data reveals the stream was likely overgrazed in the mid-80s, but is currently stable and recovering. Photos and assessments document excellent willow and bank vegetative communities, with no current grazing. While incised, the stream is no longer downcutting, nor laterally eroding. In 2004, bank vegetation was in excellent condition. No erosion was observed, although sand was prevalent in the stream bottom. Most of the sand is attributed to the fires in 2000, although a nearby road may also serve as a source.

2010 Field Investigation
Only one site on Nursery Creek was evaluated during the DEQ 2010 field investigations (**Figure 5-12**). NURS 07-01 occurs in a small first order reach with a valley gradient of 2-4%. Pool frequency was good;

and residual pool depths, although not meeting the target, may be appropriate for a stream of such small size (**Table 5-23**).

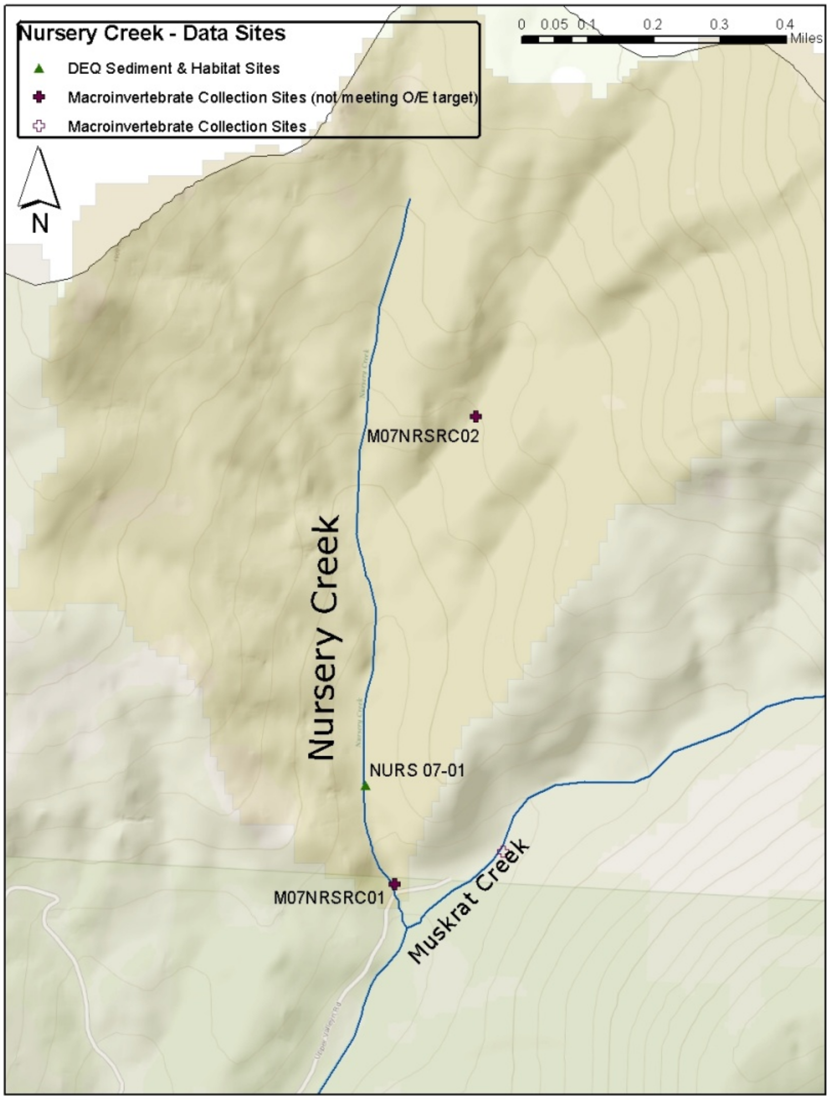

Figure 5-12. Nursery Creek Data Sites

Table 5-23. Nursery Creek Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
NURS 07-01	17w	2-1-C	4.0	8.2	5.6	**0.6**	137

Percent fines exceeded the target by a large amount. In addition, percent shrub cover did not meet the target (**Table 5-24**).

Table 5-24. Nursery Creek Substrate and Riparian Condition Data

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
NURS 07-01	**30**	**61**	**81**	**34**	0	655

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled site further:

- Nursery Creek was impacted by a forest fire through this site a number of years ago, and the site now has many standing or fallen dead trees. Cattle trampling is also evident within this site, along with signs of browse. Despite the human impacts, the stream channel appears relatively healthy with only moderate grazing impacts. The site has long riffles and short plunge pools created by wood. Numerous pieces of large wood occur throughout the channel, which affect the channel form. Pool tails have only marginal spawning gravels, but may be appropriate for the smaller sized fish that would be found here. Streambanks are stable, with limited eroding banks, and lush wetland vegetation throughout most of the site.

Macroinvertebrate Analysis

Macroinvertebrate data exists for five sampling events at two locations on Nursery Creek. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. One sample was collected in June 2004 and resulted in an O/E value of 0.5. One sample was collected in July 2010 and resulted in an O/E value of 0.8. One sample was collected in August 2010 and resulted in an O/E value of 0.6. Two samples were collected in September 2010 and resulted in O/E values of 0.5 and 0.7.

Other Information

Recent investigations related to nutrient impairment in Nursery Creek observed grazing activity and potential sediment issues in much of the watershed upstream of NURS 07-01. Nursery Creek is a relatively small watershed at 700 acres; approximately 65% of which is allotted for grazing by the BLM. According to BLM records, 54 cattle are allowed to graze in this watershed throughout the summer months. Cattle are allowed to roam during the summer and not deliberately concentrated along the valley bottoms. As a result, grazing impacts may vary throughout the watershed, and be less or more significant depending on the location and the conditions experienced in that year.

Summary/Conclusion

Although only one site was evaluated on Nursery Creek during the 2010 DEQ sediment and habitat field effort, fairly recent information in the record assessment and from other pollutant investigations describe impact from sediment. The fire in 2000 appears to be a significant cause of sedimentation to Nursery Creek, and although it occurred a number of years ago the system still has remnants of those impacts. Presently, cattle grazing in the watershed also contributes to sediment sources. Although the site investigated in 2010 is stable and desirable vegetation dominates the riparian area, areas upstream of NURS 07-01 have known sediment impacts and riparian degradation from cattle grazing. As the watershed continues to recovers from the fires, the potential for full recovery may be limited depending on grazing management practices. Based on the above information, a sediment TMDL will be developed for Nursery Creek.

5.4.3.13 Uncle Sam Gulch, headwaters to the mouth (Cataract Creek); MT41E002_010

Assessment Records

DEQ assessment records provide data and information from a variety of sources, reviewed during the assessment process, which led to the impairment determination. The most recent assessment record for Uncle Sam Gulch was compiled in 1999. A brief summary review of that information provides the following description:

Impacts to habitat result from timber harvest, road construction, cattle, siltation, severely eroding banks, and a degraded riparian zone. Large volumes of slash, sedimentation, road erosion, and iron precipitate from mine drainage is evident in the stream. Stream bottom is in the worst condition relative to all other Boulder watershed streams assessed. Granitic sedimentation has eliminated interstitial space habitat for macroinvertebrates – stream bed was so hard that a pry bar was needed to remove rocks from the stream bed. Riparian habitat is also extensively degraded. The Crystal Mine has been identified as the largest source of low pH and metals to the Cataract and Uncle Sam Gulch drainages. Iron precipitation has resulted in hardening of the stream bottom below the Crystal Mine, eliminating or severely limiting aquatic invertebrate habitat. In addition, at least 50% of the drainage has been clearcut, and no best management practices were observed. Sediment loads are high, and scouring evident with severe bank erosion common.

2010 Field Investigation

Only one site was evaluated on Uncle Sam Gulch during the DEQ 2010 field investigations (**Figure 5-13**). USGU 10-01 occurs in a small first order reach, with a valley gradient of 2-4%. Pool frequency was good and pool depths only slightly exceeded the target (**Table 5-25**).

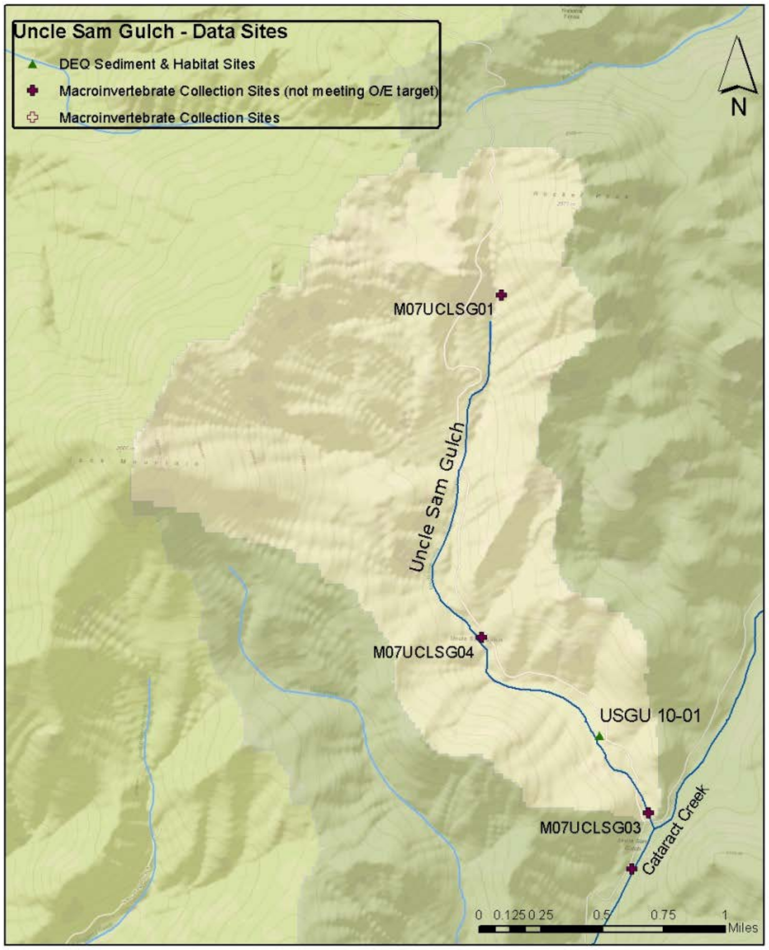

Figure 5-13. Uncle Sam Gulch Data Sites

Table 5-25. Uncle Sam Gulch Channel and Pool Quality Data

Reach	Ecoregion	Reach Type	Bankfull Width (ft)	Width/ Depth	Entrench-ment	Residual Pool Depth (ft)	Pools #/mile
USGU 10-01	17ai	2-1-U	12.2	15.6	5.7	**0.8**	132

Percent fines were considerably above the target value. Percent shrub cover was almost non-existent, and bare ground was considerably high indicating a significant disturbance to the riparian area (**Table 5-26**).

Table 5-26. Uncle Sam Gulch Substrate and Riparian Condition Data (Water & Environmental Technologies, 2010)

Reach	Wolman Pebble Count		Grid Toss in Pool Tails	Greenline		Large Wood #/mile
	Percent Fines <2mm	Percent Fines <6mm	Percent Fines <6mm	Percent Shrub Cover	Percent Bare Ground	
USGU 10-01	**25**	**44**	**81**	**3**	**51**	776

Values in **BOLD** indicate an exceedance of the target value.

Field notes from the 2010 field investigation describe the conditions of the DEQ sampled site further:

- Human impacts were abundant in USGU 10-01, including evidence of past grazing, riparian logging, an old road bed, wood structures, and campfire rings. The stream channel is dominated by a series of large wood controlled step pools, some of which may be natural, but others appear to be intentionally designed. Channel pattern is sinuous with few true riffles. Most of the stream is pool/run type features with a high percentage of fines. The stream is braided in the upper portion of the site, and there is evidence of an abandoned stream channel on river right. Substrate is highly embedded throughout the site. Bank erosion is minimal.

Macroinvertebrate Analysis
Macroinvertebrate data exists for three sampling events at three locations on Uncle Sam Gulch. An observed/expected model was run using the results of these events. O/E values only describe if the macroinvertebrate community is consistent with what would be expected for a given watershed. Values under the target value (0.80) imply conditions that are limiting the natural macroinvertebrate community. One sample was taken in July 2010 and resulted in an O/E value of 0.2. Two samples were taken in August 2010 and resulted in O/E values of 0.3 and 0.7.

Summary/Conclusion
Data from the site assessed in 2010 showed extremely high fine percentages, despite the other features being relatively good. However, assessment record information describes abundant human caused impacts and excessive sedimentation throughout the watershed. As a result of this information, a TMDL will be developed.

5.5 Source Assessment and Quantification

Four main source types for sediment were evaluated in the Boulder-Elkhorn TPA: sediment from bank erosion, sediment from roads, sediment from upland sources based on land use and land cover, and point sources as identified by permitted dischargers. The following sections describe the investigations into each of the source categories, and the subsequent sediment loading estimations used to develop the TMDL.

5.5.1 Bank Erosion

The following section describes how bank erosion was assessed in the Boulder-Elkhorn TPA, and how sediment loading values were applied to estimate existing and desired conditions.

5.5.1.1 Establishing the Existing Load

Data from the 2010 Boulder Elkhorn TPA sediment and habitat field effort was used to develop estimates of sediment loads from bank erosion for each watershed. For each stream site investigated, the sediment load for every eroding bank encountered was calculated, and then the total sediment load for that site was summed. Sites were sorted by the apparent degree of influence on eroding banks (predominantly natural vs. human causes), and reach type within which a site is located (a reach type is defined by its combination of stream order, valley slope, and valley confinement). Average sediment loads (tons/1000’) were then determined from these representative groupings. To estimate total bank erosion load for each stream of interest, average sediment loads for each reach type grouping were applied to their respective reaches. For those reach types without an estimated average sediment load, the average sediment load from the most appropriate comparable reach type was usually applied. In the case of reach types which only differ by confinement, when the confined variety of a given reach type did not have any sampled reaches by which to derive an average, one quarter of the sediment load from the unconfined variety of that reach type was used. This estimate is based on a generalized observation between paired confined and unconfined reach types that presumes that since confined reaches have less floodplain in which to migrate and are often armored and stabilized from natural geology or man-made conditions, they therefore produce less bank erosion than an unconfined reach of a similar type. **Table 5-27** presents the average sediment loads by reach type used for extrapolation.

Table 5-27. Reach Type Average Load Estimates

Reach Type*	Average Bank Erosion Sediment Load per 1000 feet (tons/year)	Number of Sampled Reaches	Sampled Reaches
MR-0-2-U	8.6	3	BASI 08-02, BISO 04-02, LOWL 08-01
MR-0-3-U	18.8	4	BASI 15-02, BISO 11-01, LBLR 37-01, MUSK 22-08
MR-0-4-U	43.4	5	BLDR 12-04, BLDR 13-04, BLDR 13-10, BLDR 13-23, BLDR 13-33
MR-2-1-U	1.7	1	USGU 10-01
MR-2-1-C	0.4	1	NURS 07-01
MR-2-2-U	1.5	2	CATA 18-01, MUSK 18-01
MR-2-3-U	8.6	1	ELKH 28-01
MR-2-3-C	1.6	2	ELKH 23-01, LBLR 32-01
MR-4-2-U	7.1	3	HIOR 09-01, HIOR 15-01, MCCA 22-01
MR-4-2-C	2.8	1	NFLB 42-01
			Comparable Reach Type Rate Application
MR-0-1-U	*1.7*	**0**	*applied MR-2-1-U rate
MR-0-2-C	*2.2*	**0**	* applied ¼ of MR-0-2-U rate
MR-0-3-C	*4.7*	**0**	* applied ¼ of MR-0-3-U rate
MR-2-2-C	*0.4*	**0**	* applied ¼ of MR-2-2-U rate
MR-4-1-U	*1.7*	**0**	*applied MR-2-1-U rate
MR-4-1-C	*0.4*	**0**	*applied MR-2-1-C rate
MR-4-3-U	*8.6*	**0**	*applied MR-2-3-U rate
MR-4-3-C	*1.6*	**0**	*applied MR-2-3-C rate
MR-10-1-U	*1.7*	**0**	*applied MR-2-1-U rate
MR-10-1-C	*0.4*	**0**	*applied MR-2-1-C rate
MR-10-2-U	*7.1*	**0**	*applied MR-4-2-U rate
MR-10-2-C	*2.8*	**0**	*applied MR-4-2-C rate
MR-10-3-C	*1.6*	**0**	*applied MR-2-3-C rate

Reach Type values = valley gradient – stream order – valley confinement

5.5.1.2 Establishing the Total Allowable Load

Once the existing bank erosion sediment load was derived, a desired load was established to determine the target conditions and sediment load reductions. While it is difficult to precisely quantify total sediment loads from bank erosion without assessing all streambanks, quantitative data coupled with qualitative information from the sample sites provides a foundation to estimate the total load and potential for sediment load reduction.

As described in the section above, all streams were delineated into reaches defined by a specific combination of criteria. For reaches lacking “on-the-ground” data, each reach was reviewed using aerial imagery. Human and/or natural influences on bank erosion were presumed and assigned to each reach based on nearby land use and land management. Reaches that occurred in areas with land management practices conducive to bank stability and good streamside vegetative health (such as riparian fencing or healthy wetland/riparian buffers) or areas of little human influence were designated as naturally influenced. Conversely, reaches that were predominantly influenced by the effects of land or stream management that often result in bank instability (no riparian vegetation, channel straightening, road encroachment) were designated as human influenced. Human influenced reaches were defined as having 70% or greater of the reach influenced by human activities, whereas natural influenced reaches were defined as having 70% or greater of the reach influenced by natural conditions, and/or conditions that incorporate all reasonable land, soil, and water conservation practices.

In the Boulder-Elkhorn TMDL planning area, 23 sites were assessed, and the majority of those sites were influenced by human activity. Only 3 sites were categorized as naturally influenced. This small number of naturally influenced reaches, coupled with the diversity of reach types in the watershed, makes it difficult to base desired conditions on sampled sites where natural conditions were observed. Therefore, a very simplistic approach was used. DEQ reviewed recently completed TMDL documents from watersheds in the Middle Rockies ecoregion (Flint Creek, Little Blackfoot, and Beaverhead River watersheds), and calculated the average sediment reduction from bank erosion from stream segments with sediment TMDLs. The average percent reduction from these stream segments is 50%. However, of the 39 stream segments reviewed, the range in percent reduction necessary for the streams was 7%-75% and therefore, to be conservative a 40% reduction in sediment load is requested from all reaches determined to be predominantly influenced by human activities. For reaches that were determined to be naturally influenced, the desired load was applied as the existing load for that reach and no reduction is necessary. Extrapolated loads by watershed are presented in **Table 5-28**.

Table 5-28. Estimated Bank Erosion Loads by Watershed

Stream	Existing Bank Erosion Load	Desired Bank Erosion Load	Percent Reduction
Basin Creek	597	389	35%
Boulder River: Above Basin (MT41E001_010)	1051	636	39%
Boulder River: Basin to Boulder (MT41E001_021)	1490	892	40%
Boulder River: Boulder to Cottonwood Cr (MT41E001_022)	7775	4658	40%
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	3171	1900	40%
All Boulder River segments	***13487***	***8086***	***40%***
Bison Creek	1584	968	39%
Cataract Creek	236	182	23%
Upper Elkhorn Creek (MT41E002_061)	224	142	37%
Lower Elkhorn Creek (MT41E002_062)	277	169	39%
Elkhorn Creek watershed	***501***	***311***	***38%***
High Ore Creek	110	70	36%
Little Boulder River	605	406	33%
North Fork Little Boulder	165	136	18%
Little Boulder River watershed	***770***	***542***	***30%***
Lowland Creek	498	305	39%
McCarty Creek	117	85	27%
Muskrat Creek	664	408	39%
Nursery Creek	5	3	40%
Uncle Sam Gulch	14	10	29%

5.5.1.3 Allocations and Load Reduction Achievement

The existing sediment load is a gross estimate based on an extrapolation of limited, though existing field data in the watershed. The desired load is determined through a simple exercise of applying the average percent reduction from other regionally similar watersheds to the existing load rates. As such, the quantified load is not as significant for management and TMDL achievement purposes as the estimated potential percent reduction. Since the desired load is based on comparisons of natural and human influenced bank erosion in similar watersheds, it is assumed that this is a reasonable estimate for what is achievable in the Boulder River watershed.

The percent reduction allocation encompasses all adjacent land use categories and land management practices. Land owners are expected to manage their properties with all applicable and reasonable land, water, and soil conservation practices. Reasonable land, soil, and water conservation practices in this context are intended to restore stable streambanks and promote healthy riparian corridors and may include limiting riparian livestock grazing durations to reduce the effect on riparian vegetation, directing livestock to designed water gaps or off-site watering locations, establishing a specific riparian corridor free from human-related activity, or re-establishment of key riparian vegetation. Implementing all reasonable land, soil, and water conservation practices does not prohibit management activities and business practices necessary to maintain a successful ranching, farming, or other private operation. However, in many cases land management activities can be incorporated that benefit both needs, and should be implemented whenever possible.

It is acknowledged that recovery of stable banks and improvement of riparian vegetation communities throughout an entire watershed may take many decades to achieve. It is encouraged that, in addition to managing current activities with all reasonable land, soil, and water conservation practices, management decisions to promote floodplain functionality and native vegetation establishment throughout the riparian corridor will be reviewed and implemented wherever and whenever possible.

Although it is sometimes difficult to use aerial imagery and GIS to identify bank erosion, it is possible to identify potential present-day influencing factors with these methods. During the reach stratification process, adjacent land use and potential current influences on bank erosion were noted for each reach. Simple breakouts of the apparent percent influence on major land use types allows a general, but useful, overview of those activities that may be affecting bank erosion. This data can be used to help assist land managers with prioritizing areas to expedite sediment load reductions and eventually achieve the TMDL. Rough estimates of potential influence at the watershed scale are presented in **Figure 5-14** below.

It is acknowledged that the developed sediment loads and the method by which to attribute human and historical influence are estimates based on aerial photography, best professional judgment, and limited access to on-the-ground reaches. The assignment of bank erosion loads to the various land uses is not definitive; however it does provide helpful guidance for directing focus and efforts at reducing the loads from those causes which are likely having the biggest impacts on the investigated streams. Ultimately, it is the responsibility of local land owners and managers to identify the causes of bank erosion, and adopt practices to reduce bank erosion where ever practicable and possible. Complete TMDLs and allocations are presented in **Section 5.6**.

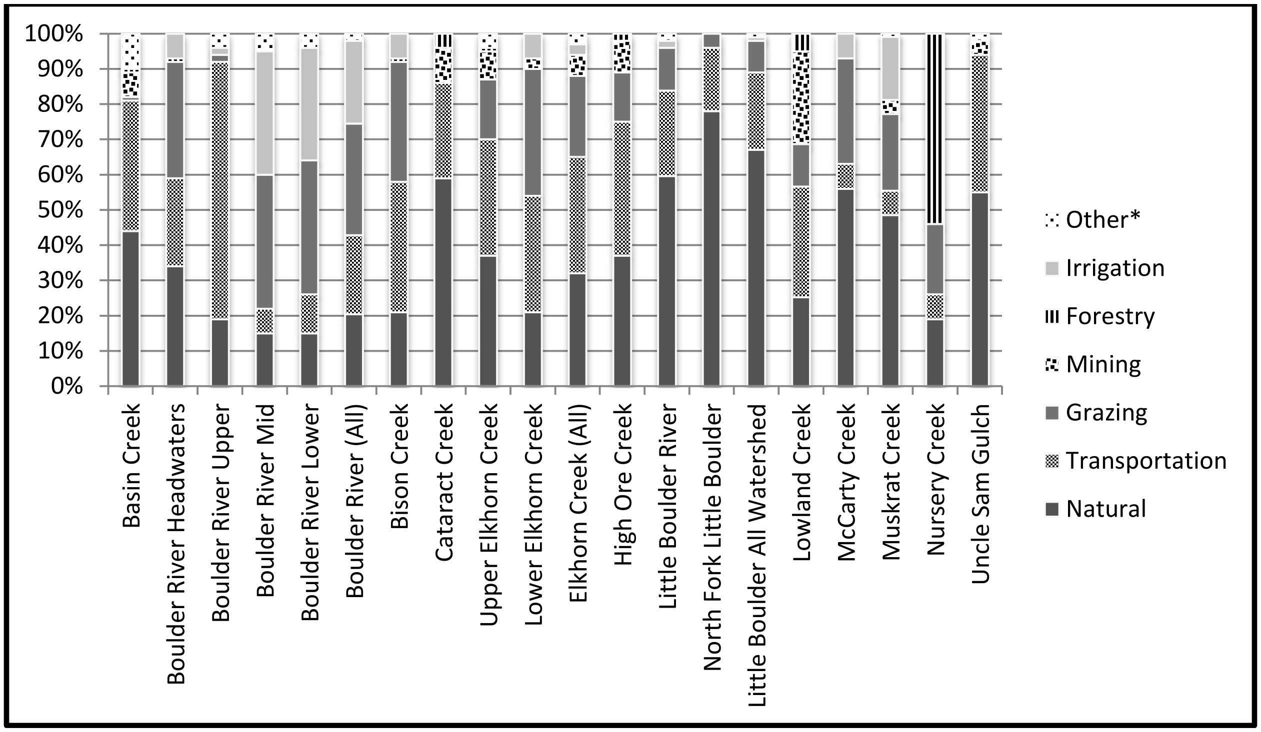

Figure 5-14. Estimated Land Use/Land Type Influences on Bank Erosion by Watershed

* Other refers to influences on bank erosion that do not appear to be the result of obvious or adjacent human activity, but do not appear to be the result of a natural condition either. Examples include destabilization of banks from past activities such as historical timber harvest, dam failure, etc.

5.5.1.4 Assumptions and Considerations

- The annual streambank erosion rates used to develop the sediment loading numbers were based on Rosgen BEHI studies developed using USDA Forest Service (in Colorado) data for streams found in sedimentary and/or metamorphic geology. While the geologies between the Rosgen research sites and the Boulder River TPA are not identical, they are similar enough in character to warrant their application.
- The bank erosion data collected during the 2010 field effort is representative of current conditions throughout the Boulder River watershed.
- The assignment of influence to the eroding banks, and distinction between natural and human caused bank erosion is based on best professional judgment by qualified and experienced field personnel.
- The application of a 40% bank erosion load reduction from reaches influenced by human activity is an estimate based on the average bank erosion load reductions determined in previous bank assessments. This percent reduction is considered reasonable given the amount of human influence throughout the Boulder-Elkhorn watershed, and is generally consistent land use and management throughout the region.
- Specific quantification of the load reductions estimated here is not as significant as the complete application of best management practices in each of the watersheds of interest. Through application of all reasonable land, soil, water conservation practices it is expected that the allocation will be achieved.

- The land use influence percentages identified in **Figure 5-14** are general and may not be entirely accurate. They are intended to provide a starting point for further investigation and activities to address bank erosion by land owners, land use planners, and watershed managers.

5.5.2 Sediment From Roads

Roads located near stream channels can impact stream function through a degradation of riparian vegetation, channel confinement, and sediment loading. The degree of impact is a function of a number of factors including road type, construction specifications, drainage, soil type, topography, precipitation, and the use of best management practices (BMPs). In the Boulder-Elkhorn planning area, sediment from roads has been identified as one of three major source categories potentially contributing to sediment loads in impaired tributary streams.

5.5.2.1 Establishing the Existing Load

In 2011, DEQ conducted a GIS study of road systems in the Boulder-Elkhorn planning area to identify both stream crossings and sections of road impinging upon streams. At the same time, the BDNF conducted a field survey of the road network on USFS lands in order to complete an environmental impact statement (EIS) for a proposed timber sale. The BDNF agreed to share their field survey data with DEQ. This dataset is the basis for the quantification of sediment contribution from the road network. DEQ used a soil erosion model (WEPP:Road) to quantify the amount of sediment produced at each measured location. The model was used to quantify loads for both existing conditions and potential BMP conditions. Results from assessed road features were then extrapolated to non-assessed features. The following subsections present summary information regarding the road assessment and load calculations. Expanded details of this assessment are provided in **Appendix E**.

Computer models are often used to simulate road surface erosion response to the hydrology and climate for a given area. These models take into account weather, road condition, road shape, road orientation, topography, buffering vegetation, and other factors. Most models require a certain amount of specific field information as input parameters to derive loads from discrete locations. In large areas of study, representative conditions from a subset of locations may be modeled, and the results extrapolated to the remaining roads.

In 2011, DEQ used GIS software to identify crossings and parallel segments in the road network, and classified them relative to the subwatersheds of interest, precipitation zone and road type. DEQ developed the model of unpaved road crossings using an intersection of perennial streams in the 1:100,000 scale National Hydrography Dataset (NHD) and the roads layer in the transportation data framework maintained by the Montana Basemap Service Center. Road surface type (paved, gravel, native) was assigned where needed. The resulting layer of road/stream intersections was manually edited using aerial photographs to remove duplicates or other geometric intersections created by errors in the source GIS data. Road mile and road density results from GIS assessment are presented by watershed in **Table 5-29**.

Table 5-29. Road Miles and Road Density by Watershed

Stream	Watershed Area (mi^2)	Stream Miles	Road Miles	Road Density (mi/mi^2)
Basin Creek	41.62	59.9	70.8	1.7
Bison Creek	77.66	74.7	139.1	1.8
Boulder River: Above Basin (MT41E001_010)	68.87	86.3	199.8	2.9
Boulder River: Basin to Boulder (MT41E001_021)	36.93	33.5	90.9	2.5

Table 5-29. Road Miles and Road Density by Watershed

Stream	Watershed Area (mi^2)	Stream Miles	Road Miles	Road Density (mi/mi^2)
Boulder River: Boulder to Cottonwood Cr (MT41E001_022)	77.4	133.1	194.8	2.5
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	56.43	39.1	69.9	1.2
Cataract Creek	30.41	33.9	78.5	2.6
Dry Creek	31.38	22.4	35.0	1.1
Upper Elkhorn Creek (MT41E002_061)	31.79	28.1	44.7	1.4
Lower Elkhorn Creek (MT41E002_062)	5.66	4.0	4.5	0.8
High Ore Creek	8.87	9.6	24.6	2.8
Little Boulder River	39.86	47.2	48.4	1.2
Lowland Creek	42.93	41.2	124.7	2.9
North Fork Little Boulder River	18.58	15.7	34.0	1.8
McCarty Creek	5.77	7.7	6.2	1.1
Muskrat Creek	38.89	43.0	81.6	2.1
Nursery Creek	1.07	1.9	1.5	1.4
Uncle Sam Gulch	3.15	4.0	12.6	4.0

In previous unpaved road assessments, DEQ has randomly selected a subset representing approximately 10% of the crossings in a planning area and measured the required model parameters at those pre-selected crossings. The BDNF field data was collected differently. The BDNF field crews traveled the length of the study roads, measuring and recording field parameters at any road feature seen to be a sediment source. The BDNF crews measured 44 sites, which DEQ integrated into the road model. Using provided field notes and photographs, DEQ determined that 22 of the USFS sites are stream crossings. The other 22 are used to represent road segments impinging on streams. Where a USFS field site was determined to correspond to a GIS-modeled crossing, the latter was deleted from the GIS layer to avoid duplication. The total number of unpaved road crossings in the planning area model is 506.

Because the BDNF survey was sufficiently broad to include roads attributes typically used for TMDL analysis (graveled and native surfaces, high to low traffic), DEQ decided that it was a reasonable sample from which to extrapolate and represent the planning area. To account for the variation in climate across the planning area, DEQ modeled each measured site twice, using two different climate zones. One climate zone represents the mountain climate of the Boulder Mountains, and the other represents the valley climate near Boulder. The boundary between climate zones was set at the 20 inch average annual precipitation contour.

DEQ modeled sediment production from the assessed sites using the WEPP:Road forest road erosion prediction model (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995). WEPP:Road was developed by the USFS and other agencies to predict runoff, erosion, and sediment delivery from forest roads. The model predicts sediment yields based on soil, climate, ground cover, and topographic conditions. Specifically, the following model input data is collected in the field: soil type, percent rock, road surface, road design, traffic level, and specific road topographic values (road grade, road length, road width, fill grade, fill length, buffer grade, and buffer length). In addition, supplemental data is collected on vegetation condition of the buffer, evidence of erosion from the road system, and potential for best management practice implementation. Model results for road crossings and parallel roads are presented separately.

Sediment From Road Crossings

Intersections of road and stream are natural drainage locations and generally have limited capacity for buffering or diverting sediment laden runoff from the road. The contributing sediment load at road crossings is a function of the road length and condition adjacent to the crossing, and other physical and hydrologic characteristics of the immediate area. Addressing road/stream crossings and their contributing sediment load is an important component to managing the sediment load from road networks.

Using the field notes provided by the BDNF, DEQ sorted the 44 measured sites into stream crossings (n = 22) and stream-adjacent sites (n = 22) and then calculated a mean sediment load for the crossings. This was done twice, once for each climate zone (mountain and valley). The mean loads are 44.83 pounds/year for the mountain precipitation zone and 17.76 pounds/year for the valley precipitation zone.

Sediment loads for the Boulder-Elkhorn TPA road crossings were then extrapolated by assigning the average sediment load for each climate zone to all the road crossings within that zone, except for the field sites. These were assigned the specific load calculated for that specific site, using the appropriate climate zone. Of the crossing identified, 67 crossings are paved and therefore determined to not contribute road sediment from erosion. Sediment from traction sand application on highways (I-15 and MT-69) is discussed later in this section. Sediment loads from road crossings per TMDL stream segment are presented in **Table 5-30**.

Table 5-30. Road Crossing Load Estimates by Stream Segment

Stream	Number Crossings	Estimated Total Load (tons/year)	BMP
Basin Creek	51	1.13	0.100
Bison Creek	48	1.237	0.0828
Boulder River: Above Basin (MT41E001_010)	82	1.713	0.1616
Boulder River: Basin to Boulder (MT41E001_021)	38	0.532	0.0563
Boulder River: Boulder to Cottonwood Creek (MT41E001_022)	56	0.7	0.0791
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	10	0.102	0.0128
Cataract Creek	39	0.847	0.0759
Dry Creek	16	0.291	0.0279
Upper Elkhorn Creek: (MT41E002_061)	28	0.546	0.0509
Lower Elkhorn Creek: (MT41E002_062)	4	0.036	0.0048
High Ore Creek	12	0.242	0.0223
Little Boulder River	24	0.461	0.0431
Lowland Creek	34	0.781	0.0739
North Fork Little Boulder River	8	0.103	0.0108
McCarty Creek	6	0.067	0.0080
Muskrat Creek	28	0.249	0.0337
Nursery Creek	5	0.044	0.006
Red Rock Creek	13	0.208	0.0212
Uncle Sam Gulch	4	0.09	0.0079

Sediment From Parallel Segments
Sediment contributed from road/stream crossings addresses discrete locations in a watershed where the road and stream intersect. However, road sediment from those sections of road directly adjacent to the stream that may not have a direct entry point to the stream channel must also be considered and included with the overall sediment load quantification. As the BDNF crews measured WEPP:Road parameters for all sediment producing features they encountered, DEQ was able to quantify sediment produced both from road crossings and also from road segments parallel to stream channels.

In the Boulder-Elkhorn TPA, parallel road segments were modeled with WEPP:Roads to calculate the sediment shed from roads that are within a distance of 150 feet of the stream. The WEPP:Road model limits the maximum contributing length to 1,000 feet, so this value was substituted for several sites measured by the USFS. The calculated load for each parallel segment was converted to an annual load per mile of road length.

The average load per mile was then multiplied by the total miles of parallel road segments in each watershed (as was identified during the GIS analysis) and an estimate of sediment load from parallel segments was determined for each watershed. Sediment loads from parallel segments per watershed are presented in **Table 5-31**. Note that these loads are not additive, as the load for each TMDL stream includes the load for any tributaries to that stream. The load for Cataract Creek includes the load for Uncle Sam Gulch, for example. Similarly, the load estimated for the lower segment of Elkhorn Creek includes the load for the upper segment.

Table 5-31. Parallel Road Load Estimates by Stream Segment

Stream	Miles of Parallel Road w/in 150’	Estimated Total Load (tons/year)	BMP (tons/year)
Basin Creek	9.7	2.8	0.067
Bison Creek	8.25	2.144	0.051
Boulder River: Above Basin (MT41E001_010)	10.83	3.193	0.076
Boulder River: Basin to Boulder (MT41E001_021)	15.253	2.515	0.0636
Boulder River: Boulder to Cottonwood Creek (MT41E001_022)	10.215	1.791	0.045
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	0.45	0.083	0.002
Cataract Creek	8.03	2.077	0.050
Dry Creek	2.89	0.853	0.020
Upper Elkhorn Creek: (MT41E002_061)	8.156	1.992	0.048
Lower Elkhorn Creek: (MT41E002_062)	0.526	0.058	0.002
High Ore Creek	4.599	0.979	0.024
Little Boulder River	9.94	1.92	0.048
Lowland Creek	10.778	2.753	0.066
North Fork Little Boulder River	1.496	0.390	0.011
McCarty Creek	0.2	0.022	0.001
Muskrat Creek	8.766	0.973	0.026
Nursery Creek	1.425	0.158	0.004
Red Rock Creek	4.187	1.066	0.026
Uncle Sam Gulch	1.247	0.368	0.009

Sediment From Traction Sand

Traction sand applied to highways during winter maintenance is another potential source of sediment from roads. DEQ estimated these loads using information provided by MDT of annual miles plowed and sand applied in the planning area on sections of I-15 and MT 69, based on data from 2007-2011. However, not all traction sand applied to the road ends up in nearby streams. A study conducted for the St. Regis River TMDL (Montana Department of Environmental Quality, 2008) looked at traction sand delivery as a function of distance to the stream. That study determined that 41% of applied traction sand makes it to the stream when the road is 25 feet or less from the stream, 6% makes it to the stream for distances of 26 to 50 feet, and only 3% is delivered when the road is 51 to 100 feet from the stream. Traction sand on roads greater than 100 feet from the stream is presumed to be completed captured. With this report in mind, using GIS software, DEQ identified sections of highway for three distance categories: <25 feet to the stream, 25-50 feet to the stream, and 51-100 feet to the stream.

The St. Regis watershed is somewhat unique however due to the steep terrain and narrow stream corridor that accommodates both the river and highway, and therefore may not be appropriate as the sole reference for estimating traction sand in the Boulder Elkhorn. The Montana Department of Transportation has also conducted traction sand contribution studies. One study conducted in 2005 along Trail Creek in the Beaverhead watershed (Hydrometrics, Inc., 2005), estimated that at two sites investigated, the percent of traction sand that reached the river was 4.9% and 1.5%, respectively. The sites assessed were located within 25’ of the stream, in areas of relatively flat shoulder and low slope between the road and creek. Another study, conducted in 2007 along Nevada Creek in Powell County (Hydrometrics, Inc., 2007), found even less sediment contribution from traction sand. Of the three sites described in that report, two had traction sand contribution less than 1% and one found no traction sand contribution at all, with one of the sites occurring on a steep embankment between the road and stream.

Both the St Regis study and the two MDT studies make a decent starting place to consider traction sand contribution in the Boulder Elkhorn, however neither represents road conditions in the Boulder Elkhorn particularly well. The methods used in the studies are not entirely relatable to each other, and questions related to those methods remain for both. Road and road side conditions in the St. Regis watershed are considerably steeper than typically found along highways in western Montana, and the studies recently conducted by MDT occur in areas less steep and that have more buffering capacity than what is typical in the Boulder watershed. As a result, estimations for traction sand contribution in the Boulder Elkhorn are consigned to gross assumption based on the mid-range and variability of the references reviewed. Therefore, traction sand delivery is estimated as 20% for roads within 25 feet or less of the stream, 3% for roads within 26 to 50 feet, and 1% for roads within 51 to 100 feet.

Using the MDT records for road sand application in the Boulder Elkhorn, DEQ was able to estimate an average annual volume of traction sand applied per mile of highway. MDT also provided information that roughly estimated approximately 25% of what is applied each year is later reclaimed through road maintenance and shoulder cleanup. DEQ then used the distance categories and delivery percentages described above to estimate an average traction sand load to the stream for both the Boulder River and Bison Creek (**Table 5-32**). The average annual load to the Boulder River from traction sand along Interstate 15 and MT Hwy 69 is an average of 22.3 tons/year. Bison Creek receives an average of 1.2 tons/year.

Table 5-32. Major Highway Road Sanding Load Estimates

Road Segment Categories	Average Application of Traction Sand (tons/mile)	Road Length (miles)	Sand Applied (tons)	Road Maintenance Reduction (25%)	Percent Delivery to the Stream	Sediment Delivery Load (tons)
Boulder River						
Hwy 69 – 51-100’	17.9	0.19	3.4	2.6	1%	<0.1
I-15 - <25’	131.7	0.84	110.6	83.0	20%	16.6
I-15 – 25-50’		1.0	131.7	98.8	3%	3.0
I-15 – 51-100’		2.72	358.2	268.7	1%	2.7
Total						22.3
Bison Creek						
I-15 - <25’	131.7	0.03	4.0	3.0	20%	0.6
I-15 – 25-50’		0.03	4.0	3.0	3%	0.1
I-15 – 51-100’		0.53	69.8	52.4	1%	0.5
					Total	1.2

The amount of sand applied to Montana highways varies each year according to the severity of winter weather; however MDT has been actively pursuing strategies to reduce the amount of sand applied to the roads. Over the period of record (2007-2012), the amount of sand applied per mile has shown a decreasing trend. In fact, road sand application on I-15 in 2012 was approximately 35% less than the average of the previous five years, and almost 90% less on Hwy 69. While the milder winter weather conditions of 2012 certainly had some effect on those values, this significant reduction is also a result of changing management practices by the MDT. To the extent practical, management practices designed to protect water quality and the state’s beneficial uses should always be pursued, however a balance must be struck between maintaining or improving water quality, ensuring the safety of driving conditions on Montana highways, and financial, equipment, and human resource constraints. It appears MDT is actively pursuing methods to find this balance, and as such, no percent reduction of road sand is included in the BMP loads in the sections below. MDT is encouraged to continue investigating and implementing solutions that work toward protecting Montana’s water resources, while keeping Montana’s roadways safe.

5.5.2.2 Establishing the Total Allowable Load

The sum of the loads from road crossings and parallel segments is an estimate of the existing sediment load from the road network in the Boulder-Elkhorn TPA. In order to determine the load that would result from the implementation of all best management practices (the desired load), each of the measured sites was modeled again in WEPP:Roads with changes made to represent the improved road conditions. Potential on-the-ground improvements include improving road surface type, reducing the contributing length of road to the crossing through installation of waterbars or additional drainage features, and improvement of roadside vegetation for filtering purposes. BMP implementation was modeled by reducing contributing lengths to a maximum of 200 feet, changing surface category from rutted to unrutted (except where traffic levels are ‘high’), and changing ditch classification from bare to rocked/vegetated. As with existing loads, sites were modeled for both climate zones and the values were extrapolated throughout the watersheds. Mean estimated loads for the mountain and valley climate zones are 3.97 pounds/year and 2.41 pounds/year, respectively (**Table 5-33)**. **Table 5-34** also provides a normalized load (load/square mile) to illustrate relative degree of loading between watersheds.

Table 5-33. Total Estimated Existing Loads and BMP Loads for Major Tributaries and Stream Segments

Stream	Crossings Load	Parallel Load	Total Load	BMP Crossing Load	BMP Parallel Load	BMP Total Load
Basin Creek	1.13	2.8	3.93	0.1	0.07	0.17
Bison Creek	1.24	2.14	4.58*	0.08	0.05	1.33*
Boulder River: Above Basin (MT41E001_010)	1.71	3.19	4.9	0.16	0.08	0.24
Boulder River: Basin to Boulder (MT41E001_021)	0.53	2.52	25.35*	0.06	0.06	22.42*
Boulder River: Boulder to Cottonwood Creek (MT41E001_022)	0.7	1.79	2.49	0.08	0.04	0.12
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	0.1	0.08	0.18	0.01	<0.01	0.01
Cataract Creek	0.85	2.08	2.93	0.08	0.05	0.13
Dry Creek	0.29	0.85	1.14	0.03	0.02	0.05
Upper Elkhorn Creek: (MT41E002_061)	0.55	1.99	2.54	0.05	0.05	0.1
Lower Elkhorn Creek: (MT41E002_062)	0.04	0.06	0.1	<0.01	<0.01	0.01
High Ore Creek	0.24	0.98	1.22	0.02	0.02	0.04
Little Boulder River	0.46	1.92	2.38	0.04	0.05	0.09
Lowland Creek	0.78	2.75	3.53	0.07	0.07	0.14
North Fork Little Boulder River	0.1	0.39	0.49	0.01	0.01	0.02
McCarty Creek	0.07	0.02	0.09	0.01	<0.01	0.01
Muskrat Creek	0.25	0.97	1.22	0.03	0.03	0.06
Nursery Creek	0.04	0.16	0.2	0.01	<0.01	0.01
Red Rock Creek	0.21	1.07	1.28	0.02	0.03	0.05
Uncle Sam Gulch	0.09	0.37	0.46	0.01	0.01	0.02

*Includes road sand load estimates

5.5.2.3 Allocations and Load Reduction Achievement

Allocations for the reduction of sediment from roads in the Boulder-Elkhorn TPA are presented as general percent reduction by watershed. It is expected that the maintenance of roads and ultimate achievement of the desired load is the responsibility of those individuals or entities controlling and managing the roads.

Examples of management practices that may achieve load reductions include a variety of measures such as the installation of structural BMPs (drive through dips, culvert drains, settling basins, silt fence, etc), road surface improvement, reduction in road traffic levels (seasonal or permanent road closures), and timely road maintenance to reduce surface rutting. It is recognized that in reality, in some cases the majority of the sediment load may come from only a few discrete locations within a watershed, or some watersheds may currently have some or all of their roads addressed with appropriate BMPs and the allocations may already have been met. It is expected however, that the derived sediment load and expected reductions in this document serve as a starting point for road management investigations, and a guideline for where to begin additional studies to improve and refine these estimates. Complete TMDLs and allocations are presented in **Section 5.6**.

Table 5-34. Existing Sediment Loads Normalized by Watershed Area

Stream	Area (miles^2)	Estimated Total Load (tons/year)	Normalized Total Load (tons/year/mi^2)
Basin Creek	41.62	3.93	0.09
Bison Creek	77.66	4.58*	0.06
Boulder River: Above Basin (MT41E001_010)	68.87	4.9	0.07
Boulder River: Basin to Boulder (MT41E001_021)	36.93	14.15*	0.38
Boulder River: Boulder to Cottonwood Creek (MT41E001_022)	77.4	13.69*	0.43
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	56.43	0.18	<0.01
Cataract Creek	30.41	2.93	0.09
Dry Creek	31.38	1.14	0.04
Upper Elkhorn Creek: (MT41E002_061)	31.79	2.54	0.08
Lower Elkhorn Creek: (MT41E002_062)	5.66	0.1	0.02
High Ore Creek	8.87	1.22	0.13
Little Boulder River	39.86	2.38	0.06
Lowland Creek	42.93	3.53	0.08
North Fork Little Boulder River	18.58	0.49	0.03
McCarty Creek	5.77	0.09	0.02
Muskrat Creek	38.89	1.22	0.03
Nursery Creek	1.07	0.2	0.19
Red Rock Creek	20.79	1.28	0.06
Uncle Sam Gulch	3.15	0.46	0.15

*Total includes load from traction sand

5.5.2.4 Assumptions and Considerations

- It is assumed the sites used in this analysis are representative of conditions throughout the Boulder-Elkhorn TPA.
- The WEPP:Roads model reasonably characterizes the sediment loads for the road and climate conditions observed in the Boulder Elkhorn.
- The BMP scenarios are reasonable applications of improvements that can be expected at most sites throughout the watershed.
- The BMP reductions simulated in WEPP represent the likely achievable reductions in sediment load that may be achieved from BMP application throughout the watershed.
- BMPs may have already have been implemented on roads but have not been accounted for in the GIS information used in this analysis and therefore the reductions necessary may be less than described in this document.

5.5.3 Upland Erosion Sediment Source Loads

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of BMPs. The BMPs evaluated assumed modifications in upland management practices as well as improvements within the riparian buffer zone. When reviewing the results of the upland sediment load model, it is important to note that a significant portion of the sediment load is the natural upland load and not affected by the application of BMPs to the upland management practices.

5.5.3.1 Establishing the Existing Load

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (United States Department of Agriculture, 1983) as:

1) A = RK(LS)CP (in tons per acre per year)

Where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice (P) (Renard et al., 1997; Wischmeier and Smith, 1978). USLE was selected for the Boulder Elkhorn watershed due to its relative simplicity and ease in prediction models. These include: (1) the Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe et al., 1999).

A sediment delivery ratio (SDR), based on work conducted by Megahan and Ketcheson (1996), was incorporated with the USLE results to better account for sediment redeposition along a hillslope, and the percentage of sediment ultimately delivered to the stream. In addition, given that riparian zones can be effective sediment filters when wide and well vegetated, that riparian zone health is susceptible to anthropogenic impacts and thus to land management decisions, and that the effectiveness of riparian zones as sediment filters has been quantified in the literature, riparian zone health was qualitatively assessed using aerial imagery and further incorporated into the distance based SDR.

5.5.3.2 Establishing the Total Allowable Load

From the model output, an average annual sediment load delivered to the stream is determined for each watershed (or listed segment watershed). This sediment load represents the best estimation of existing conditions (land use, land cover, riparian condition) and resultant sediment load from upland sources.

To determine the total allowable load from upland sources, land use/land cover categories are modified (through an alteration to the C-Factor, or vegetative condition), riparian condition categories improved to represent those changes on the landscape, and the USLE model is run again. The resultant sediment loads represent a desired condition where all reasonable land, soil, and water conservation practices are employed.

For the purposes of this assessment, only a few land use categories were modified. The ‘grasslands/herbaceous’, ‘shrub/scrub’, ‘pasture/hay’, ‘cultivated crops’, and ‘woody wetlands’ BMP C-factors were conservatively changed to reflect a 10 percent increase in ground cover over existing conditions. This represents a modest improvement that may be generally achievable given improved land and cattle management practices. ‘Transitional’ land classification was changed to reflect the forest cover that is returning after forest fires.

Riparian classifications were also improved in BMP scenarios where of the five riparian quality categories (good, moderately good, fair, moderately fair, and poor), moderately good was improved to good, fair was improved to moderately good, and poor or moderately fair was improved to fair. The changes represent improvement to the riparian corridor that may result, over time, when management practices limit effects on riparian vegetation and allow riparian vegetation to mature.

Results of the existing condition upland modeling scenario and BMP scenarios are presented in **Table 5-35**. Details of the modeling effort are included in **Attachment X**.

Table 5-35. USLE Sediment Load Modeling Results by Watershed

Watershed	Existing Condition (tons/year)	Land Use/Land Cover BMP Implementation (tons/year)	Percent Change From Existing	Land Use/Land Cover BMPs and Riparian Improvement (tons/year)	Percent Change From Existing Condition
Basin Creek	195	169	***13***	134	***31***
Bison Creek	441	375	***15***	216	***51***
Boulder River: Above Basin (MT41E001_010)	769	601	***22***	348	***55***
Boulder River: Basin to Boulder (MT41E001_021)	272	185	***32***	167	***39***
Boulder River: Boulder to Cottonwood Creek (MT41E001_022)	2430	1381	***43***	875	***64***
Boulder River: Cottonwood Creek to mouth (MT41E001_030)	594	329	***45***	220	***63***
Cataract Creek	151	122	***19***	97	***36***
Upper Elkhorn Creek: (MT41E002_061)	297	220	***26***	139	***53***
Lower Elkhorn Creek: (MT41E002_062)	72	41	***43***	32	***56***
High Ore Creek	126	83	***34***	48	***62***
Little Boulder River	154	128	***17***	102	***34***
Lowland Creek	521	379	***27***	173	***67***
McCarty Creek	20	15	***25***	12	***40***
Muskrat Creek	154	110	***29***	83	***46***
North Fork Little Boulder River	49	42	***14***	38	***22***
Nursery Creek	5	3	***40***	3	***40***
Uncle Sam Gulch	14	13	***7***	10	***29***

5.5.3.3 Allocations and Load Reduction Achievement

The upland sediment loads are estimations based on the land uses, land cover types, riparian conditions, and potential for improvements that exist within a watershed. The difference between the modeled existing condition and the modeled desired condition provides the amount of sediment that must be reduced to achieve acceptable sediment loads from upland sources. Because it is difficult to discretely quantify the sediment loads at the watershed scale, the percent reduction serves to best describe the degree of sediment load reduction necessary for each watershed. This value is then incorporated into each TMDL calculation. In the Boulder-Elkhorn TPA, although a general percent reduction value is provided for the major source types, land use/land cover types and the associated percent reductions are provided to assist with future planning and prioritization or management activities. This information is contained in **Attachment B**.

5.5.3.4 Assumptions and Considerations

As with any modeling effort, and especially when modeling at a watershed scale, there are a number of assumptions that must be accepted. For the Boulder-Elkhorn TPA, the following points serve as some of the more significant considerations:

- The USLE model is sufficiently accurate for TMDL purposes. The USLE model has been in widespread use for more than thirty years, and has been found to be sufficient for natural resource management decision making at the field scale.
- It is appropriate to extend the field scale USLE model to the watershed scale. Many watershed scale implementations of the USLE model have been developed and presented in the peer reviewed literature. This model is a similar gridded USLE implementation, and it faithfully executes the methodology specified in USDA Agriculture Handbook No. 703. It operates in field scale on a 10 meter analytical pixel and achieves watershed scale implementation through aggregation of field scale results.
- The data sources used are appropriate for USLE parameterization. Data sources for USLE R and K factors were purposely built for that use. The USLE C factor is derived from Landsat thematic mapper imagery, classified by a rigorous process of peer reviewed methods into the NLCD landcover dataset. Specific assignment of C factors to landcover classes was performed under the guidance of natural resource professionals well versed in the application of USLE and USLE based sediment production models at the field scale. The USLE P factor was not used, as the best professional judgment of these same land managers is that the agricultural practices intended to be reflected by the USLE P factor are not in significant use in the Boulder Elkhorn watershed. The USLE L& S factors are mathematical constructs representing landform, and are derived here from Digital Terrain data. This analysis assumes that a 10 meter pixel grid adequately describes the micro terrain slope and slope length at the field scale. To the extent that this assumption is not met, results may deviate.
- The Riparian Health Assessment is of sufficient accuracy, resolution, and coverage to serve as the basis for a sediment delivery ratio. The Riparian Health Assessment only surveyed mainstem reaches. The condition of mainstem reaches here is considered to be broadly representative of overall watershed condition. To the extent that this assumption is not met, results may deviate proportionately.
- It is appropriate to use Megehan and Ketcheson's (1996) dimensionless equation relating sediment travel to distance and delivered volume as the basis for a sediment delivery ratio. Megehan and Ketcheson (1996) establishes that the purpose of the work is to provide an empirical alternative to process based modeling approaches for sediment delivery to streams. A decade later, Megehan and Ketcheson went on to produce the Washington Road Surface Erosion Model (Dube et al., 2004) which uses the Megehan and Ketcheson (1996) dimensionless equation as an SDR to account for delivery across fillslopes to streams. Here, we replicate Megehan and Ketcheson's use of the three variable dimensionless equation for the WARSEM SDR, evaluating that equation for a representative maximum sediment travel distance, and arriving at a scaled distance/sediment delivery relationship.
- A specific concern is that the Megehan and Ketcheson method, because it does not explicitly account for changes in vegetation as might be expected transitioning an upland/riparian zone boundary, may not adequately represent sediment delivery across a riparian zone. We note that whereas Megehan and Ketcheson used a single scaling of the dimensionless equation for all locations in an attempt to render the WARSEM model broadly applicable with minimum data collection needs, we take advantage of the available Boulder Elkhorn Riparian Health

Assessment data to derive site-specific scaling of the dimensionless equation for Boulder Elkhorn sub-basins, based on riparian condition.
- The uncalibrated watershed scale USLE model and sediment delivery ratio are sufficiently accurate for Boulder Elkhorn TMDL purposes. The USLE is an empirical model developed initially for eastern U.S. croplands, but has been extended via revised C factors and other means to be more broadly applicable. The C factors used for this effort were chosen to be as representative of Boulder Elkhorn conditions as professional judgment allows. The Megehan and Ketcheson dimensionless equation was similarly developed as an empirical method for sediment delivery accounting in watersheds similar to the Boulder Elkhorn. The implementation of that SDR method used here is further fit to the Boulder Elkhorn project area with the use of site-specific scaling factors. Both components of the model remain uncalibrated to local conditions however, in the sense that these attempts to better represent the Boulder Elkhorn watershed have not been tested empirically. Use of the results for relative comparison (as between sub-basins or alternative management scenarios) is well supported. Use of the results of predictors of absolute sediment load should be undertaken with care. Though both the USLE and the Megehan and Ketcheson SDR are currently in widespread use for absolute prediction of sediment load, local verification of predictive power is (as here) rarely taken.

5.5.4 Permitted Point Sources

As of January 7, 2013, there were nine active Montana Pollutant Discharge Elimination System (MPDES) permitted point sources within the Boulder-Elkhorn TPA. The permit name, permit number, and permit type are listed below:
- City of Boulder WWTF (MT0023078) – MPDES Individual Permit
- Boulder Hot Springs Waste Water Treatment Lagoon (WWTL) (MT0023639) – MPDES Individual Permit
- Harold Green Snowdrift Dredge Mining (MTG370320) – Suction Dredge
- William Duncan Midsummer Dream Boulder River (MTG370322) – Suction Dredge
- Leonard Saarinen Basin Creek Suction Dredge (MTG370331) – Suction Dredge
- Jim Gilman Excavating – Carlson Pit (MTR103333) – Storm Water, Construction Activity
- MDOT Elkhorn Road South Waste Water Treatment Lagoon (ARRA) 69 1 27 22 (MTR103698) – Storm Water, Construction Activity
- AM Welles – Compton Site (MTR103724) – Storm Water, Construction Activity
- Elkhorn Goldfields Inc Elkhorn Mine Site (MTR300264) – Storm Water, Mining, Oil & Gas Extraction

To provide the required wasteload allocation (WLA) for permitted point sources, activity and conditions related to the permit were assessed for these point sources. The WLAs are typically not intended to add load limits to the permits, rather the WLAs further describe the conditions set forth in the permit. It is therefore assumed that the WLAs will be met by adherence to permit requirements. Description of the WLAs in the Boulder-Elkhorn TPA are presented in the following sections.

5.5.4.1 City of Boulder Wastewater Treatment Facility

The Boulder Wastewater Treatment Facility, which discharges to the Boulder River, is a three cell facultative lagoon treatment system with a design flow of 0.25 million gallons per day (MGD). The facility is authorized under an individual permit (MT0023078), which describes a 7-day average total suspended solids (TSS) concentration limit of 65 mg/l and a 30-day average TSS concentration limit of 45 mg/l. Like most wastewater discharge, it is noted that the suspended solids in the effluent are likely predominantly organic matter and not sediment.

Discharge Monitoring Reports (DMRs) submitted by the facility catalogue monthly TSS and flow since 2001. There have been nine exceedances of the 30-day average concentration limit of 45 mg/l in that time (out of 103 reported values), with the most recent occurring in August, September, and October 2012. The highest reported single value 30-day average concentration was 104 mg/l in July 2004, and the highest monthly 30-day average concentration occurs in June, with an average value of 27.7 mg/l. The average value of all 30-day average concentration samples is 18.9 mg/l. A conservative calculation of the existing load was made by assuming an average daily discharge of .054 MGD (the average MGD discharge value derived from the DMR data), at a TSS concentration of 18.9 mg/l (the average of all 30-day average TSS concentration values). This would result in an annual load of 1.9 tons TSS. For comparison, using maximum recorded flow (from DMR data) and 30-day average maximum TSS concentrations of 0.272 MGD and 45 mg/l TSS as stated in the permit, would result in an annual load of 22.4 tons/year.

The maximum allowable permit values can be used to evaluate impact to the Boulder River by evaluating the potential increase in TSS loading to the Boulder River from the Boulder WWTF discharge. Based on flow data collected by the USGS (Gage #06033000), the lowest average monthly flow for the Boulder River near the city of Boulder is 27 cfs. There was no readily available TSS data for the Boulder River immediately upstream of the WWTF, but a general estimate of low flow TSS concentrations in western Montana streams is 5.0 mg/l. The Boulder WWTF design capacity discharge of 0.25 MGD is approximately 0.4 cfs. If the Boulder facility was discharging with a TSS concentration of 45 mg/l into the Boulder River when the Boulder River was flowing 27 cfs, the result would be an increase in TSS concentration in the river from 5.0 mg/l to 5.6 mg/l. This would be an acceptably low level that is not expected to cause harm to aquatic life (Newcombe and Jensen, 1996) nor is it expected to result in aesthetic concerns.

5.5.4.2 Boulder Hot Springs Wastewater Treatment Lagoons

The Boulder Hot Springs wastewater treatment system, which discharges to the Little Boulder River, is a two cell facultative lagoon with a design flow of 0.085 MGD. The facility is authorized under an individual permit (MT0023639), which describes a 7-day average TSS concentration limit of 135 mg/L and a 30-day average TSS concentration limit of 100 mg/L. Like most wastewater discharge, it is noted that the suspended solids in the effluent are likely predominantly organic matter and not sediment.

DMRs submitted by the facility catalogue monthly effluent TSS and flow since 1998. There has been only one exceedance of the 30-day average concentration limit of 100 mg/l in that time (out of 167 reported values). The exceedance was a reported value of 449 mg/l in December 2007. Excluding the 449 mg/l value, no other reported value in the DMR records was higher than 35 mg/l, which therefore questions the validity of the December 2007 value. If that exceedance value is discounted, the highest monthly 30-day average concentration occurs in February, with an average value of 11.9 mg/l. The average value of all 30-day average concentration samples is 6.2 mg/l. In contrast to the TSS concentration values, of 80 reported values for the effluent discharge flow, only two values do NOT exceed the design flow as described in the facility permit. Overall average flow is 0.131 MGD, with a maximum recorded flow of 0.21 MGD on July 28, 2011. A conservative calculation of the existing load was made by assuming an average daily discharge of 0.131 MGD (the average MGD discharge value derived from the DMR data), at a TSS concentration of 6.2 mg/l (the average of all 30-day average TSS concentration values). This would result in an annual load of 1.5 tons TSS. For comparison, using maximum design flow and 30-day average maximum TSS concentrations as stated in the permit of 0.085 MGD and 100 mg/l TSS would result in an annual load of 15.5 tons/year.

The maximum allowable permit values can be used to evaluate impact by evaluating the potential increase in TSS loading to the Little Boulder River from the Boulder Hot Springs effluent discharge. The DEQ measured two flow values in the Little Boulder River above the Boulder Hot Springs in the summer of 2009. One measurement in June 2009 recorded a flow of 161.6 cfs. The other flow measurement occurred in August 2009 and recorded 16.42 cfs. There was no readily available TSS data for the Little Boulder River directly upstream of the treatment lagoons, but a general estimate of low flow TSS concentrations in western Montana streams is 5.0 mg/l. The Boulder Hot Springs wastewater treatment lagoon design capacity discharge of 0.085 MGD is approximately 0.16 cfs. If the Boulder Hot Springs lagoons were discharging at design flow with a TSS concentration of 100 mg/l into the Little Boulder River when the Little Boulder River was flowing 16.42 cfs, the result would be an increase in TSS concentration in the river from 5.0 mg/l to 5.9 mg/l. This would be an acceptably low level that is not expected to cause harm to aquatic life (Newcombe and Jensen, 1996) nor is it expected to result in aesthetic concerns. Using the average effluent values for flow and TSS from the DMR records, (0.24 cfs; 6.2 mg/l TSS), there would only be an increase of TSS concentration in the Little Boulder River of 0.02 mg/l. Using the maximum effluent values for flow and TSS from the DMR records, (0.39 cfs; 35 mg/l TSS), there would be an increase of TSS concentration in the Little Boulder River of 0.7 mg/l. All scenarios reviewed indicate no significant increase in TSS concentration, however it should be noted that treatment facility operations should be investigated to determine why the treatment facility so consistently discharges above design flow specifications. The minimal increase in TSS concentrations for the Little Boulder River is therefore presumed to have even less effect on the Boulder River, due to the volume of water and water chemistry in the Boulder River.

5.5.4.3 Suction Dredge Permits

The Suction Dredge General Permit describes portable suction dredges and their operation as "mechanical devices that float on the stream surface and pump stream water and stream bed material through a suction dredge intake to a sluice box, from which gold or other precious metals are recovered. Unwanted gravels and other naturally occurring stream bottom material fall off the end of the sluice box and are redeposited back onto the stream bottom. Since the discharge consists of naturally occurring stream bottom material and no chemicals are allowed to be added to enhance gold recovery, there is no additional load of pollutants to the receiving stream."

Specific effluent limitations described in the general permits are as follows:

- No visual increase in turbidity (cloudiness or muddiness) observable at the end of the mixing zone. The mixing zone is defined as 10 stream widths downstream of the suction dredge.
- No visible oil sheen caused by the suction dredge operation.
- No discharge of floating solids or visible foam in other than trace amounts.
- No added chemicals allowed in the discharge.

Currently, there are three active Portable Suction Dredge General Permit Authorizations in the Boulder Elkhorn TMDL planning area. In addition to the conditions of the general permit as described above, each permit authorization may carry further provisions. Information for the suction dredge permits is presented in **Table 5-36** below.

Table 5-36. Active Suction Dredge Permits in the Boulder-Elkhorn TPA

Permit Number	Receiving Water	Permit Authorization Provisions
MTG370320	Snowdrift Creek (tributary to Cataract Creek	None Listed
MTG370322	Boulder River	Operations Seasonally Restricted to January 1 – August 31
MTG370331	Basin Creek	Operations Seasonally Restricted to July 1 – September 15

Permit conditions do not allow for a visual increase in turbidity at the end of the mixing zone, nor any additional load of pollutants to the receiving stream. Therefore, assuming the proper operation of the suction dredge in accordance with the requirements of the permit, there should be no increase in sediment load from suction dredge operations.

5.5.4.4 Stormwater Associated with Construction Activity

General permit coverage is required for construction activities that include clearing, grading, grubbing, excavation, or other earth disturbing activities that disturb one or more acres and discharge stormwater to state surface waters or to a storm sewer system that discharges to a state surface water. All construction stormwater permits are authorized under General Permit MTR100000.

According to Section 2.1.1 of the General Permit for Storm Water Discharges Associated with Construction Activity, a permittee must "design, install, and maintain effective erosion and sediment controls to minimize the discharge of potential pollutants." In addition, according to Section 2.2.1., "a stormwater discharge associated with construction activity may not cause or contribute to an exceedance of applicable water quality standards."

Although construction activities at a site are relatively temporary and short term in nature, the number of construction sites covered by the general permit at any given time varies. Collectively, these areas of severe ground disturbance have the potential to be significant sediment sources if proper BMPs are not implemented and maintained. Each construction stormwater permittee is required to develop a SWPPP that identifies the stormwater BMPs that will be in place during construction. Prior to permit termination, disturbed areas are required to have a vegetative density equal to or greater than 70% of the pre-disturbed level (or an equivalent permanent method of erosion prevention).

To estimate the disturbed acreage associated with construction stormwater permits, the permit files were reviewed for anticipated acres to be disturbed. As of January 10, 2013 there were three active construction stormwater permits in the Boulder-Elkhorn TMDL Planning Area (**Table 5-37**).

Table 5-37. Active Storm Water Associated with Construction Activity Permits in the Boulder-Elkhorn TPA

Permit Number	Receiving Water	Disturbed Acreage Estimate
MTR103333	Red Rock Creek (tributary to Boulder River)	6
MTR103698	Boulder River, Little Boulder River	105
MTR103724	Boulder River	24.5

In order to estimate sediment loading from permitted construction sites, the universal soil loss equation (USLE) is used to provide estimates of sediment loads from the site during construction if no BMPs were used, and then again to simulate all proper BMPs. R and K actors for the USLE equation were derived using the output from the upland erosion assessment (**Section 5.5.3** & **Attachment 2**). LS factors were based on site dimensions and slope assumptions. Construction sites have the potential to have C-factors ranging from 0.3 to 1 (Pudasaini et al., 2004; Sinha and Labi, 2007; Toy and Foster, 1998), with variability associated with soil type and slope, stage of construction, and level of BMP implementation. C-factors were estimated for these sites based on review of C-factors listed in Construction Site Erosion and Sediment Controls: Planning, Design, and Performance (Pitt et al., 2007). P values were assumed a constant value of 1.0. The USLE output value is then multiplied by the disturbed acreage associated with construction stormwater permits.

To estimate sediment loads from these same sites with BMPs in place, C-factors representing established ground cover and a stable site were identified in Pitt, Clarke, and Lake and used as an equivalent BMP condition. These lower values represent the estimated existing loads from permitted construction sites when all appropriate BMPs are in place and being properly maintained. Descriptions of the permits are presented below.

MTR103333 – Carlson Pit

The Carlson Pit is a gravel pit used to support a local MDT project. Associated construction activities include stripping and stockpiling of topsoil, mining and crushing aggregate, and replacing and reseeding of topsoil. Total site area is described in the permit as 6 acres.

According to the permit, construction activity was scheduled for the summer of 2009, with final project stabilization to occur in October 2012. In addition, terrain and drainage patterns of the area were anticipated to contain all stormwater runoff within the pit itself; however, additional containment ditches, silt fence, straw waddles, and gravel berms were identified as BMPs to be used to filter any water exiting the site. Upon completion, the area was to be sloped and graded to allow stormwater to return to natural drainage structures and/or infiltration basins. Undisturbed and reestablished vegetation would serve as future stormwater pollution controls.

Estimates for sediment loading from this site are calculated using the USLE parameter values in **Table 5-38**.

Table 5-38. USLE Factor Values for Carlson Pit Load Estimates

	R	K	LS	C	Tons/Year/Acre	Acres	Tons/Year
Disturbed Condition	16.1	0.281	0.56	0.94	2.38	6	14.3
BMP Condition	16.1	0.281	0.56	0.042	0.11	6	0.7

MTR103698 – MDOT Elkhorn Road South ARRA 69 1 27 22

The Elkhorn Road project has a total length of 9.2 miles, but based on permit information only 105 acres of disturbance. There are eight identified creek, ditch, or drainage crossings throughout the project, and ditches and streams parallel the road at various distances along the road. There were 69 designated locations fiber rolls protection was to be used at all inlets/outlets of under-road drainage to irrigation ditches and culverts, along with silt fence along all wetlands bordering the roadway.

According to the permit, construction activity is complete and is under maintenance and monitoring until it achieves “final stabilization”. Existing natural vegetation and the replacement of disturbed vegetation are anticipated to control and pollutant discharges after the project is completed.

Estimates for sediment loading from this site are calculated using the USLE parameter values in **Table 5-39**.

Table 5-39. USLE Factor Values for Elkhorn Road Load Estimates

	R	K	LS	C	Tons/Year/Acre	Acres	Tons/Year
Disturbed Condition	11.5	0.318	0.13	0.45	0.21	105	22.1
BMP Condition	11.5	0.318	0.12	0.042	0.02	105	2.1

MTR103724 – Compton Site

The Compton Site is a gravel pit used to support a MDT highway reconstruction project adjacent to the project site. The site is predominantly flat with only pasture grass and the result of material excavation will be a large shallow basin. The estimated project completion data is listed as August 2011, with final stabilization to occur September 2013.

This site is anticipated to capture all sediment and runoff within the disturbed area by constructing it with inward sloping sides. Stockpiled topsoil will be protected with silt fence to prevent erosion. In addition, vegetative buffers will be used to prevent sediment from entering a ditch along the northeast side. Livestock will be excluded from the area until vegetation is established.

Estimates for sediment loading from this site are calculated using the USLE parameter values in **Table 5-40**.

Table 5-40. USLE Factor Values for Compton Site Load Estimates

	R	K	LS	C	Tons/Year/Acre	Acres	Tons/Year
Disturbed Condition	11.5	0.319	0.56	0.94	1.93	11.5	47.3
BMP Condition	11.5	0.319	0.56	0.042	0.09	11.5	2.2

Summary for Stormwater Associated with Construction Activity

Based on the source assessment, the current construction stormwater MPDES permits in the Boulder-Elkhorn TPA have an allowable load of 5.0 tons of sediment per year. Allowable loads assumed the resultant load when all permit requirements are met. In contrast, estimates show that these three sites could potentially account for 83.7 tons/year if no BMP measures were implemented. Depending on actual implementation and maintenance of BMPs, the existing load may actually be less than the allowable load; or, if BMPs are currently not in place or insufficient to meet the permit requirements, the existing load may be exceeding the allowable load. For the purpose of estimated existing loads in **Tables 5-39 - 5-41**, USLE values were estimated to assume compliance with BMP requirements when no site-specific BMP data was available.

The number of active construction stormwater permits may vary over time, and the resulting level of disturbance and associated loads may also vary. As such, the relative contribution of permitted activities may be more or less significant in any given year. Full compliance with the permit and BMP designs as outlined in an approved SWPPP should address issues related to sediment for construction stormwater permittees, however it should be noted that depending on the receiving water and level of sediment contribution the State may require an individual permit or specify additional limitations to ensure the discharge does not cause or contribute to an exceedance of water quality standards.

5.5.4.4 Storm Water Associated with Industrial Activity

General permit coverage is required for facilities conducting industrial activities that discharge stormwater to state surface waters or to a storm sewer system that discharges to a state surface water. Industrial activities covered by this permit are determined by the facility's standard industrial classification (SIC) code. The general permit for stormwater associated with industrial activity was recently updated to include stormwater discharges associated with mining, oil, and gas activities.

As with the general permit for stormwater associated with construction activity, "discharge must be controlled as necessary to meet applicable water quality standards. No discharge of stormwater associated with industrial, mining, and oil and gas activity shall cause or contribute to a violation of water quality standards." In addition, Section 2.2.5 states "you must stabilize exposed areas and contain runoff using structural and/or non-structural control measures to minimize onsite erosion and sedimentation, and the resulting discharge of pollutants."

Along with the requirements described above, Section 2.5.1.1 describes required benchmark monitoring which may be applicable depending on the type of activity being permitted. "Benchmark concentrations are not effluent limitations; a benchmark exceedance, therefore is not a permit violation. Benchmark monitoring data are primarily for your use to determine the overall effectiveness of your control measures and to assist you in knowing when additional corrective action(s) may be necessary to comply with the effluent limitations in Parts 2 and 3.4." For most activities, the stormwater associated with industrial activity permit states a benchmark concentration for TSS of 100 mg/l.

There is currently one active permit in the Boulder Elkhorn TPA for stormwater associated with industrial activity. The Elkhorn Goldfields, Inc. operations are authorized to discharge stormwater at two out falls, one to Elkhorn Creek and one to Greyback Gulch under permit MTR300264. The permit includes a Storm Water Pollution Prevention Plan and requires biannual reporting of discharge monitoring data. The SWPPP sets forth the procedures, methods, and equipment used to prevent the pollution of stormwater discharges from the site. In addition, this SWPPP describes general practices used to reduce pollutants in stormwater discharges.

Review of the permit provides information pertaining to site conditions and probable sediment loads. The average annual precipitation for this site, based on Oregon State University PRISM data, is 23.3 inches. There is limited data available in the DMR records, however the maximum concentration of TSS recorded at either outlet is 44 mg/l. Although the permit boundary is roughly 384 acres, the delineated disturbed area is roughly 15.4 acres. Given the 15.4 acres of disturbed area, 23.3 inches of precipitation, and using the maximum TSS concentration as observed from the site DMR data (44 mg/l) found in the permit, the sediment load from the disturbed areas of the site is currently estimated at 1.8 tons a year. If the discharge TSS ever met the benchmark concentration (100 mg/l) under those average rainfall conditions, the sediment load would be 4.1 tons/yr.

5.5.5 Permit Source Assessment Summary

Based on the preceding permit information analysis, current permits in the Boulder-Elkhorn TPA have an anticipated load of 10.2 tons of sediment per year (**Table 5-41**). Allowable loads assume the maximum resultant load when all permit required BMPs are in place. Depending on actual implementation and maintenance of BMPs, the existing load may be significantly less than the allowable load; or, if BMPs are currently not in place or insufficient to meet the permit requirements, the existing load may be exceeding the allowable load. For the purpose of the estimated existing loads in **Table 5-41**, permitted entities were assumed to be in compliance with BMP requirements when no site-specific BMP data was available.

Table 5-41. Permit Load Summary

Permit	Receiving Watershed	Permit Type	Estimated Existing Load (ton/year)	Estimated Allowable Load (ton/year)
MT0023078	Boulder River	Individual	1.9	22.4
MT0023639	Little Boulder River/ Boulder River	Individual	1.5	15.5
MTG370322	Boulder River	Suction Dredge	0	0
MTR103333	Red Rock Creek/ Boulder River	Storm Water, Construction	0.7	0.7
MTR103698	Little Boulder River/ Boulder River	Storm Water, Construction	2.1	2.1
MTR103724	Boulder River	Storm Water, Construction	2.2	2.2
MTG370320	Snowdrift Creek/ Cataract Creek	Suction Dredge	0	0
MTG370331	Basin Creek	Suction Dredge	0	0
MTR300264	Elkhorn Creek	Storm Water, Industrial	1.8	4.1

5.6 TMDL and Allocations

This section is organized by the following topics:

- Application of percent reduction and yearly load approaches
- Development of sediment allocations by source categories
- Allocations of TMDLs by each stream
- Meeting the intent of the TMDL allocations

5.6.1 Application of Percent Reduction and Yearly Load Approaches

The sediment TMDLs for the Boulder-Elkhorn TPA will be based on a percent reduction approach discussed in **Section 4.0.** This approach will apply to the loading allocated among sources as well as each individual waterbody TMDLs. An implicit margin of safety will be applied as further discussed in **Section 5.7**. Cover, et al. (2008) observed a correlation between sediment supply and instream measurements of fine sediment in riffles and pools; it is assumed that a decrease in sediment supply, particularly fine sediment, will correspond to a decrease in the percent fine sediment deposition within the streams of interest and result in attainment of the sediment related water quality standards. A percent-reduction approach is preferable because there is no numeric standard for sediment to calculate the allowable load and because of the uncertainty associated with the loads derived from the source assessment (which are used to establish the TMDL), particularly when comparing different load categories such as road crossings to bank erosion. Additionally, the percent-reduction TMDL approach is more applicable for restoration planning and sediment TMDL implementation because this approach helps focus on implementing water quality improvement best practices (i.e., BMPs), versus focusing on uncertain loading values.

An annual expression of the TMDLs was determined as the most appropriate timescale because sediment generally has a cumulative effect on aquatic life or other designated uses, and all sources in the watershed are associated with periodic loading. Each sediment TMDL is stated as an overall percent reduction of the average annual sediment load that can be achieved after summing the individual annual source allocations and dividing them by the existing annual total load. EPA encourages TMDLs to be expressed in the most applicable timescale but also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Daily loads are provided in **Appendix F**.

5.6.2 Development of Sediment Allocations by Source Categories

The percent-reduction allocations are based on the modeled BMP scenarios for each major source type (e.g., streambank erosion, upland erosion, roads and permitted point sources). These BMP scenarios are discussed within **Section 5.5** and associated appendices, and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Sediment loading reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. Sediment loading was evaluated at the watershed scale and associated sediment reductions are also applied at the watershed scale based on the fact that many sources deliver sediment to tributaries that then deliver the sediment load to the impaired waterbodies.

It is important to recognize that the first critical step toward meeting the sediment allocations involves applying and/or maintaining the land management practices or BMPs that will reduce sediment loading. Once these actions have been completed at a given location, the landowner or land manager will have taken action consistent with the intent of the sediment allocation for that location. For many nonpoint source activities, it can take several years to achieve the full load reduction at the location of concern, even though full BMP implementation is in effect. For example, it may take several years for riparian areas to fully recover after implementing grazing BMPs or allowing re-growth in areas of historic riparian harvest. It is also important to apply proper BMPs and other water quality protection practices for all new or changing land management activities to limit any potential increased sediment loading.

Progress towards TMDL and individual allocation achievement can be gaged by adherence to point source permits, BMP implementation for nonpoint sources, and improvement in or attainment of water quality targets defined in **Section 5.4**. Any effort to calculate loads and percent reductions for purposes of comparison to TMDLs and allocations in this document should be accomplished via the same methodology and/or models used to develop the loads and percent reductions presented within this document.

The following subsections present additional allocation details for each sediment source category.

5.6.2.1 Streambank Erosion

Sediment loads associated with bank erosion were identified by separate source categories (e.g., transportation, grazing, natural) in **Appendix E**. Because of the inherent uncertainty in extrapolating this level of detail to the watershed scale, and also because of uncertainty regarding impacts from historical land management activity, all human caused sources of bank erosion were combined for the purpose of expressing the TMDL and allocations. Streambank stability and erosion rates are very closely linked to the health of the riparian zone; reductions in sediment loading from bank erosion are expected to be achieved by applying BMPs within the riparian zone.

5.6.2.2 Upland Erosion

No reductions were allocated to natural sources, which are a significant portion of all upland land use categories. The allocation to upland sources includes application of BMPs to present land use activities as well as recovery from past land use influences such as riparian harvest. For all upland sources, the largest percent reduction will be achieved via riparian improvements.

5.6.2.3 Roads
The unpaved road allocation can be met by incorporating and documenting that all road crossings and parallel segments with potential sediment delivery to streams have the appropriate BMPs in place. Routine maintenance of the BMPs is also necessary to ensure that sediment loading remains consistent with the intent of the allocations. At some locations, if road closure or abandonment is selected as a method to decreasing road related sediment, additional BMPs may not be necessary if native vegetation growth on the road surface leads to very low erosion potential.

5.6.2.4 Permitted Point Sources
In this document, WLAs are only presented for those streams with active permitted discharges. WLAs are expected to be met by adherence to permit conditions.

5.6.3 Allocations and TMDLs for Each Stream
The following subsections present of the existing quantified sediment loads, allocations and TMDL for each waterbody.

Allocation assumptions
Sediment load reductions are given at the watershed scale, and are based on the assumption that the same sources that affect a listed stream segment affect other streams within the watershed and that a similar percent sediment load reduction can be achieved by applying BMPs throughout the watershed. However, it is acknowledged that conditions are variable throughout a watershed, and even within a 303(d) stream segment. This variability affects the actual level of BMPs needed in different areas, the practicality of changes in some areas (e.g. considering factors such as public safety and cost-effectiveness), and the potential for significant reductions in loading in some areas. Also, as discussed in **Section 4.4**, note that BMPs typically correspond to all reasonable land, soil, and water conservation practices, but additional conservation practices above and beyond BMPs may be required to achieve compliance with water quality standards and restore beneficial uses.

The sediment TMDLs for all streams and stream segments presented below are expressed as a yearly allowable load, and the equivalent percent reductions from sediment sources identified in the associated tables (**Tables 5-42** through **5-54).** Loads are first given for the watershed specific to the stream or stream segment of interest, and then where applicable, the sum of all upstream sediment loads that may be contributing to the stream segment. (Total watershed sediment loads are rounded to the nearest ton.)

5.6.3.1 Basin Creek, headwaters to mouth (Boulder River) (MT41E002_030)

Table 5-42. Sediment Source Assessment Loads, Allocations and TMDL for Basin Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	3.93	0.17	96
Eroding Banks	597	389	35
Upland Erosion	195	134	31
Point Source – Suction Dredge Permit (MTG370331)	0	0	0
Watershed Sediment Load	**796**	**523**	**TMDL = 34% Load Reduction**

5.6.3.2 Bison Creek, headwaters to mouth (Boulder River) (MT41E002_070)

Table 5-43. Sediment Source Assessment Loads, Allocations and TMDL for Bison Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	4.58	1.33	71
Eroding Banks	1584	968	39
Upland Erosion	441	216	51
Watershed Sediment Load	**2030**	**1185**	**TMDL = 42% Load Reduction**

5.6.3.3 Boulder River, Town of Boulder to Cottonwood Creek (MT41E001_022)

Table 5-44. Sediment Source Assessment Loads, Allocations and TMDL for Boulder River (MT41E001_022)

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	2.49	0.12	95
Eroding Banks	7775	4658	40
Upland Erosion	2430	875	64
Point Source - Individual Permit (MT0023078)	*1.9*	*22.4*	*0*
Point Source – Individual Permit (MT0023639)	*1.5*	*15.5*	*0*
Point Source – Suction Dredge (MTG370322)	*0*	*0*	*0*
Point Source – Stormwater, Construction (MTR103333)	*0.7*	*0.7*	*0*
Point Source – Stormwater, Construction (MTR103698)	*2.1*	*2.1*	*0*
Point Source – Stormwater, Construction (MTR103724)	*2.1*	*2.1*	*0*
Point Sources Total	8.3	42.8	0
Watershed Sediment Load	10216	5576	45
Upper Watershed Load*	21101	13509	36
Total Sediment Load Including All Upstream Watershed Loads	**31317**	**19085**	**TMDL = 39% Load Reduction**

*Includes all loads in Boulder-Elkhorn TPA except lower Boulder River (MT41E001_030)

5.6.3.4 Boulder River, Cottonwood Creek to mouth (Jefferson Slough), T9N R35W S2 (MT41E001_030)

Table 5-45. Sediment Source Assessment, Allocations and TMDL for Boulder River (MT41E001_030)

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.18	0.01	94
Eroding Banks	3171	1900	40
Upland Erosion	594	220	63
Watershed Sediment Load	3765	2120	44
*Upper Watershed Load	31317	19085	39
Total Sediment Load Including All Upstream Watershed Loads	**35082**	**21205**	**TMDL = 39% Load Reduction**

*Includes all loads in the Boulder-Elkhorn TPA

5.6.3.5 Cataract Creek, headwaters to mouth (Boulder River) (MT41E002_020)

Table 5-46. Sediment Source Assessment, Allocations and TMDL for Cataract Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	2.93	0.13	96
Eroding Banks	236	182	23
Upland Erosion	151	97	36
Point Source – Suction Dredge (MTG370320)	0	0	0
Watershed Sediment Load	387	279	28
*Upper Watershed Load	28	20	29
Total Sediment Load Including All Upstream Watershed Loads	**415**	**299**	**TMDL = 28% Load Reduction**

*Includes loads from Uncle Sam Gulch

5.6.3.6 Elkhorn Creek, headwaters to Wood Gulch (MT41E002_061)

Table 5-47. Sediment Source Assessment, Allocations and TMDL for Elkhorn Creek (MT41E002_061)

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	2.54	0.1	96
Eroding Banks	224	142	37
Upland Erosion	297	139	53
Point Source – Stormwater, Construction (MTR300264)	1.8	4.1	0
Watershed Sediment Load	**526**	**285**	**TMDL = 46% Load Reduction**

5.6.3.7 Elkhorn Creek, Wood Gulch to mouth (Unnamed Canal/Ditch), T5N R3W S21 (MT41E002_062)

Table 5-48. Sediment Source Assessment, Allocations and TMDL for Elkhorn Creek (MT41E002_062)

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.1	0.01	90
Eroding Banks	277	169	39
Upland Erosion	72	32	56
Watershed Sediment Load	349	201	44
*Upper Watershed Load	526	285	46
Total Sediment Load Including All Upstream Watershed Loads	**875**	**486**	**TMDL = 44% Load Reduction**

*Includes loads from upper Elkhorn Creek (MT41E002_061)

5.6.3.8 High Ore Creek, headwaters to mouth (Boulder River) (MT41E002_040)

Table 5-49. Sediment Source Assessment, Allocations and TMDL for High Ore Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	1.22	0.04	97
Eroding Banks	110	70	36
Upland Erosion	126	48	62
Watershed Sediment Load	**237**	**118**	**TMDL = 50% Load Reduction**

5.6.3.9 McCarty Creek, headwaters to mouth (Boulder River) (MT41E002_110)

Table 5-50. Sediment Source Assessment, Allocations and TMDL for McCarty Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.09	0.01	89
Eroding Banks	117	85	27
Upland Erosion	20	12	40
Watershed Sediment Load	**137**	**97**	**TMDL = 29% Load Reduction**

5.6.3.10 Muskrat Creek, headwaters to mouth (Boulder River) (MT41E002_100)

Table 5-51. Sediment Source Assessment, Allocations and TMDL for Muskrat Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	1.22	0.06	95
Eroding Banks	664	408	39
Upland Erosion	154	83	46
Watershed Sediment Load	819	491	40
*Upper Watershed Load	10	6	40
Total Sediment Load Including All Upstream Watershed Loads	**829**	**497**	**TMDL = 40% Load Reduction**

*Includes load from Nursery Creek

5.6.3.11 North Fork Little Boulder River, headwaters to mouth (Little Boulder River), (MT41E002_090)

Table 5-52. Sediment Source Assessment, Allocations and TMDL for North Fork Little Boulder River

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.49	0.02	96
Eroding Banks	165	136	18
Upland Erosion	49	38	22
Watershed Sediment Load	**214**	**174**	**TMDL = 19% Load Reduction**

5.6.3.12 Nursery Creek, headwaters to mouth (Muskrat Creek) (MT41E002_130)

Table 5-53. Sediment Source Assessment, Allocations and TMDL for Nursery Creek

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.2	0.01	95
Eroding Banks	5	3	40
Upland Erosion	5	3	40
Watershed Sediment Load	**10**	**6**	**TMDL = 40% Load Reduction**

5.6.3.13 Uncle Sam Gulch, headwaters to mouth (Cataract Creek) (MT41E002_010)

Table 5-54. Sediment Source Assessment, Allocations and TMDL for Uncle Sam Gulch

Sediment Sources	Current Estimated Load (tons/year)	Total Allowable Load (tons/year)	Load Reductions (% reduction)
Roads	0.46	0.02	96
Eroding Banks	14	10	29
Upland Erosion	14	10	29
Watershed Sediment Load	**28**	**20**	**TMDL = 29% Load Reduction**

5.7 Seasonality and Margin of Safety

Seasonality and margin of safety are both required elements of TMDL development. This section describes how seasonality and margin of safety were applied during development of the Boulder-Elkhorn TPA sediment TMDLs.

5.7.1 Seasonality

All TMDL documents must consider the seasonal applicability of water quality standards as well as the seasonal variability of pollutant loads to a stream. Seasonality was addressed in several ways as described below.

- The applicable narrative water quality standards (**Appendix B**) are not seasonally dependent, although low flow conditions provide the best ability to measure harm to use based on the selected target parameters. The low flow or base flow condition represents the most practical time period for assessing substrate and habitat conditions, and also represents a time period when high fine sediment in riffles or pool tails will likely influence fish and aquatic life. Therefore, meeting targets during this time frame represents an adequate approach for determining standards attainment.

- The substrate and habitat target parameters within each stream are measured during summer or autumn low flow conditions consistent with the time of year when reference stream measurements are conducted. This time period also represents an opportunity to assess effects of the annual snow runoff and early spring rains, which is the typical time frame for sediment loading to occur.
- The DEQ sampling protocol for macroinvertebrates identifies a specific time period for collecting samples based on macroinvertebrate life cycles. This time period coincides with the low flow or base flow condition.
- All assessment modeling approaches are standard approaches that specifically incorporate the yearly hydrologic cycle specific to Boulder-Elkhorn TPA. The resulting loads are expressed as average yearly loading rates to fully assess loading throughout the year.
- Allocations are based on average yearly loading and the preferred TMDL expression is as an average yearly load reduction, consistent with the assessment methods.

5.7.2 Margin of Safety

Natural systems are inherently complex. Any approach used to quantify or define the relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty or error. To compensate for this uncertainty and ensure water quality standards are attained, a margin of safety is required as a component of each TMDL. 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 (U.S. Environmental Protection Agency, 1999). This plan incorporates an implicit MOS in a variety of ways:

- By using multiple targets to assess a broad range of physical and biological parameters known to illustrate the effects of sediment in streams and rivers. These targets serve as indicators of potential impairment from sediment and also help signal recovery, and eventual standards attainment, after TMDL implementation. Conservative assumptions were used during development of these targets.
- TMDL development was pursued for all listed streams evaluated, even though some streams were close to meeting all target values. This approach addresses some of the uncertainty associated with sampling variability and site representativeness, and recognizes that sediment source reduction capabilities exist throughout the watershed.
- By using standards, targets, and TMDLs that address both coarse and fine sediment delivery.
- By properly incorporating seasonality into target development, source assessments, and TMDL allocations.
- By using an adaptive management approach to evaluate target attainment and allow for refinement of load allocation, targets, modeling assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development (discussed below in **Section 5.9** and in **Sections 6.0** and **7.0**).
- By using naturally occurring sediment loads as described in ARM 17.30.602(17) (see **Appendix B**) to establish the TMDLs and allocations based on reasonably achievable load reductions for each source category. Specifically, each major source category must meet percent reductions to satisfy the TMDL because of the relative loading uncertainties between assessment methodologies.
- TMDLs are developed at the watershed scale addressing all potentially significant human related sources beyond just the impaired waterbody segment scale. This approach should also reduce loading and improve water quality conditions within other tributary waterbodies throughout the watershed.

5.8 Uncertainty and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management is a key component of TMDL implementation. The process of adaptive management is predicated on the premise that TMDLs, allocations and their supporting analyses are not static, but are processes that can be subject to periodic modification or adjustment as new information and relationships are better understood. Within the Boulder-Elkhorn TPA, adaptive management for sediment TMDLs relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts from human activities and natural conditions, and continued assessment of how aquatic life and coldwater fish respond to changes in water quality and stream habitat conditions.

As noted in **Section 5.8.2**, adaptive management represents an important component of the implicit margin of safety. This document provides a framework to satisfy the MOS by including a section focused on TMDL implementation, monitoring and adaptive management (**Section 6.0**). Furthermore, state law (ARM 75-5-703), requires monitoring to gage progress toward meeting water quality standards and satisfying TMDL requirements. These TMDL implementation monitoring reviews represent an important component of adaptive management in Montana.

Perhaps the most significant uncertainties within this document involve the accuracy and representativeness of 1) field data and target development and 2) the accuracy and representativeness of the source assessments and associated load reductions. These uncertainties and approaches used to reduce uncertainty are discussed in following subsections.

5.8.1 Sediment and Habitat Data Collection and Target Development

Some of the uncertainties regarding accuracy and representativeness of the data and information used to characterize existing water quality conditions and develop water quality targets are discussed below.

Data Collection

The stream sampling approach used to characterize water quality is described within **Appendix C**. To control sampling variability and improve accuracy, the sampling was done by trained environmental professionals using a standard DEQ procedure developed for the purpose of sediment TMDL development (Montana Department of Environmental Quality, 2010). This procedure defines specific methods for each parameter, including sampling location and frequency to ensure proper representation and applicability of results. Prior to any sampling, a sampling and analysis plan (SAP) was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the SAP, and was based on a stratification process described in **Appendix C**. The stratification work ensured that each stream included one or more sample sites representing a location where excess sediment loading or altered stream habitat could affect fish or aquatic life.

Even with the applied quality controls, a level of uncertainty regarding overall accuracy of collected data will exist. There is uncertainty regarding whether or not the appropriate sites were assessed and whether or not an adequate number of sites were evaluated for each stream. Also, there is the uncertainty of the representativeness of collecting data from one sampling season. These uncertainties are difficult to quantify and even more difficult to eliminate given resource limitations and occasional stream access problems.

Target Development

DEQ evaluated several data sets to ensure that the most representative information and most representative statistic was used to develop each target parameter consistent with the reference approach framework outlined in **Appendix B**. Using reference data is the preferred approach for target setting, however, some uncertainty is introduced because of differing protocols between the available reference data and DEQ data for the Boulder-Elkhorn TPA. These differences were acknowledged within the target development discussion and taken into consideration during target setting. For each target parameter, DEQ stratified the Boulder-Elkhorn sample results and target data into similar categories, such as stream width or Rosgen stream type, to ensure that the target exceedance evaluations were based on appropriate comparison characteristics.

The established targets are meant to apply under median conditions of natural background and natural disturbance. It is recognized that under some natural conditions such as a large fire or flood event, it may be impossible to satisfy one or more of the targets until the stream and/or watershed recovers from the natural event. The goal, under these conditions, is to ensure that management activities are undertaken in a way that the achievement of targets is not significantly delayed in comparison to the natural recovery time. Also, human activity should not significantly increase the extent of water quality impacts from natural events. For example, extreme flood events can cause a naturally high level of sediment loading that could be significantly increased from a large number of road crossing or culvert failures.

Because sediment target values are based on statistical data percentiles, DEQ recognizes that it may be impossible to meet all targets for some streams even under normal levels of disturbance. On the other hand, some target values may underestimate the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluation during adaptive management. It is important to recognize that the adaptive management approach provides the flexibility to refine targets as necessary to ensure protection of the resource and to adapt to new information concerning target achievability.

5.8.2 Source Assessment and Load Reduction Analysis

Each assessment method introduces uncertainties regarding the accuracy and representativeness of the sediment load estimates and percent load reduction analyses. For each source assessment, assumptions must be made to evaluate sediment loading and potential reductions at the watershed scale, and because of these uncertainties, conclusions may not be representative of existing conditions and achievable reductions at all locations within the watershed. Uncertainties are discussed independently for the three major source categories of bank erosion, upland erosion, and unpaved road crossings.

Bank Erosion

The load quantification approach for bank erosion is based on a standard methodology (BEHI) as defined within **Appendix C**. Field data collection was by trained environmental professionals per a standard DEQ procedure (Montana Department of Environmental Quality, 2010). Prior to any sampling, a SAP was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the SAP, and was based on a stratification process described in **Appendix C**. The results were then extrapolated across the Boulder-Elkhorn watersheds as defined in **Appendix E** to provide an estimate of the relative bank erosion loading from various streams and associated stream reaches.

Even with the above quality controls, there is uncertainty regarding the bank retreat rates, which directly influence loading rates, since it was necessary to apply bank retreat values established from similar geology in Colorado. Although each field site was thoroughly assessed for bank erosion, assessing each unique reach type was not practical, therefore adding to uncertainty associated with the load extrapolation results. Also, the complexity of the BEHI methodology can introduce error and uncertainty, although this is somewhat limited by the averaging component of the measured variables.

The desired load was estimated from an average of percent reductions from other watersheds in the region, and therefore conditions in the Boulder watershed may be somewhat more or less severe. There is also uncertainty in the attribution of human activity to bank erosion influence in that discerning the degree of influence on a particular bank is based in best professional judgment rather than any quantified method. This is further complicated by historic human disturbances in the watershed, which could still be influencing proper channel shape, pattern and profile and thus contributing to increased bank erosion loading that may appear natural. Even if difficult to quantify, the linkages between human activity such as riparian clearing and bank erosion, are well established and these linkages clearly exist at different locations throughout the Boulder-Elkhorn watershed. Evaluating bank erosion levels, particularly where best management practices have been applied along streams, is an important part of adaptive management that can help define the level of human-caused bank erosion, as well as the relative impact that bank erosion has on water quality throughout the Boulder-Elkhorn watershed.

Upland Erosion

Upland erosion loads were derived from a standard erosion model as defined in **Appendix F**. As with any model, there will be uncertainty in the model input parameters including uncertainties regarding land use, land cover and assumptions regarding existing levels of BMP application. For example, the model only allows one vegetative condition per land cover type (i.e., cannot reflect land management practices that change vegetative cover from one season to another), so an average condition is used for each scenario in the model. To minimize uncertainty regarding existing conditions and management practices, model inputs were reviewed by stakeholders familiar with the watershed.

The upland erosion model integrates sediment delivery based on riparian health, with riparian health evaluations linked to the stream stratification work discussed above. The potential to reduce sediment loading was based on modest land cover improvements to reduce the generation of eroded sediment particles in combination with riparian improvements. The uncertainty regarding existing erosion prevention BMPs and ability to reduce erosion with additional BMPs represents a level of uncertainty. Also, the reductions in sediment delivery from improved riparian health also introduces some uncertainty, particularly in forested areas where there is uncertainty regarding the influence that historical riparian logging has on upland sediment delivery. Even with these uncertainties, the ability to reduce upland sediment erosion and delivery to nearby waterbodies is well documented in literature and the reduction values used for estimating load reductions and setting allocations are based on literature values coupled with specific assessment results for the Boulder-Elkhorn watershed.

Roads

The road crossings sediment load was estimated via a standardized simple yearly model developed by the U.S. Forest Service. This model relies on a few basic input parameters that are easily measured in the field, as well as inclusion of precipitation data from local weather stations. Data for existing road conditions was collected by the USFS throughout the Beaverhead-Deer Lodge National Forest, and shared with DEQ for modeling current and BMP scenario sediment contributions from unpaved roads. Although the data was taken within the boundaries of the National Forest, it is presumed that unpaved road conditions in this watershed are roughly similar regardless of ownership and jurisdiction. The results from these sites were extrapolated to the whole population of roads and stratified by climate zone. The potential to reduce sediment loads from unpaved roads through the application of Best Management Practices (BMPs) was assessed in the model by reducing contributing road segment lengths and changing the road conditions from rutted to unrutted. This approach introduces uncertainty based on how well the sites and associated BMPs represent the whole population. Although the exact percent reduction will vary by road, the analysis clearly shows a high potential for sediment loading reduction by applying standard road BMPs in places where they are lacking or can be improved.

Application of Source Assessment Results

Model results should not be applied as absolute accurate sediment loading values within each watershed or for each source category because of the uncertainties discussed above. Because of the uncalibrated nature of the source assessment work, the relative percentage of the total load from each source category does not necessarily indicate its importance as a loading source. Instead, the intention is to separately evaluate source impacts within each assessment category (e.g., bank erosion, upland erosion, roads) and use the modeling and assessment results from each source category to evaluate reduction potentials based on different BMP scenarios. The process of adaptive management can help sort out the relative importance of the different source categories through time.

6.0 TEMPERATURE TMDL COMPONENTS

This portion of the document focuses on temperature as an identified cause of water quality impairment in the Boulder-Elkhorn watershed. It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the specific stream segments of concern; (3) information sources used for temperature TMDL development; (4) temperature target development; (5) assessment of sources contributing to excess thermal loading; (6) the temperature TMDLs and allocations; (7) seasonality and margin of safety; and (8) uncertainty and adaptive management.

6.1 TEMPERATURE (THERMAL) EFFECTS ON BENEFICIAL USES

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the ability of the stream to regulate solar heating all increase stream temperatures. Warmer temperatures can negatively affect aquatic life and fish that depend upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increase metabolism and reduce the amount of available oxygen in the water. In turn, coldwater fish, and other aquatic species, may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, sometimes creating lethal conditions for a percentage of the fish population. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). Assessing thermal effects upon a beneficial use is an important initial consideration when interpreting Montana's water quality standard (**Appendix C**) and subsequently developing temperature TMDLs.

6.2 STREAM SEGMENTS OF CONCERN

Three waterbody segments in the Boulder-Elkhorn TMDL Planning Area (TPA) appeared on the 2012 Montana impaired waters list as having temperature limiting a beneficial use: the Boulder River from the town of Boulder to Cottonwood Creek, the Boulder River from Cottonwood Creek to the mouth at Jefferson Slough, and High Ore Creek from the headwaters to the mouth where it flows into the Boulder River (**Appendix A, Figure A-4**). As discussed in **Section 3.1**, all three segments are classified as B-1, which requires that the streams be maintained suitable for several uses, including salmonid fishes and associated aquatic life.

6.3 INFORMATION SOURCES AND DATA COLLECTION

As part of this TMDL project, DEQ used several information and data sources to analyze and assess the stream segments of concern.

6.3.1 Fish Populations & Specific Temperatures of Concern

To help understand potential thermal effects on aquatic life, information on fish populations along with information on temperatures that may cause harm to these fish populations was collected and is summarized below.

6.3.1.1 Fish Populations in the Boulder River

Above the town of Basin (approximately 6 miles upstream of the City of Boulder), the river contains a healthy population of fish and is capable of supporting significant recreational fishery (1,135 trout/mile). Below Basin, however, the number of fish and their condition begins to deteriorate; and below the mouth of High Ore Creek, trout numbers are only 15% of the population upstream of Basin. This degraded condition extends almost to the river mouth: above Basin, trout populations were estimated at 1,135 trout/mile; between the city of Boulder and Cottonwood Creek, 232-275 trout/mile (Knudson, 1984).

Based on a query of the Montana Fisheries Information System (MFISH), brook trout, rainbow trout, and brown trout can all be found in the Boulder River, as well as mountain whitefish. In addition, longnose dace, longnose sucker, mottled sculpin, and white sucker are rare but present in the river between the city of Boulder and the mouth.

6.3.1.2 Fish Populations in the High Ore Creek

Past channel alterations and metals contamination from the Comet Mine in the High Ore Creek watershed has severely hindered aquatic life in most of High Ore Creek. For High Ore Creek, the MFISH database classifies brook trout as rare from the mouth to mile 1.6, with no other observations, and westslope cutthroat as rare, occurring above river mile 4.3 (which generally refers to the stream above the Comet Mine site). Genetically pure westslope cutthroat trout were found in High Ore Creek on July 1, 1996.

6.3.1.3 Temperature Levels of Concern

Special temperature considerations are warranted for the westslope cutthroat trout, which are listed in Montana as a species of concern and occur within the Boulder River watershed. Research by Bear et al., (2007) found westslope cutthroat maximum growth around 56.5° F (13.6° C) with an optimum growth range, based on 95% confidence intervals, from 50.5° F to 62.6° F (10.3-17.0° C). Rainbow trout were found to have a similar optimum growth temperature; however, rainbow trout were predicted to grow better over a wider range of temperatures than cutthroat trout, with growth significantly better at temperatures below 44.2° F and above 69.4° F (6.8-20.8° C), possibly allowing for increased competition with cutthroat trout in lower-elevation (warmer) streams.

Additionally, the average 60 day upper incipient lethal temperature (UILT) for westslope cutthroat trout is 67.5° F (20.0° C). The 7-day UILT was found to be 75.4° F (Bear et al., 2007). The UILT is the temperature considered to be survivable indefinitely by 50% of the population over a specified time period. The lethal concentration (LD10) for westslope cutthroat is 73.0° F (22.8° C), which is the temperature that, on a sustained basis, will kill 10% of the population in a 24-hour period (Lines and Graham, 1988).

Brown trout are a common trout species found in the Boulder River. Brown trout better tolerate temperature increases than the native westslope cutthroat species; however, high temperatures can negatively affect the brown trout population as well. Studies conducted by Elliott (1981) and Brett (1952) found a range of 7-day UILT between 76.5° and 80.1° F. The upper lethal concentration for juvenile brown trout is 75.4° F, as presented in Beschta et al. (1987). The critical thermal maximum (CTM) is the arithmetic mean of collected thermal points at which locomotor activity becomes disorganized such that the organism loses its ability to escape lethal conditions (Cowles and Bogert, 1944). The CTM for brown trout, according to Elliott and Elliott (1995), is 85.8° F.

6.3.2 DEQ Assessment Files

DEQ maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations. This information was compiled in 1999 during DEQ's most recent formal assessment of streams in the Boulder Watershed. Following is short review and general characterization of stream conditions in relation to temperature impairment determinations DEQ made in 1999.

6.3.2.1 Boulder River; City of Boulder to Cottonwood Creek

The depression in trout populations reflects numerous environmental effects, including metals contamination, excessive sedimentation, severe dewatering, and removal of streambank cover. A 1976 report by the Jefferson Valley Conservation District for the North Boulder Drainage District describes metals pollution from the vicinity of Basin. The report also notes a loss in bank stability and riparian vegetation from prolonged dewatering and livestock concentration in bottomlands. A 1997 report documented water temperatures in the Boulder River, as high as 73.4^{o} F in some places.

6.3.2.2 Boulder River; Cottonwood Creek to the mouth (Jefferson Slough)

The conditions of the lower section of the Boulder River mirror many of the problems of the section just upstream, with perhaps more significant influence from dewatering and riparian degradation. A 1979 report by the Montana Department of Fish and Game (now Fish, Wildlife & Parks) described summer flows in the lower river as severely depleted from irrigation but also being supplemented by Big Spring. As a result, aquatic habitat was in poor condition from dewatering in the lower end and metals contamination in the upper end.

A 1984 report by Ken Knudson also describes streambank and channel alterations, excessive sedimentation, dewatering, pollution from mining, and effects from Interstate 15. In addition, according to the report, riprapping and riparian grazing resulted in a loss of bank cover. Further, during the irrigation season, nearly 30 miles of the Boulder River contained less water than required to sustain an optimal fishery.

A 1989 report from Montana Fish, Wildlife & Parks describes the section from High Ore Creek to Cold Spring Creek as severely degraded from metals pollution, sedimentation, bank and channel alterations, irrigation withdrawals, and elevated temperatures. From Cold Spring to the mouth, Cold Spring flows and groundwater return flows help rejuvenate the river and improve habitat, although sedimentation affects instream habitat through here. The 1989 report, which was part of an application for reservations of water in the Missouri River Basin above Fort Peck Dam, also requested a minimum 24-cfs instream flow from High Ore Creek to Cold Spring and a 47-cfs flow to maintain instream flows from Cold Springs to the mouth. According to the Knudson report (1994), during irrigation season, nearly 30 miles of the Boulder River contain less water than required to sustain an optimal fishery.

Reach assessments conducted in 1997 also described extensive agricultural use along the river (i.e., irrigated croplands and pasture, encroachment of hayfields upon streambanks, and grazing) as moderate to severe. Irrigation severely depletes flows, and peak temperatures were documented as high as 78.8^{o} F.

6.3.2.3 High Ore Creek

Mining in the drainage has greatly modified and affected High Ore Creek. A 1999 report from Pioneer Technical Services ("Expanded Engineering Evaluation/Cost Analysis for High Ore Creek") presents photos illustrating channel alterations, bank erosion, and varying degrees of riparian denudation associated with the Comet Mine tailings. A 1998 report by the BLM also describes that the effects of grazing were minor compared with mining. The stream is described as negatively affected by thermal modifications, habitat alterations, toxics, metals, siltation, suspended solids, and turbidity. Timber harvest on private lands and lack of drainage structures on roads contribute to water quality problems as well.

In 2000, reclamation began on High Ore Creek as a joint project between BLM and DEQ. In that project, historic mine wastes were removed and the stream channel was restored. Since that time, fenced enclosures have been maintained around BLM sections of the stream to exclude browsing and grazing, and recovery progress has been monitored.

In 2009, a report prepared for the BLM (Reclamation Research Group, LLC., 2009) evaluating reclamation activities described the vegetation throughout High Ore Creek to be "a mix of areas of good vegetation that appear to be on a positive trajectory and conversely, many areas appear to be deteriorating due to low pH soils, erosion and noxious weed infestations."

Observations in the High Ore Creek watershed in the summers of 2012 noted considerable portions of the creek that had been fenced off and appeared to be allowing for recovery of riparian areas. Cattle grazing is present in the watershed however, and cattle were observed grazing riparian vegetation and traveling through the stream in places where fencing was not present.

Temperature data collected by DEQ from a single sampling event in August of 2009 described temperatures as high as 63.4^{o} F. Fish population information from the Montana Rivers Information System (MRIS) classifies both brook trout and westslope cutthroat trout as uncommon, but that genetically pure westslope cutthroat trout were found in High Ore Creek on July 1, 1996.

6.3.3 Boulder River TMDL Field Data Collection

DEQ's methods for Boulder River temperature TMDL development included a combination of characterizing water temperatures throughout the summer and collecting additional vegetation, channel condition, shade, and streamflow data, which used to model stream temperature. As described in **Attachment 3**, the QUAL2K temperature model was calibrated to existing flow, shade, and temperature conditions, with the ability to evaluate temperature impacts from differing riparian health (shade) and streamflow conditions. The following sections describe the data collected in the Boulder River watershed for temperature assessment.

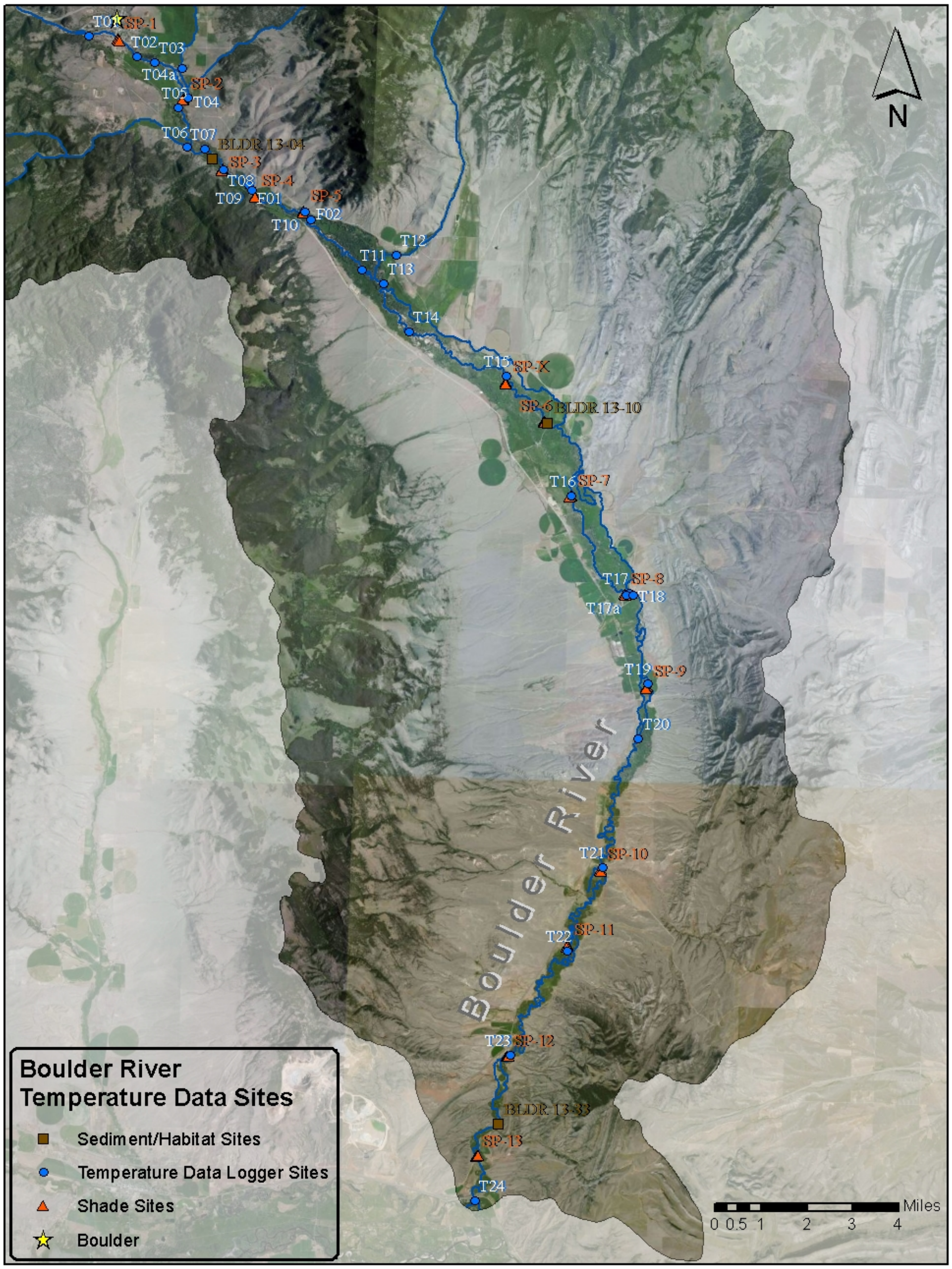

Figure 6-1. Boulder River Temperature Data Sites

6.3.3.1 Temperature Monitoring

In 2010 temperature monitoring was conducted in the Boulder River between late June and late September. The study examined stream temperatures during the period when streamflows tend to be the lowest and water temperatures the warmest; therefore, the negative effects to the coldwater fishery and aquatic life beneficial uses are likely most pronounced. Temperature monitoring consisted of placing temperature data logging devices at 22 sites in the Boulder River (**Figure 6-1**). In addition, temperature data logging devices were placed on three tributary streams (Muskrat Creek, Elkhorn

Creek, and Little Boulder River) and at three sites within major irrigation canals. Temperature monitoring sites were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width. Temperature monitoring locations are shown in **Figure 6-1**.

Of the 22 temperature monitoring sites established on the Boulder River, temperature data loggers were retrieved from 21 sites (the temperature data logger from BLDR-T07 was not recovered). Of the 21 sites with temperature data, four sites (BLDR-T01, BLDR-T03, BLDR-T16, and BLDR-T18) have incomplete datasets because of low flows, which meant the data loggers were out of the water for a portion of the monitoring period in late July and early August. In addition, the original data logger at BLDR-T23 was not found and was subsequently replaced in August. Further, one additional data logger was added. Therefore, these sites have data from only August up until their retrieval in September.

Overall, 15 sites have complete temperature datasets July-September. Of those sites with complete datasets, the 7-day average maximum temperature occurred between July 22 and August 18. The 7-day average maximum temperature was reported at five sites on July 22, five sites on July 31, two sites on August 2, two sites on August 4, and one site on August 18. Thus, temperature data recorded in 2010 indicates that the warmest extended temperatures in the Boulder River occurred between July 22 and August 18, with the majority of 7-day average maximum temperatures between July 22nd and August 6. The 7-day average maximum temperature ranged from 67.8^{o} F to 71.1^{o} F in the upper segment Boulder River sites and 69.2^{o} F to 75.1^{o} F in lower segment sites. Since nearly all of the 7-day average daily maximum temperatures occurred on July 25 and this date occurs within the period of greatest 7-day average temperatures, the July 25 timeframe was selected for modeling temperature for the Boulder River. In the Boulder River, a 3-day travel time (the time it takes for water to flow through the study reach to the City of Boulder to the mouth) is estimated. Temperature data from July 24, 25, and 26 were averaged for input into the model and then run to represent that timeframe.

Although the prolonged period of high temperatures occurred in July, single day maximum temperatures occurred in September at many of the sites, signifying potential stressors from temperature throughout the summer months. Single-day maximum temperatures ranged from 71.0^{o} F to 78.9^{o} F, depending on the location. The upper segment single day highs ranged from 71.1^{o} F to 76.4^{o} F, and the lower segment single day highs ranged from 71.0^{o} F to 78.9^{o} F.

6.3.3.2 Streamflow
Streamflow measurements occurred at temperature monitoring locations (**Figure 6-1**). Flow was measured at five sites in the Boulder River watershed in late July, at 27 sites in early August, and at 24 sites in late September. Higher flows than normal and a prolonged duration of high flows prohibited measurements at most sites in July 2010; however the data from early August was ultimately used for model development. Included with the flow measurements on the Boulder River were three locations in irrigation ditches, as well as a site on Muskrat Creek and a site on the Little Boulder River. Elkhorn Creek was dry during the August monitoring event.

6.3.3.3 Riparian Shading
Riparian shading was assessed at 14 sites along the Boulder River (**Figure 6-1**). DEQ used a Solar Pathfinder instrument to collect shade information. The Solar Pathfinder measures the amount of effective shade at a site in 1-hour intervals over a given day. Measurements were taken in August. At each site, shade was measured at three locations over a 200-foot reach. Data collected included solar

pathfinder readings, stream azimuth, bankfull width, wetted width, and dominant tree species. Riparian shading data were used to assess existing and potential riparian shading conditions relative to the level of human-caused disturbance at a site.

Before field data was collected, the Boulder River was divided into 33 distinct reaches categorized by riparian conditions. Aerial imagery from 2009 was used to determine the reaches and categorize riparian density as dense, moderate, or low. Approximately 13% of the reach was designated as dense, 18% as moderate, and 69% as low. Dense riparian vegetation areas were described with a mix of deciduous trees and shrubs. Moderate riparian vegetation represented areas with fewer deciduous trees and generally had an understory comprising deciduous shrubs and herbaceous vegetation. Areas with low riparian vegetation density generally lacked overstory vegetation and comprised herbaceous vegetation with sparse deciduous shrubs in the understory.

Solar Pathfinder data was then used to estimate an average percent effective shade for the three riparian vegetation categories. Of the 14 field sites where solar pathfinder data was collected, 3 were in the dense riparian vegetation category, 3 in the moderate, and 8 in the low. Percent shade values were then applied directly to the reach where they were measured. For those reaches that did not have a Solar Pathfinder site, the average effective shade for that category was applied. Dense riparian shade was applied at 37%, moderate riparian shade was applied at 22%, and low riparian shade was 4%. It is expected that the Boulder River corridor should not have less than 22% effective shade under desired conditions reflective of a healthy riparian corridor.

6.3.3.4 Channel Geometry

Although not a direct measure of thermal effect on the stream, channel geometry can influence the rate of thermal loading. Wide, shallow streams transfer heat energy faster than narrow, deep streams. Therefore, channel geometry can be used to identify areas that may be destabilized, and may be more prone to rapid thermal loading, particularly in locations where shading is minimal.

Between the city of Boulder and the mouth, DEQ investigated four sites on the Boulder River during the 2010 sediment and habitat field work (**Figure 6-1**). Target development work used for sediment determined an average width-to-depth ratio target of <30 for the Boulder River. For comparison, this value can be considered when evaluating channel geometry as it applies to temperature conditions. Of the four sites reviewed, width-to-depth ratios were 40.5, 68.1, 31.9, and 37.9 at BLDR 13-04, BLDR 13-10, BLDR 13-23, and BLDR 13-33, respectively.

6.3.4 High Ore Creek TMDL Field Data Collection

A relatively low level of detail was applied for High Ore Creek temperature TMDL development because of its very small stream size and a low level of source complexity. Since the sources generally affecting temperature in High Ore Creek are mostly linked to the mine discussed in **Section 6.3.2.3**, and BMPs to address the problems can be readily determined along this short stream, a model was deemed unnecessary. Temperature assessment was limited to readily available data and the information collected during the sediment and habitat field work (**Attachment 1**), and Solar Pathfinder shade data collected in the summer of 2012.

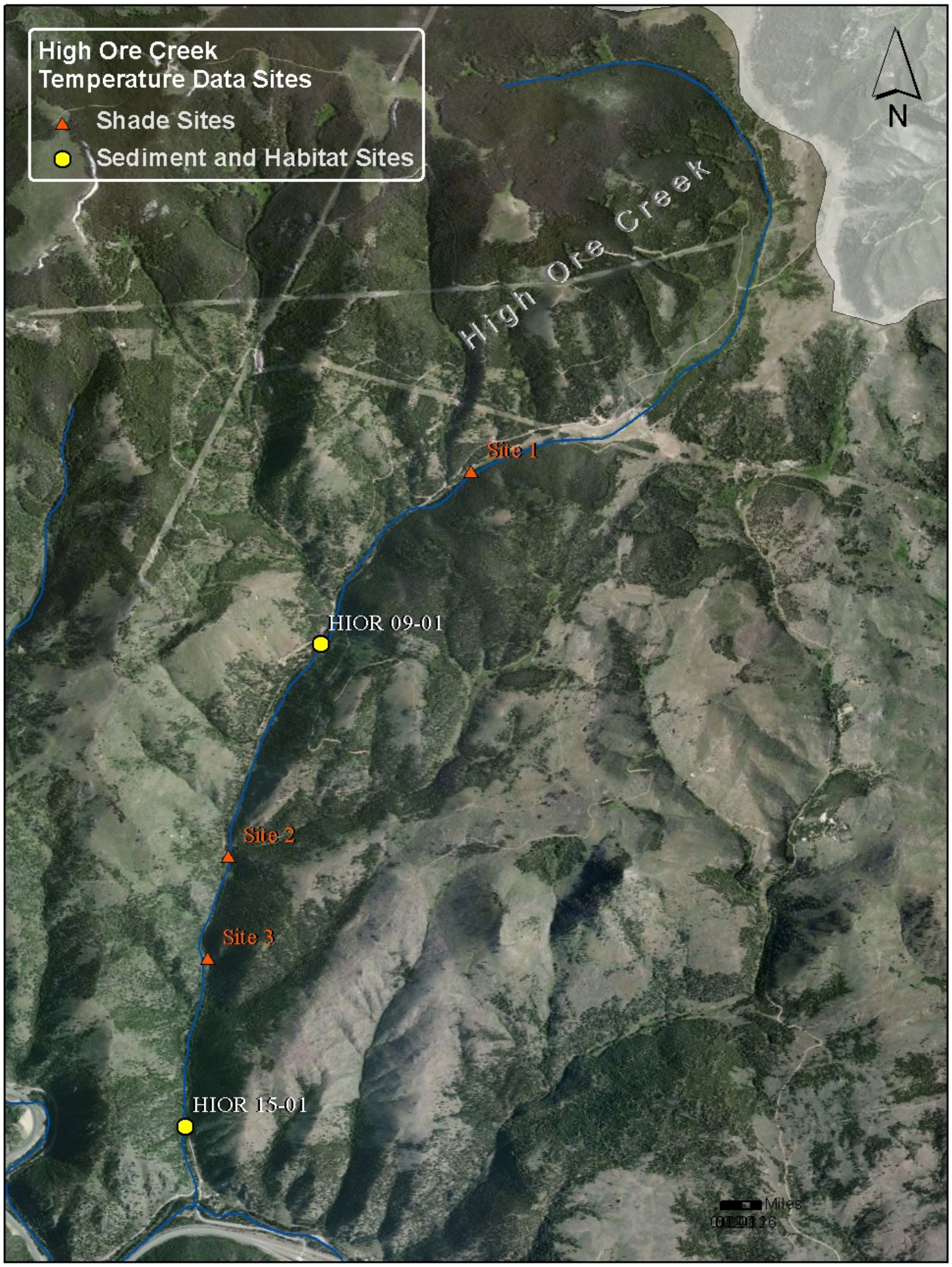

Figure 6-2. High Ore Creek Temperature Data Sites

6.3.4.1 Temperature Data

Continuous temperature data loggers were not deployed by DEQ as part of this project. A search of available water temperature data in EPAs STORET database found data from two sampling events from summer 2009 (June and August) at four sites on High Ore Creek (**Figure 6-2**). Water temperatures ranged from 53.6⁰ F to 58.8⁰ F in June and 50.6⁰ F to 63.3⁰ F in August. During these sampling events, instream flows at the four locations ranged from 2 to 5 cfs in June and 0.4 to 0.8 cfs in August.

BLM data from a single sampling even at three sites (**Figure 6-2**), on July 23, 2012, observed stream temperatures of 66.2° F and 64.2° F (64.2° F occurred at two sites), with flows ranging from 0.35 – 0.62 cfs.

6.3.4.2 Riparian Shading

The Solar Pathfinder instrument is used to determine the amount of effective shade at a specific site, and therefore can be used to gage riparian shade effectiveness for various vegetative communities and riparian conditions. On August 31, 2012, DEQ Solar Pathfinder data was collected from three sites on High Ore Creek (**Figure 6-2**). One site occurred just below the Comet Mine, where recent restoration is evident. Vegetation at that site was limited to mostly herbaceous plants, with some established young woody vegetation. Effective shade at this site averaged 28.7%. The second site was further downstream in an area where more young woody species were present, as well as more mature trees in areas away from the bank. However, cattle grazing was observed at this site and stream channel over-widening and vegetative loss was apparent. Effective shade at this site was 37.7%. A final site was measured further downstream, in an area that appeared to have a mix of mature trees and shrubs and young woody shrub species both along the stream channel and within the riparian perimeter, and generally looked to be close to potential for riparian condition along High Ore Creek. However, some road encroachment and riprap was present indicating this is not a site absent from human influence. Effective shade at this site was 72.7%.

6.3.4.3 Channel Geometry

Although not a direct measure of thermal effect on the stream, channel geometry can influence the rate of thermal loading. Wide, shallow streams transfer heat energy faster than narrow, deep streams. Therefore, channel geometry can be used to identify areas that may be destabilized, and may be more prone to rapid thermal loading, particularly in locations where shading is minimal.

It is expected that much of High Ore Creek matches the characteristics of a Rosgen A, B, or E channel and therefore the width-to-depth ratios in these areas will typically be <12. Two sites were evaluated on High Ore Creek during the 2010 DEQ field data collection (HIOR 09-01, HIOR 15-01) (**Figure 6-2**). HIOR 09-01 had a width-to-depth ratio of 14.0 indicating some slight over-widening. HIOR 15-01 had a width-to-depth ratio of 7.4, typical of expected conditions.

BLM data from 2011 measured data from three sites (**Figure 6-2**). The upper site had a width-to-depth ratio of 3.5, the middle site had a width-to-depth ratio of 4.5, and the lower site was 8.4.

Data collected in 2012 by DEQ as part of the Solar Pathfinder data collection also measured the width-to-depth ratios at each site (**Figure 6-2**). The width-to-depth ratio at the upper site was 3.6, the middle site was 6.6, and the lower site was 5.6.

Although limited, the channel geometry data for High Ore Creek does not seem to indicate that channel geometry is a significant contributor to elevated temperature conditions in the creek. Since much of the stream has undergone restorative channel work in the last decade, it makes sense that this would be true. However, a few discrete locations where cattle access was observed do show small, isolated areas of channel widening. Cattle grazing practices should be conducted to limit, if not eliminate, these types of effects, and consideration should be given to ensure the maintenance of the extensive restoration work.

6.3.5 Other Information Sources

The following sections describe data used in the analysis of the Boulder River and High Ore Creek from outside of the DEQ.

6.3.5.1 USGS Gaging Station

In addition to temperature data collected in the Boulder River, USGS gaging station data from the Jefferson River near Three Forks (Station #06036650) recorded a maximum temperature of 75.6° F on July 25; the 14 days with the highest maximum temperatures occurred between July 21 and August 7. This information helps validate the late-July time period to represent the warmest temperature conditions in the Boulder River during 2010.

The USGS gaging station flow information was also used to evaluate yearly streamflow statistics discussed above. Per this station, the summer of 2010 represented higher than normal flows for the Boulder River. Data from the USGS gaging station from the Boulder River at Boulder (Station #06033000) showed an average discharge in 2010 of 201 cfs for July, 113 cfs for August, and 91 cfs for September. In comparison, the average monthly discharge for the period of record (1929-2011) is 98 cfs for July, 33 cfs for August, and 29 cfs for September. This information implies that water temperature peaks and duration may have been lower when TMDL data was collected in 2010 than what would be found in a more typical water year in the Boulder River.

6.3.5.2 Climatic Data

In addition to the field-measured values for the Boulder River, climatic data inputs for the QUAL2K model were obtained from the Western Regional Climate Center station in Whitehall, MT, and included air temperature, dew point temperature, and wind speed. The dew point temperature was adjusted by increasing relative humidity by 15%, based on local conditions within the stream corridor as measured in a similar assessment in the Big Hole River watershed (Kron et al., 2009).

6.4 Target Development

The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of indicator parameters used for target TMDL development; 3) how target values were developed; and 4) a summary of the temperature target values for the Boulder River and High Ore Creek.

6.4.1 Framework for Interpreting Montana's Temperature Standard

As discussed in **Section 4.0**, the TMDL targets represent attainment of applicable water quality standards. Montana's water quality standard for temperature is narrative in that it specifies a maximum allowable increase above the "naturally occurring" temperature in order to protect the existing thermal regime for fish and aquatic life. For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature is 1° F, when the naturally occurring temperature is less than 66° F. Within the naturally occurring temperature range of 66° F to 66.5° F, the allowable increase cannot exceed 67° F. If the naturally occurring temperature is greater than 66.5° F, the maximum allowable increase is 0.5° F [**ARM 17.30.623(e)**]. Note that under Montana water quality law, naturally occurring temperatures incorporate natural sources, yet may also include human sources with reasonable land, soil, and water conservation practices that protect current and reasonably anticipated beneficial uses.

Evaluating the extent that human activities are influencing stream temperatures is important. For the Boulder River, a model (QUAL2K) was used to estimate the extent of human influence on temperature by evaluating the temperature deviation when existing conditions of riparian health and associated shade, channel geometry, and streamflow were compared with naturally occurring conditions for these parameters. Per the above water quality standard, human activity leading to increased temperature deviations from 0.5° F to 1.0° F - depending on the baseline naturally occurring condition - would be consistent with the existing impairment determinations for the Boulder River segments.

A non-modeling TMDL development approach for High Ore Creek instead focused on identifying the naturally occurring conditions for riparian health and associated shade. These naturally occurring conditions were then compared with past and existing conditions as a direct indicator of increased thermal loading from past and existing human influences.

To help evaluate the extent and implications of impairment it is useful to evaluate the degree to which existing temperatures harm fish populations or other aquatic life. For example, as discussed in **Sections 6.3.3** and **6.5.1**, the existing temperatures within the Boulder River are often greater than 67° F, with maximum values on the order of 76° F for the middle segment and 79° F for the lower segment. These temperatures are high enough to harm multiple species of trout found in the Boulder River (**Section 6.3.1**). Temperature results for High Ore Creek are much lower because of the headwater nature of this stream. Limited data suggests that peak summer temperatures exceeded levels above the optimal growth range for cutthroat trout (**Section 6.3.1.3**) at the time that DEQ made the impairment determination for High Ore Creek.

6.4.2 Selection of Indicator Parameters for TMDL Target Development

Naturally occurring temperatures can be estimated for a given set of conditions using QUAL2K or other modeling approaches. Because naturally occurring temperatures can significantly vary throughout the summer, as well as from year to year, the quantified temperature targets include those indicator parameters that influence temperature and can be linked to human causes. These target or indicator parameters include riparian health and associated shade, channel geometry, improved streamflow conditions where applicable, and allowable increases from MPDES-permitted point sources.

6.4.3 Developing Target Values

Values are developed for each target parameter and are set at levels that result in attainment of Montana's temperature standard under all seasonal and yearly variability. The goal is to set most of the target values at levels that would contribute to naturally occurring temperature conditions, while ensuring that any variability from naturally occurring conditions is less than that allowed by the standard. Although the resulting target values are protective of fish and aquatic life use, the targets are protective of all designated uses because they are based on the reference approach, which strives for the highest achievable condition.

6.4.3.1 Riparian Canopy and Shade Target Values

Increased shading from riparian vegetation reduces sunlight hitting the stream and, thus, reduces heat load to the stream. Riparian vegetation also reduces near-stream wind speed and traps air against the water surface, which reduces heat exchange with the atmosphere. In addition, lack of established riparian areas can lead to bank instability, which could result in overwidened streams. Human influences affecting riparian canopy cover in the Boulder watershed include present and historic agricultural activities, timber harvest, transportation corridor development, and some limited areas of recreational activity in the watershed.

DEQ uses a reference approach to define naturally occurring conditions for riparian health. DEQ defines "reference" 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, the reference condition reflects a waterbody's greatest potential for water quality given past and current land-use activities. The riparian canopy cover target for the Boulder River segments of concern is based on measurements made in the field from sites with good to moderate riparian conditions to represent a potential reference condition for this stream. The target for a healthy riparian corridor throughout the Boulder River is a minimum of 22% effective shade, which is the average riparian shade as measured from sites defined with moderate riparian canopy as discussed in **Section 6.3.3.3**.

The riparian canopy cover target for High Ore Creek is based on effective shade data collected during the summer of 2012 and from data collected during the 2010 sediment and habitat investigations throughout the Boulder Creek watershed. A riparian greenline measurement average of 65% shrub cover is the minimum vegetative cover recommended for Boulder River tributaries and is applied here to High Ore Creek. This value represents riparian conditions that have mature communities of woody shrubs (typically willows, alders, etc) adjacent to the stream throughout most of the reach. This type of vegetative community provides shade and bank stability. Mature trees also provide shade and are often a component of a healthy riparian corridor; although the DEQ uses percent shrub cover as a target in this case, it is presumed that with a healthy shrub community, other vegetative types and age classes will exist within the riparian area to provide additional canopy and shade.

Of the three sites assessed for effective shade on High Ore Creek, the upper two had some shrub cover (albeit very young) where restorative plantings had occurred, but minimal additional vegetation to provide shade. The lower-most site had a much more developed and mature shrub community, with near-stream trees providing additional canopy. Of these sites, effective shade was measured at 28.7% and 37.7% in the upper two sites, and 72.7% in the lower site. As the lower site represents conditions that would be typical in a High Ore Creek riparian community absent of the effects of the mine and including grazing BMPs (and typical of conditions meeting the shrub community target), the lower site serves as a reference for a what a typical effective shade might be under normal conditions. Therefore, it is presumed that the corresponding effective shade for High Ore Creek would be approximately 70% if the shrub cover target was met.

6.4.3.2 Width-to-Depth Ratio Target Values

A lower width-to-depth ratio equates to a deeper, narrower channel that has a smaller contact area with warm afternoon air and is slower to absorb heat. Also a lower width-to-depth ratio will increase the effectiveness of shading produced by the riparian canopy. Much of the stream channel widening in the Boulder watershed is a result of destabilized streambanks from present or past agricultural activities (mostly riparian area grazing, although other human-related activities, such as stream channel alterations to accommodate roads or railroads, have also overwidened stream channels) .

Channel dimensions were not altered in the QUAL2K model scenarios; however, a channel geometry target has been developed for the dimensionless width-to-depth ratios in association with sediment TMDLs for the Boulder River. The width-to-depth ratio target value is <30, based on the same reference approach concepts as used for sediment related targets (**Appendix D**). That target value is also used here since a smaller width-to-depth ratio indicates a stream with stable channels and healthy riparian areas, directly affecting temperature. Generally, improved riparian areas will lead to gradual improvements in width-to-depth ratio values over time. However, improvement in both riparian health and channel morphology need significant time before changes are visible. DEQ does not expect these targets to be met in the short-term; however, changes in land management practices and a commitment to those practices would need to be implemented to start meeting goals for temperature in the Boulder River. Further, because of where highways and the railroad are located, some areas of the Boulder River will never be able to meet the target width-to-depth ratios. The target is not intended to be specific to every given point on the stream, the intent rather, is to achieve an average width-to-depth ratio of <30 as a general trend throughout the Boulder River corridor.

The width-to-depth ratio target for High Ore Creek is also based on data collected during the 2010 sediment and habitat investigations throughout the Boulder Creek watershed. For Boulder River tributary streams, the target for width-to-depth ratios is <18 for C channels and <13 for B channels. These targets will apply to High Ore Creek temperature conditions as well.

6.4.3.3 Instream Discharge (Streamflow Conditions) Target Values

Larger volumes of water take longer to heat up during the day. The volumetric heat capacity of the stream is reduced if water volumes are reduced. In the Boulder River valley, streamflow reductions are largely attributed to agricultural uses or other land-use activities where streamflow is diverted for human-related use. Therefore, improvements in water diversion infrastructure and water use efficiencies may leave more in the stream, and it is presumed that voluntary actions by water users could increase instream flow volume.

For modeling purposes, a scenario was run to represent all reasonable land, soil, and water conservation practices that included an improvement in irrigation and domestic water use efficiency that would result in reducing water withdrawals by 15%. This number was based on assumptions presented within the Middle Blackfoot - Nevada Creek TMDL document. The document suggested that a 15% reduction in water withdrawal from water use efficiency improvements was a conservative estimate for what is reasonable and achievable, based on a review of typical irrigation efficiency improvements documented by the USDA (Middle Blackfoot Reference). The temperature improvements in the Boulder River model show that riparian improvement combined with water use efficiency could reduce temperatures by as much as 2.2^{o} F in the upper segment, and 3.6^{o} F in the lower segment. However, the irrigation efficiency improvement is only a guideline. As described earlier, a thorough investigation into irrigation infrastructure, water management, and relationships to groundwater has not yet been conducted. The assumption that some improvements can be made is based on the extent of water use in the Boulder River watershed, and trends in water use and irrigation infrastructure throughout western Montana. Water users in the Boulder River watershed are encouraged to work with the USDA Natural Resource Conservation Service, the Montana Department of Natural Resources & Conservation, the local conservation district, and other local land management agencies to review their systems and practices. If warranted and practical, users should consider changes that increase instream flows, and/or reduce warmwater return flows in the Boulder River.

6.4.3.4 Allowable Temperature Increase from Point Source Discharges

Wastewater treatment plants (WWTPs) and other point source effluents may influence a stream's water temperature. The temperature TMDL target is performance based for WWTPs and other point source effluents. This target requirement states that these point sources shall not warm the stream individually or in combination by more than the allowable increase in temperature under Montana's temperature standard which applies to the Boulder River. This translates to no more than 0.5° F under conditions where the receiving water is greater than 66.5° F, or 1.0° F when the receiving water is cooler than 66.5° F.

6.4.4 Target Values Summary

The allowable temperatures defined via Montana's temperature standard represent the primary target that must be achieved. Alternatively, compliance with the temperature standard can be attained by meeting all other targets for shade, channel width-to-depth ratio, streamflow and allowable temperature increase from point sources. In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, state standards are met. These targets, which need to be met in combination, are referred to as "temperature-influencing targets." **Table 6-1** presents a summary of the temperature influencing targets for both segments of the Boulder River and High Ore Creek. Note that an irrigation efficiency target is not applicable to High Ore Creek because of the lack of irrigation diversions.

Table 6-1. Temperature-influencing Targets for the Boulder River and High Ore Creek

Boulder River	
Target Parameter	Target Value
Riparian Health - Shade	Minimum of 22% average effective shade at a given sample site
Width to Depth Ratio	Average ≤30 at a given sample site
Increased Streamflow (via water use efficiencies)	Improvement of water-use resulting in a 15% reduction in summer water withdrawal (based on 2012 conditions)
Allowable Temperature Increases from Point Sources	No more than 0.5° F under conditions where the receiving water is greater than 66.5° F, or 1.0° F when the receiving water is cooler than 66.5° F.
High Ore Creek	
Target Parameter	Target Value
Riparian Health - Shade	Minimum 70% average effective shade at a given sample site
Width to Depth Ratio	Average ≤18 for C channels, and ≤13 for B channels at a given sample site
Increased Streamflow (via water use efficiencies)	Improvement of water-use resulting in a 15% reduction in summer water withdrawal (based on 2012 conditions)
Allowable Temperature Increases from Point Sources	No more than 0.5° F under conditions where the receiving water is greater than 66.5° F or 1.0° F when the receiving water is cooler than 66.5° F.

6.4.4.1 Boulder River Comparison to Targets

As part of the temperature analysis, aerial photographs were used to identify study reaches and provide broad classifications of riparian vegetation condition in three categories: Dense, Moderate, and Low. Sites were then analyzed in the field in a selected number of study reaches and average effective shade for those sites was assessed. For modeling purposes, the average of the results for sites in each category was then applied to the corresponding category for those reaches that were not sampled. Average effective shade for reaches classified as Dense was 37%; Moderate classification was given 22% effective shade; and Low classification was given 4%. In reviewing the entire stream lengths for the Boulder River segments of interest, 13% of the stream was classified as having dense riparian condition, 18% of the stream has Moderate riparian condition, and 69% of the stream has Low riparian condition. Using this analysis, approximately 69% of the stream is below the target.

As described in **Section 5.4.1.1**, width-to-depth ratio targets are included because higher w/d ratios signify a wider stream channel with shallower depths. Wide, shallow streams absorb thermal energy from the sun much faster than narrow, deep channels and therefore overwidened streams will be more sensitive to thermal loading. The width-to-depth target for temperature is the same target as discussed in the Sediment TMDL discussions and represents a width-to-depth value that is assumed to be representative of naturally occurring conditions. Four sites on the Boulder River were analyzed during the sediment and habitat investigations. The average width-to-depth ratios for these four sites were 40.5, 68.1, 31.9, and 37.9. It is noted however that meeting the width-to-depth target in the Boulder River will likely take many years to accomplish and is dependent on recovery of riparian areas and re-stabilization of eroding streambanks.

The target of improving water use efficiencies for a 15% reduction in summer water withdrawals is selected based on best professional judgment and a review of information related to water use in Montana. Although no analyses specific to water use, related to the TMDL have been conducted throughout the Boulder River watershed, research has shown “the available evidence indicates there are substantial opportunities for improving the efficiency of irrigation in Montana.” (Montana Department of Natural Resources and Conservation, 2008a). The most recent (2000) data from the U.S. Geological Survey (USGS) show that Montana withdrew 5.3 acre-feet of water per acre of irrigated land, twice the national average, and the average efficiency for all irrigation systems, calculated as the ratio of total consumption to total withdrawals, was 21 percent. (Cannon and Johnson, 2004) – Also from the ECONorthwest paper). Improvements that result in 15% less stream water withdrawn are considered a reasonable and conservative target to address this issue.

Point sources of thermal load to the Boulder River are required to meet temperature discharges that are consistent with the appropriate water quality standards. The City of Boulder WWTP discharge is currently satisfying this target as evaluated in **Section 6.5** below.

6.4.4.2 High Ore Creek Comparison to Targets

Three sites were measured for shade on High Ore Creek. High Ore Creek is a rather small stream in a largely wooded environment, however past mining and stream alteration has resulted in major disturbances to some places in the riparian corridor. Shade measurements were taken at three sites on the stream, one site just below the High Ore mining complex where recent stream restoration and plantings have occurred; one site further downstream in an area adjacent to the road and where cattle were observed; and one site downstream in an area adjacent to the road but where vegetation appeared largely undisturbed. The three sites had effective shade measurements of 29%, 38% and 73% respectively. The target value for High Ore Creek is $\geq$70% effective shade.

As described in **Section 5.4.1.1**, width-to-depth ratio targets are included because higher w/d ratios signify a wider stream channel with shallower depths. Wide, shallow streams absorb thermal energy from the sun much faster than narrow, deep channels and therefore overwidened streams will often be more sensitive to thermal loading. The width-to-depth target for temperature is the same target as discussed in the Sediment TMDL discussions and represents a width-to-depth value that is assumed to be representative of naturally occurring conditions. Two sites on High Ore Creek were analyzed during the sediment and habitat investigations. The average width-to-depth ratios for the two sites were 14.0 and 7.4.

Water use efficiency improvements should be sought throughout the entire Boulder Elkhorn TMDL planning area and therefore the target applies to the entire watershed. However there are no known water use issues in High Ore Creek at this time.

Similarly, all point sources in the Boulder Elkhorn watershed need to follow permit conditions and ensure compliance with the state water quality standards for temperature. There are no permitted point source discharges on High Ore Creek at this time.

6.5 Source Assessment

As discussed above, source assessment for the Boulder River largely involved QUAL2K temperature modeling, whereas the source assessment for High Ore Creek involved a summary review of existing information supplemented with limited field data collection.

6.5.1 Boulder River Assessment Using QUAL2K

Water temperature, flow, channel dimension, and riparian shade data were incorporated in a QUAL2K water quality model to characterize existing temperature conditions and to evaluate differing land management scenarios for the Boulder River. This section provides a summary of the QUAL2K modeling presented in **Attachment 3**, including a description of the model and the modeling scenarios used to evaluate human influences.

The QUAL2K model was used to determine the extent that human-caused disturbances within the Boulder River watershed have increased the water temperature above the naturally occurring level. QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Within the model, water temperatures are estimated based on climate data, riparian shading, and channel conditions. For this assessment, the QUAL2K model was used to evaluate maximum summer water temperatures in the Boulder River.

The water temperature data collected in the Boulder River (**Section 6.3.3**), along with climate data (**Section 6.3.5**), was incorporated into the model and used to calibrate to existing conditions. A number of various scenarios were then modeled to investigate the potential influences of human activities on temperatures in the Boulder River. The following sections describe those modeling scenarios. A more detailed report of the development and results of the QUAL2K model is included in **Attachment 3**.

6.5.1.1 Baseline Scenario

The baseline scenario represents the existing conditions within the Boulder River during July 24-26, 2010, which was determined to be the hottest period for water temperatures of the 2010 summer. To inform the model, this scenario used the measured field data to represent temperature, flow, and shade. When field data was unavailable, reasonable assumptions and extrapolation were used. The model was then run and compared with measured conditions. Hydraulic output in the model accurately reflected measured conditions, indicating that water routing and channel morphology were adequately calibrated. To assure consistency when evaluating the potential to reduce stream temperatures, subsequent model scenarios were compared with the existing-conditions results of the baseline model and not to the field-measured values.

6.5.1.2 Increased Shade Scenario #1
Shade scenario #1 altered the model to represent dense riparian vegetation throughout the entire Boulder River corridor, from the city of Boulder to the mouth. This scenario assumes that the length of the Boulder River is capable of supporting a riparian area comprising large cottonwood trees in the overstory and shrubs in the understory. There is a relatively broad floodplain along the majority of the study reach, and the meandering channel is not entrenched, allowing natural gravel bars to form and new cottonwood stands to establish. In this scenario, riparian shade density was increased along a total of 44.1 miles on the Boulder River. This represents a 37% effective shade for the entire Boulder River corridor. Percent effective shade for dense riparian was based on the field assessed sites. The results of shade scenario #1 indicate that a dramatic increase in streamside shading along the Boulder River would decrease stream temperatures between 1.0^{o} F and 5.8^{o} F, depending on the reach. One site (BLDR-T10) showed a 0.2^{o} F increase, however this increase likely reflects model variability at a location with minimal shade influence.

6.5.1.3 Increased Shade Scenario #2
While it is interesting to simulate a condition where the entire Boulder River corridor is restored with mature overstory and understory vegetation, it may not be realistic to assume that this condition is achievable, even under the best conditions, given natural and human-caused variability. However, some degree of improvement in riparian vegetation can occur, and as such, shade scenario #2 was run to provide a more reasonable simulation of improved riparian character and its associated effect on temperature. In this scenario, those reaches categorized as moderate were increased to dense riparian (9.1 miles effected), and those reaches with low riparian were increased to moderate (35.1 miles effected). Reaches currently exhibiting dense riparian were assigned the average value for dense riparian vegetation based on the field collected data. Dense riparian represents a 37% effective shade, while moderate riparian represents a 22% effective shade. Results showed decreases in temperature between 0.7^{o} F and 2.7^{o} F, depending on the reach. However, one site, (BLDR-T10) showed a 0.5^{o} F increase, again likely the result of model variability.

6.5.1.4 Decreased Water Consumptive Use Scenario
The water consumptive use scenario is used to describe the potential thermal effect of irrigation and domestic water use on water temperatures in the Boulder River. This scenario was modeled by removing existing water diversions from the study reach as identified in the hydrologic balance. This scenario is used only to investigate the degree of water temperature change under natural flow conditions and should <u>not</u> be interpreted as an achievable scenario or condition that would otherwise infringe upon legal water rights in the watershed. Simply, this scenario investigates how much influence flow has on water temperature throughout the stream. This scenario showed decreases in temperature ranging from 1.2^{o} F to 5.6^{o} F, depending on the reach. These decreases affected only the Boulder River from BLDR-T11 to the mouth. Note, that this scenario deals with water withdrawals from the Boulder River only; the removal of all water withdrawals in the watershed may have additional effects on the temperature regime of the Boulder River. Investigating water use on each tributary to the Boulder River was beyond the scope of this project.

6.5.1.5 Natural Background Scenario (No Human-caused Effects)
The natural background scenario reflects the temperature regime that might occur absent human influence. Factors applied in this scenario include the application of dense riparian vegetation throughout the entire Boulder River riparian corridor and the absence of any water withdrawals. The wastewater treatment plant input was also removed from the model. All other parameters from the

baseline scenario were retained. The results from this scenario indicate stream temperatures would decrease by between 1.1° F and 9.3° F, depending on the reach. Temperature decreases of greater than 3.1° F occurred at all sites from BLDR-T14 to the mouth. This scenario is not intended to be used to determine what is achievable; rather it simply provides insight into the degree of change that may have occurred over time in the Boulder watershed. Even so, the results of this scenario should be viewed with caution because the application of a complete dense riparian corridor may not be achievable, and the water withdrawal component does not include water withdrawals from tributary streams that may also be affecting temperatures.

6.5.1.6 Naturally Occurring Scenario (Full Application of BMPs With Current Land Use)

The naturally occurring scenario represents water temperature conditions resulting from implementing all reasonable land, soil, and water conservation practices as outlined in **ARM 17.30.602**. This scenario identifies the naturally occurring temperature in waterbodies of interest and establishes the temperatures to which a 0.5° F (0.23° C) temperature increase is allowable. In turn, this can be used to identify the impairment status of a waterbody and forms the basis for the allocations and temperature TMDLs in this document. The naturally occurring scenario used the conditions included in shade scenario 2, along with a 15% increase in irrigation and domestic water use efficiency (removing 15% less water from the stream). Water use efficiency was estimated by reducing the identified irrigation withdrawal volume by 15%, which is an efficiency improvement estimate taken from the Middle Blackfoot-Nevada Creek TMDL described earlier. **Figure 6-3** presents the results for both the existing condition (baseline scenario) and the naturally occurring scenarios. Based on these results, there is the potential for significant reductions in stream temperatures relative to the existing condition (baseline scenario). The potential temperature decreases ranged from 0.7° F to 3.6° F, depending on the reach.

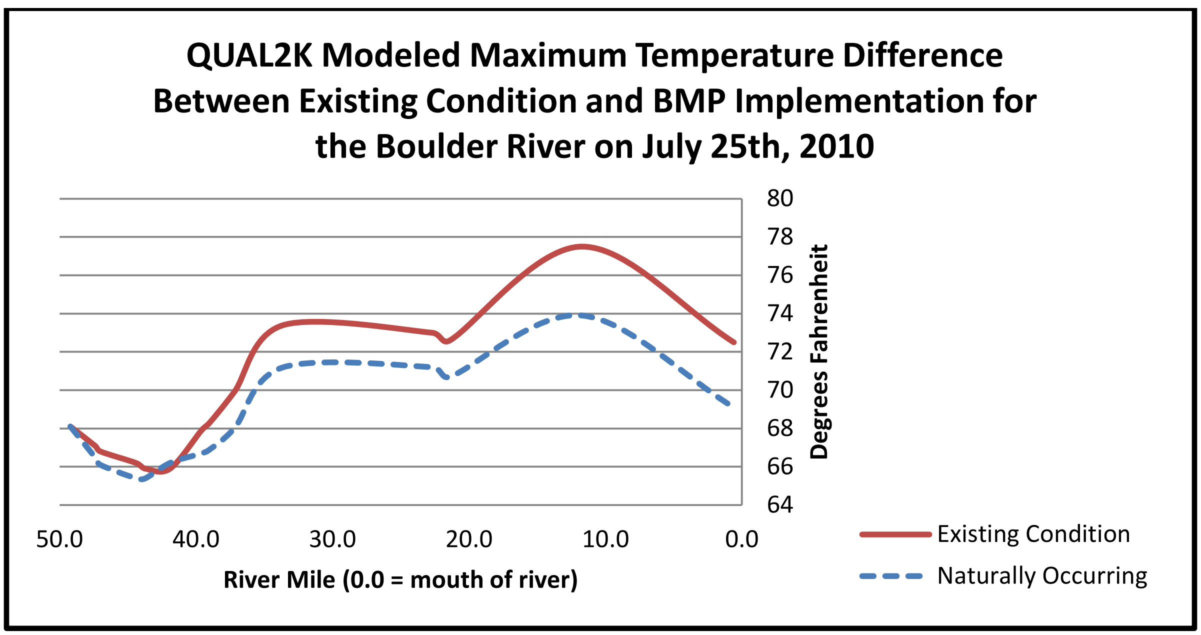

Figure 6-3. Comparison Between Modeled Existing Condition and BMP Implementation Outputs

6.5.2 Boulder River WWTP Point Source Discharge Assessment

The City of Boulder WWTP is the only MPDES-permitted point source discharging directly into the Boulder River. To evaluate the effects of temperature, an instantaneous thermal load (in kilocalories) can be calculated for the streamflow and WWTP discharge flows per **Equation 6-1** below. Note, this loading equates to the thermal load applicable to the water from the freezing point at 32^o F. The effects of the WWTP discharge can then be calculated by mixing the discharge water with the flow of the Boulder River under differing conditions.

Equation 6-1: Instantaneous Thermal Load (ITL) = (Δ-32)*Q*(15.6)

Where:
Δ = water temperature (F)
Q = streamflow or WWTP discharge
15.6 = conversion factor

Records from the DMR data associated with the Boulder WWTP indicate that on July 28, 2010, the effluent flow from the WWTP was 0.42 cfs at a temperature of 70.0^o F. The instantaneous thermal load entering the stream from the WWTP on this date was 250 kilocalories (kcal) per second (s).

Data from the 2010 field effort from a site just upstream of the WWTP (site BLDR-T02) recorded a flow of 61.8 cfs and an average water temperature of 53.4^o F (this data was recorded on August 4, which is the closest date to the DMR data available for this site). Applying **Equation 6-1**, the river's instantaneous thermal load associated with that flow and temperature is 20,650 kcal/s. The WWTP discharge added to the river at a flow of 61.8 cfs results in a flow of 62.22 cfs, with a thermal load of 20,900 kcal/s after mixing (20,650 kcal + 250 kcal). This calculates to temperature of 53.53^o F in the Boulder River after mixing, an increase of about 0.13^o F. This is well under the allowable 1^o F temperature increase per the standard.

When the allowable increase from the water quality standard could most likely be exceeded and lead to negative thermal effects from high temperatures is when the river is at 66.5^o F and only a 0.5^o F increase is allowed. This is because at lower river temperatures, a greater allowable increase up to 1^o F is allowed and also because at temperatures above 66.5^o F, the difference between the river and discharge temperatures is reduced. Using the above flow and discharge temperature conditions, the river's thermal load upstream is 33,261 kcal/s and 33,511 below the discharge. This equates to a temperature of 66.52^o F, an increase of less than 0.1^o F.

As previously discussed, 2010 was a higher-than-normal flow year for the Boulder River. Boulder River flows can often be as low as 13 cfs during low-flow conditions based on the 25th percentile results for the USGS gaging station above the town of Boulder. This information can be used as a typical worst-case scenario to evaluate the WWTP discharge effects when the river temperature is 66.5^o F and flowing at 13 cfs. The river's thermal load upstream would be 6,997 kcal/s at 13 cfs and 7,247 kcal/s downstream below the discharge after mixing, with a mixed flow of 13.42 cfs. This equates to a temperature of 66.6^o F after effluent mixing, which is an increase of 0.1^o F, well below the allowable increase of 0.5^o F.

Because of the limited data for effluent temperature, it would be good to know the maximum allowable effluent temperature under the above river flow conditions, a 0.42 cfs WWTP discharge, and a river temperature of 67^o F after mixing. Plugging these values into **Equation 6.1** produces a thermal load of 7327 kcal in the river, of which 6,997 kcal is the upstream thermal load before mixing. This equates to an allowable thermal increase of 330 kcal, which further equates to an allowable maximum WWTP discharge temperature of 82.4^o F.

Another scenario can be based on a WWTP effluent discharge increase up to 1 cfs using the upstream Boulder River flow of 13 cfs upstream at 66.5° F. The WWTP discharge thermal load would be 593 kcal/s, the downstream thermal load would be 7,590 kcal (6,997 kcal + 593 kcal), and the downstream flow would be 14 cfs after mixing. This resulting Boulder River temperature after mixing would then be 66.75° F, an increase of 0.25° F, which is still well below the allowable 0.5° F increase. This is a conservative estimate of potential WWTP effects on stream temperature since the design flow for the Boulder WWTP is about 0.4 cfs, significantly lower than the 1 cfs used for this scenario.

6.5.3 High Ore Creek Source Assessment

The effects of mining in the High Ore Creek watershed are well documented. Loss of riparian vegetation and the resultant over-widening of the stream channel account for the most obvious and significant influences on temperature. Recent efforts by the BLM and DEQ to restore channel morphology and establish healthy riparian vegetation throughout the watershed attest to the streams degraded past, but also signal that recovery of the watershed (at least from a temperature perspective) is well on its way. Review of available data, along with some limited field investigation illustrate that channel morphology is currently not likely to be an issue in most places, but that riparian vegetation necessary to provide shade is not yet at potential (although is on an improving trend as restoration work continues to progress). In addition, although cattle grazing throughout the watershed is frequently limited by riparian fencing, there still exist discrete locations where cattle do access the stream. These locations are often recognized by destabilized banks, overwidened stream channel, and limited riparian growth as a result of browse. Grazing management should be included as prescription for High Ore Creek temperature improvement such that future grazing practices limit the negative effects on the stream channel and riparian corridor, and restoration efforts of recent years are preserved.

6.6 Temperature TMDLs and Allocations

Total maximum daily loads (TMDLs) are a measure of the maximum load of a pollutant a particular waterbody can receive and still maintain water quality standards (**Section 4.0**). A TMDL is the sum of wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. A TMDL includes a margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. Allocations represent the distribution of allowable load applied to those factors that influence loading to the stream. In the case of temperature, thermal loading is assessed.

6.6.1. Boulder River and High Ore Creek Temperature TMDLs

Because of the dynamic temperature conditions throughout the course of a day, the temperature TMDL is the thermal load, at an instantaneous moment, associated with the stream temperature when in compliance with Montana's water quality standards. As stated earlier, the temperature standard for the Boulder River and High Ore Creek is defined as follows: For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature is 1° F, if the naturally occurring temperature is less than 66° F. Within the naturally occurring temperature range of 66° F to 66.5° F, the allowable increase cannot exceed 67° F. If the naturally occurring temperature is greater than 66.5° F, the maximum allowable increase is 0.5° F. Montana's temperature standard for B1 classified waters, relative to naturally occurring temperatures, is depicted in **Figure 6-4**.

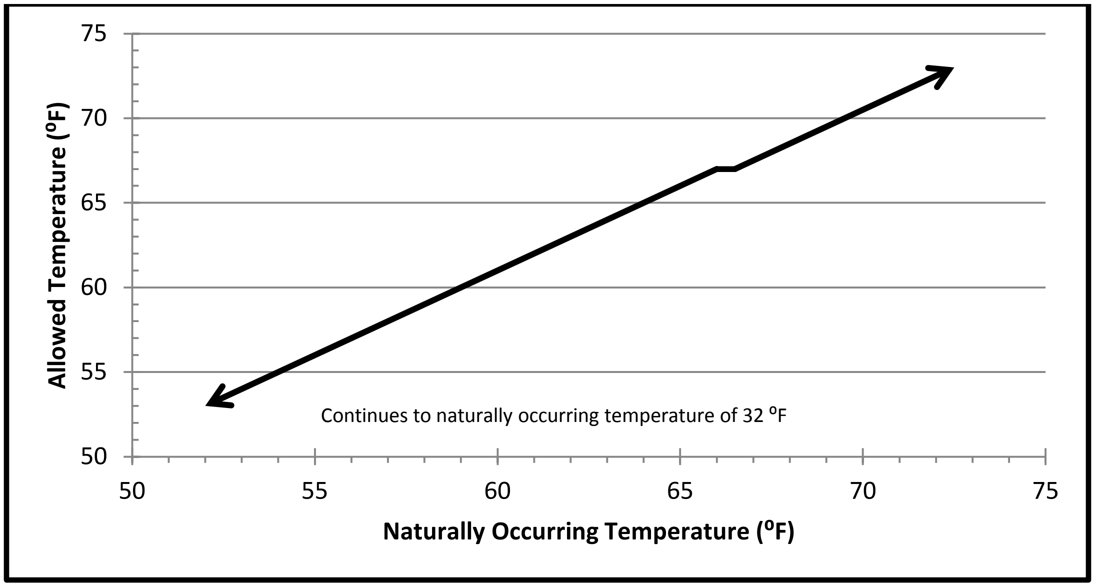

Figure 6-4. Instream Temperatures Allowed by Montana's B-1 Classification Temperature Standard

An instantaneous load is computed by the second and applied at all times. The allowed temperature can be calculated using Montana's B-1 classification standards (**Figure 6-4**) and using a modeled, measured, or estimated naturally occurring instantaneous temperature. The allowable instantaneous total maximum load (per second) at any location in the waterbody is provided by **Equation 6-2**. This equates to the kCal increase associated with the warming of the water from 32° F to the temperature that represents compliance with Montana's temperature standard, as determined from **Figure 6-4**.

Equation 6-2: TMDL = [(Δ+A)-32]*Q*(15.6)

Where:
Δ = naturally occurring water temperature (° F)
A = allowable increase above naturally occurring temperature (° F)
Q = streamflow (cfs)
15.6 = conversion factor
TMDL = allowable thermal load expressed as kilocalories per second above 32° F

The use of a load per second to define the temperature TMDL is appropriate to address the most sensitive summer afternoon timeframe when fish are most distressed by temperatures and when human-caused thermal loading would have the most effect. Providing thermal loads based upon an average daily temperature does not protect fish because diurnal shifts in temperature create average daily conditions. Streams with significant shade loss can be warmer than natural during the day and cooler than natural at night, resulting in circumstances that do not deviate from Montana's temperature standard when averaged over a daily timeframe. Evaluating impairment and expressing the TMDL using a short time step provides proper fishery use protection.

6.6.2 Temperature TMDL Allocations

While **Equation 6-2** provides a translation of allowable instantaneous temperature to an allowable instantaneous thermal load, the development of the TMDL allocations based on this variable thermal load does not readily translate to on-the-ground management.

Furthermore, the challenge in deriving a Total Maximum Daily Load for a parameter such as temperature is in defining the naturally occurring temperature at any given point during the day. In the case of the Boulder River, a model was used to investigate the likelihood of temperatures above the allowable limit described by the state standard. Although not a perfect representation of the complex interactions that occur in the watershed, the model has shown that human-caused activities have elevated temperatures. In addition, on-the-ground information tells us that not all reasonable land, soil, and water conservation practices (human activity under naturally occurring conditions) are currently being practiced in the watershed. Thus, in lieu of developing allocations based on quantified temperatures or thermal loads that apply under a specific set of conditions, we can express the TMDL and associated allocations through surrogate indicators of local conditions that would comply with the temperature standard. Therefore, the allocations necessary to achieve the TMDL are described using the restoration targets (**Section 6.4.4**). Linking achievement of these targets to land management activities where the application of all reasonable land, soil, and water conservation practices would achieve the state temperature standard.

6.6.2.1 Temperature Allocations for the Boulder River; City of Boulder to Cottonwood Creek (MT41E001_022) and Cottonwood Creek to the Mouth (MT41E001_030)

Thermal conditions affecting the Boulder River are complex and influenced by many inter-related factors throughout the river. Although all of these relationships have not been completely analyzed during the assessment of the Boulder River, field data and water quality modeling do indicate that temperatures in the Boulder River are influenced by human activity, that temperature increases are likely harmful to aquatic life during certain periods of the summer, and that improvements in vegetative canopy cover and increased flow will reduce water temperatures throughout most of the Boulder River, from the City of Boulder to the mouth.

The temperature TMDL allocations for the Boulder River are conveyed via surrogate allocations based on the temperature-related water quality targets described in **Section 6.4.4**. These surrogate TMDL allocations define conditions that will ensure compliance with Montana's temperature standard. The surrogate allocations applicable to the two lowest segments of the Boulder River are presented in **Table 6-2.** Note that the wasteload allocation for the City of Boulder WWTP is the allowable increase above the naturally occurring conditions per the temperature standard. Naturally occurring conditions will be achieved via meeting the nonpoint source load allocations. The maximum allowable WLA is variable at any given time based on discharge flow, river flows, and upstream river temperatures. Based on the analysis performed in **Section 6.5.2**, the Boulder WWTP currently satisfies the WLA.

Table 6-2. Temperature TMDL Allocations for the Boulder River from the City of Boulder to Cottonwood Creek (MT41E001_022) and from Cottonwood Creek to the Mouth (MT41E001_030)

Source Type	Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along the Boulder River	• In locations where current average effective shade is <22%, improve and maintain a minimum of 22% effective shade. • In locations where current average effective shade is $\geq$22%, maintain at or above current effective shade.

Table 6-2. Temperature TMDL Allocations for the Boulder River from the City of Boulder to Cottonwood Creek (MT41E001_022) and from Cottonwood Creek to the Mouth (MT41E001_030)

Source Type	Allocation
Land uses and practices that result in the overwidening of the stream channel such that widths are increased, depths are decreased, and thermal loading is accelerated	• Maintain average width-to-depth ratios of ≤30 throughout the mainstem of the Boulder River. Average width-to-depth ratios values to be evaluated according to data collected following DEQ site identification and longitudinal profile protocols.
Inefficient use or conveyance of water from the Boulder River for agricultural, residential, or urban use	No reduction in thermal buffering capacity from inefficient water conveyance or water use practices along the Boulder River (i.e. no unnecessary decreases in streamflow). This allocation essentially asks water users to identify their practices, determine if more efficient means are possible and practical given various economic and resource constraints, and applies those improvements wherever reasonable to maximize streamflow in the Boulder River. The model used in analysis for this TMDL presumed a 15% reduction in the volume of water withdrawals via water use efficiency improvement. The actual improvement potential will need to be determined by local land owners and resource professionals.
Boulder WWTP	• Discharge may not raise the water temperature by more than 1° F when river temperatures are at or below 66° F. • Discharge may not raise the water temperature to more than 67° F when river temperatures at the WWTP discharge are within 66.5° – 66° F. • Discharge may not raise the temperature more than 0.5° F when river temperatures at the WWTP discharge exceed 67° F.

6.6.2.2 Temperature Allocations for High Ore Creek (MT41E002_040)

Temperature impairment in High Ore Creek was not investigated using a water quality model. However, overwhelming evidence of historical human effects on the stream was used to justify the development of a TMDL for temperature. Past removal of riparian vegetation and alterations to the channel has undoubtedly had significant effects on thermal loading. Recent measures to improve riparian and channel health are apparent and may soon be adequate to meet the temperature allocations and targets developed within this document.

The temperature TMDL allocations for High Ore Creek are conveyed via surrogate allocations based on the temperature-related water quality targets described in **Section 6.4.4**. These surrogate TMDL allocations define conditions that will ensure compliance with Montana's temperature standard. The surrogate allocations are presented in **Table 6-3**.

Table 6-3. Temperature TMDL Allocations for High Ore Creek (MT41E002_040)

Source Type	Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along High Ore Creek	• In locations where current average effective shade is <70%, improve and maintain a minimum of 70% effective shade. • In locations where current average effective shade is ≥70%, maintain at or above current effective shade.
Land uses and practices that result in the overwidening of the stream channel such that widths are increased, depths are decreased, and thermal loading is accelerated	• Maintain average width-to-depth ratios of ≤13 in Rosgen A, B, G and E channels. • Maintain average width-to-depth of <18 in Rosgen C and F channels. Average width-to-depth ratios values to be evaluated according to data collected following DEQ site identification and longitudinal profile protocols.

6.6.3 Achieving Temperature Allocations

Improvement in both riparian health and channel morphology needs significant time before changes can be seen. DEQ does not expect these targets to be met in the short-term; however, changes in land management practices and a commitment to those practices would need to be implemented to start meeting goals for temperature in the Boulder River watershed. In addition, the targets and allocations presented represent the desired conditions that would be expected in most areas along a stream, but DEQ acknowledges that all sites may not be able to achieve them. For instance, because of the location of highways and the railroad, some areas of the Boulder River will never be able to meet the target width-to-depth ratios. Or, some riparian areas may not be physically capable of achieving the desired effective shade target due to naturally occurring conditions. The targets and allocations are not intended to be specific to every given point on the stream; the intent, rather, is to achieve these goals as a typical condition throughout the Boulder River or High Ore Creek watersheds. Note that some areas may also be able to achieve conditions greater than the target, and the best possible condition given all reasonable land, soil, and water conservation practices should be strived for in all circumstances.

6.7 Seasonality and Margin of Safety

All TMDL/Water Quality Restoration Planning documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream, and load allocations. TMDL development must also incorporate a margin of safety into the allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes, in detail, considerations of seasonality and a margin of safety in the temperature TMDL development process.

The margin of safety (MOS) is addressed in several ways as part of this document:

- MOS is implicit in each of the temperature TMDLs; they incorporate methods and assumptions that account for local conditions and assess outcomes under all reasonable land, soil, and water conservation practices, but do not ignore or prohibit current anthropogenic activity
- Montana’s water quality standards are applicable to any timeframe and any season. The temperature modeling analysis for the Boulder River investigated temperature conditions during the heat of the summer when the temperature standards are most likely to heat the stream the most.
- The assessment and subsequent allocation scenarios addressed streamflow influences that affect the streams dissipative and volumetric heat capacity.
- Compliance with targets and refinement of load and wasteload allocations are all based on an adaptive management approach (**Section 6.8**) that relies on future monitoring and assessment for updating planning and implementation efforts.

Seasonal considerations are significant for temperature. Obviously, with high temperatures being a primary limiting factor for salmonids, summer temperatures are a paramount concern. Therefore, focusing on summer thermal regime is an appropriate approach. Seasonality addresses the need to ensure year round beneficial-use support. Seasonality is addressed in this TMDL document as follows:

- Temperature monitoring occurred during the summer season, which is the warmest time of the year. Modeling simulated heat of the summer conditions when instream temperatures are most stressful to the fishery. The fishery is the most sensitive use in regard to thermal conditions.

Effective shade for both the Boulder River and High Ore Creek was based on the August solar path, which is during the typical hottest month of the year.
- Temperature targets, TMDL, load and wasteload allocations apply year round, but it is likely that exceedances occur mostly during summer conditions.
- Restoration approaches will help to stabilize stream temperatures year round.

6.8 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, source assessments, water quality models, loading calculations and other considerations are inherent when evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management approaches is a key component of ongoing TMDL implementation activities. Uncertainties, assumptions and considerations are applied throughout this document and point to the need for refining analyses when needed or living with the uncertainty when more effort is likely unnecessary to restore uses by easily identified sources.

The process of adaptive management is predicated on the premise that TMDLs, allocations and their supporting analyses are not static, but are processes which are subject to periodic modification and adjustment as new information and relationships are better understood. As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment which occurred for this document.

As part of the adaptive management approach, changes in land and water management that affect temperature should be tracked. As implementation of restoration projects which reduce thermal input or new sources that increase thermal loading arise, tracking should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

The TMDLs and allocations established in this section are meant to apply to recent conditions of natural background and natural disturbance. Under some periodic but extreme natural conditions, it may not be possible to satisfy all targets, loads, and allocations because of natural short term affects to temperature. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant longer term excess loading during recovery from significant natural events.

Any influencing factors that increase water temperatures, including global climate change, could impact thermally sensitive fish species in Montana. The assessments and technical analysis for the temperature TMDLs considered a worst case scenario reflective of current weather conditions, which inherently accounts for any global climate change to date. Allocations to future changes in global climate are outside the scope of this project but could be considered during the adaptive management process if necessary.

Uncertainties in environmental assessments should not paralyze, but should point to the need for flexibility in our understanding of complex systems and to adjust our current thinking and future analysis. Implementation and monitoring recommendations presented in **Sections 9.0** and **10.0** provide a basic framework for reducing uncertainty and further understanding these issues.

7.0 Nutrient TMDL Components

This section focuses on nutrients (nitrogen and phosphorus forms) as a cause of water quality impairment in the Boulder-Elkhorn TPA. It includes 1) a discussion on nutrient impairment of beneficial uses; 2) identification of the specific stream segments of concern; 3) currently available data on nutrient impairment assessment in the watershed, including target development and a comparison of existing water quality targets; 4) quantification of nutrient sources based on recent studies; and 5) identification of and justification for nutrient TMDLs and TMDL allocations.

7.1 Effects of Excess Nutrients on Beneficial Uses

Nitrogen and phosphorus are natural background chemical elements required for the healthy and stable functioning of aquatic ecosystems. Streams in particular are dynamic systems that depend on a balance of nutrients, which is affected by nutrient additions, consumption by autotrophic organisms, cycling of biologically fixed nitrogen and phosphorus into higher trophic levels, and cycling of organically fixed nutrients into inorganic forms with biological decomposition. Additions from natural landscape erosion, groundwater discharge, and instream biological decomposition maintain a balance between organic and inorganic nutrient forms. Human influences may alter nutrient cycling pathways, causing damage to biological stream function and water quality degradation.

Human activities can increase the biologically available supply of nitrogen and phosphorus. An overabundance of these nutrients in aquatic ecosystems accelerates the process known as eutrophication. Eutrophication is the enrichment of a waterbody, usually by nitrogen and phosphorus, leading to increased aquatic plant production (including algae). The increased aquatic plant or algal growth can reach nuisance levels and harm multiple beneficial uses of the waterbody. Respiration rates from nuisance algal can deplete the oxygen supply available for other aquatic organisms, potentially to levels that can kill fish and other forms of aquatic life. Nuisance algae can shift the macroinvertebrate community structure, which may affect fish that feed on macroinvertebrates (U.S. Environmental Protection Agency, 2010).Nuisance algae can also reduce water clarity, negatively affect waterbody aesthetics, and increase treatment costs of drinking water. Changes in water clarity, fish community structure, and aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al., 2009; Suplee et al., 2009).

Nuisance algae can pose health risks if ingested in drinking water (World Health Organization, 2003). It can also lead to blue-green algae blooms (Priscu, 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans. Excess nitrogen in the form of dissolved ammonia (which is typically associated with human sources) can be toxic to aquatic life, and excess nitrogen in the form of nitrates in drinking water can inhibit normal hemoglobin function in infants.

7.2 Stream Segments of Concern

A total of six waterbody segments in the Boulder-Elkhorn TPA appeared on the 2012 Montana 303(d) List for nutrient (phosphorus and/or nitrogen) impairments. Four of these are addressed via TMDL development within this portion of the document (**Table 7-1**): Bison Creek, Uncle Sam Gulch, Nursery Creek, and McCarty Creek. Cataract Creek and the North Fork of the Little Boulder River were also included on the 2012 303(d) List as impaired for nutrients. As noted in **Section 1, Table 1-1,** DEQ subsequently concluded that Cataract Creek and the North Fork of the Little Boulder River are not impaired for nutrients after collection and assessment of additional data.

Table 7-1. Nutrient Impaired Streams from the 2012 303(d) List Addressed via TMDL Development

Stream Segment	Waterbody ID	*Nutrient Pollutant Listing
BISON CREEK, headwaters to mouth (Boulder River)	MT41E002_070	**Nitrates
UNCLE SAM GULCH, headwaters to mouth (Cataract Creek)	MT41E002_010	**Nitrate
NURSERY CREEK, headwaters to mouth (Muskrat Creek-Boulder River)	MT41E002_130	**Nitrate+Nitrite; & Total Nitrogen
McCARTY CREEK, Headwater to mouth (Boulder River)	MT41E002_110	Total Phosphorus

* Since creation of the 2012 303(d) List, DEQ has reassessed all four streams identified in **Table 7-1**. **Section 7.4** provides a summary of the assessment results with updated nutrient impairment determinations.
** These three pollutant listings represent the same cause of impairment: Nitrate + Nitrite; generally referred to as $N0_3$+NO_2 throughout this document.

7.3 Information Sources

To assess nutrient conditions for TMDL development, DEQ compiled nutrient data and undertook additional monitoring. The following data sources represent the primary information used to characterize water quality for the four streams identified in **Table 7-1**.

1) DEQ TMDL Sampling. DEQ conducted water quality sampling from 2009 through 2010 to update impairment determinations and assist with the development of nutrient TMDLs. In 2009, water quality samples were collected and analyzed for nutrients through two events during the algal growing season (July–September). In 2010, sampling was conducted again through three events during the growing season. In 2011, follow-up sampling took place during two events during the growing season.

   Sample locations bracketed tributaries and changes in land-use type or management. In addition to water quality samples, algal samples were collected during growing season sampling in 2009, 2010, and 2011. Algae samples were analyzed for Chlorophyll-*a* concentration and ash free dry weight (AFDW) (**Figure 7-1**). AFDW is a measurement that captures living and dead algal biomass and is particularly helpful for streams where some or all of the algae are dead (because chlorophyll-*a* measures only living algae). Macroinvertebrate data were collected on some streams in 2010 to aid in nutrient impairment determinations.

2) DEQ Assessment Files. The files contain information used to make existing nutrient impairment determinations (i.e., water quality and algal data collected between 2009 and 2011).

Growing-season nutrient data used for impairment assessment purposes and TMDL development are included in **Appendix E**. This and other nutrient data from the watershed are publicly available through EPA's STORET water quality database and DEQ's EQuIS water quality database.

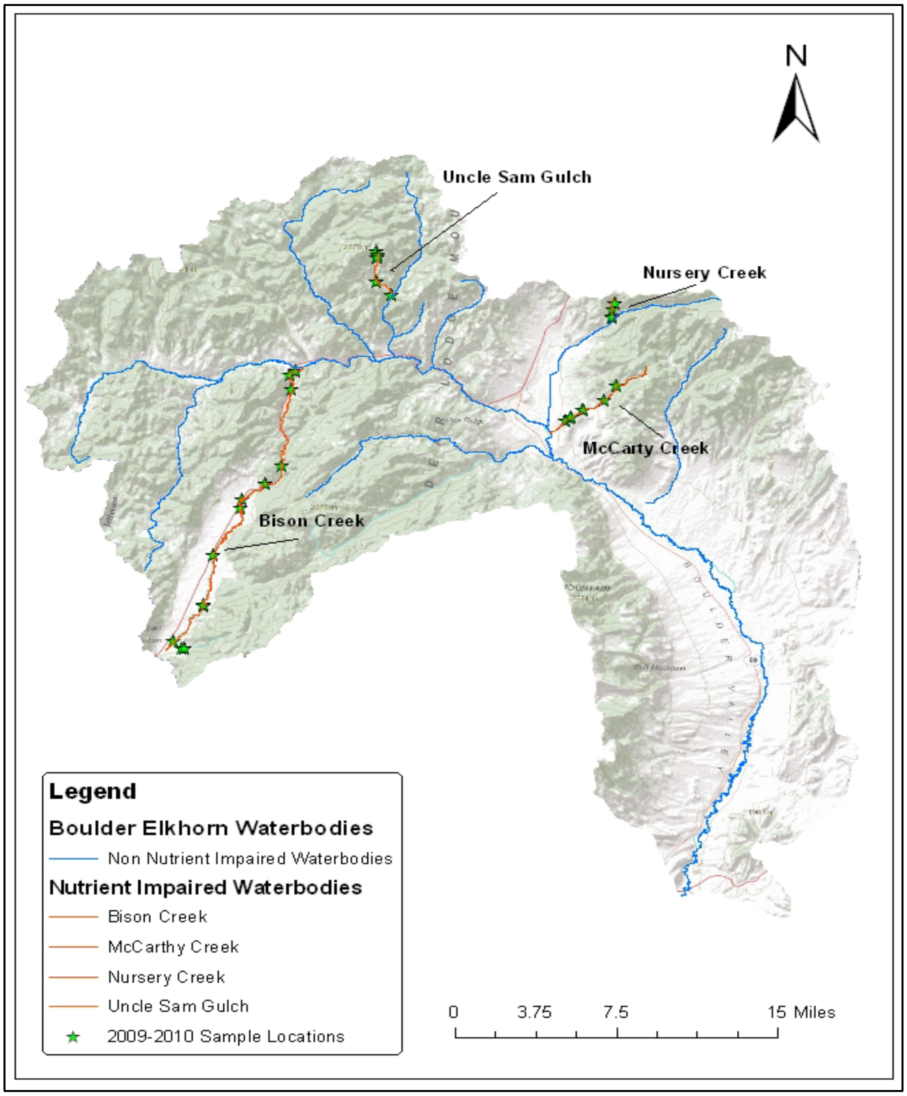

Figure 7-1. Nutrient impaired streams and associated sampling locations.

Additional sources of information used to develop TMDL components (**Section 4.0**) include the following:

- Chemical, physical, and biological water quality monitoring results collected during nutrient assessment work
- Streamflow data
- GIS data layers
- Outside agency and university websites and documentation
- Land-use information

The above information and water quality data are used to compare existing conditions to waterbody restoration goals (targets), to assess nutrient pollutant sources, and to help determine TMDL allocations.

7.4 Water Quality Targets

TMDL water quality targets are numeric indicator values used to evaluate whether water quality standards have been met. These are discussed further in **Section 4.0**. This section presents nutrient water quality targets and compares them with recently collected nutrient data in the Boulder-Elkhorn TPA following DEQ's draft assessment methodology (Suplee and Sada de Suplee, 2011). To be consistent with DEQ's draft assessment methodology, and because of improvements in analytical methods, only data from the past 10 years are included in the review of existing data.

7.4.1 Nutrient Water Quality Standards

Montana's water quality standards for nutrients (nitrogen and phosphorous) are narrative and are addressed via narrative criteria. Narrative criteria require state surface waters to be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: 1) produce conditions that create concentrations or combinations of material toxic or harmful to aquatic life, and 2) create conditions that produce undesirable aquatic life (ARM 17.30.637 (1) (d-e)). DEQ is currently developing numeric nutrient criteria that will be established at levels consistent with narrative criteria requirements. These draft numeric criteria are the basis for the nutrient TMDL targets and are consistent with EPA's guidance on TMDL development and federal regulations (40 CFR Section 122.44(d).

7.4.2 Nutrient Target Values

Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae chlorophyll-*a* concentrations (a form of aquatic life that at elevated concentrations is undesirable). The target concentrations for nitrogen and phosphorus are established at levels believed to protect aquatic life and prevent the harmful growth and proliferation of excess algae. Since 2002, Montana has conducted a number of studies in order to develop numeric criteria for nutrients (N and P forms). DEQ has developed draft numeric nutrient standards for total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* based on: 1) public surveys defining what level of algae was perceived as "undesirable" and 2) the outcome of nutrient stressor-response studies that determine nutrient concentrations that will maintain algal growth below undesirable and harmful levels 3) a literature review of stressor-response studies, and 4) a comparison of nutrient stressor-response thresholds to eco-regionally stratified reference data from Montana (Suplee et al., 2008).

Nutrient targets for TN, TP, and chlorophyll-*a* are based on DEQ's draft numeric nutrient criteria and are presented in **Table 7-2**. DEQ has determined that these values provide an appropriate numeric translation of the applicable narrative nutrient water quality standards based on existing water quality data in the Boulder-Elkhorn TPA and on the type of typical coldwater wadeable streams addressed by nutrient TMDL development in this document. These targets are appropriate for the three Level IV ecoregions that compose the Boulder-Elkhorn TPA (Boulder Batholith, Townsend Basin and Townsend-Horseshoe-London Sedimentary Hills). DEQs draft DEQ-12 circular incorporates the **Table 7-2** target values for TN and TP and is discussed further in **Appendix C. Table 7-2** also presents a nitrate plus nitrite (NO_3 +NO_2) target. This NO_3 +NO_2 target was derived from the same studies (Suplee et al., 2009), (Suplee et al., 2008) and associated linkage to reference condition, used to develop the draft numeric TN and TP criteria.

Although a numeric NO_3 +NO_2 standard that addresses aquatic life and aesthetics is not being pursued at this time, the target value in **Table 7-2** represents an appropriate translation of the narrative nutrient criteria for NO_3 +NO_2. There is currently a 10 mg/L numeric standard for NO_3 +NO_2 that addresses protection of human health. This human health value is 100 times the **Table 7-2** target. Application of the Table 7-2 target represents protection of all beneficial uses including human health.

In addition to the targets presented in **Table 7-2**, macroinvertebrate biometrics (Hilsenhoff Biotic Index (HBI) score) are also considered in further evaluation of impairment in situations where assessment conclusions are unclear after application of the **Table 7-2** targets. A HBI score of greater than 4.0 is then used to indicate nutrient impairment.

Because numeric nutrient chemistry is established to maintain algal levels below target chlorophyll-*a* and AFDW concentrations, target attainment applies and is evaluated during the summer growing season (July 1–September 30) when algal growth will most likely affect beneficial uses. Targets listed here have been established specifically for nutrient TMDL development in the Boulder-Elkhorn TPA and may or may not be applicable to streams in other TMDL project areas. See **Section 7.6** for the adaptive management strategy as it relates to nutrient water quality targets.

Table 7-2. Nutrient Targets for the Boulder-Elkhorn TPA

Parameter	Target Value
Nitrate + Nitrite (NO_3+NO_2)	≤ 0.100 mg/L
Total Nitrogen (TN)	≤ 0.300 mg/L
Total Phosphorus (TP)	≤ 0.030 mg/L
Chlorophyll-*a* (or Ash Free Dry Weight)	≤ 125 mg/m² (≤35 g AFDW/m^2)

7.4.3 Existing Conditions and Comparison with Targets

To evaluate whether nutrient targets have been met, the existing water quality conditions in each waterbody segment are compared to the water quality targets in **Table 7-2** using the methodology in the DEQ draft guidance document "2011 Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nitrogen and Phosphorus Levels" (Suplee and Sada de Suplee, 2011). This approach provides DEQ with updated impairment determinations used for TMDL development determinations. Because the original impairment listings are based on old data or were listed before developing the numeric criteria, each stream segment is evaluated for impairment from NO_3+NO_2, TN, and TP using data collected within the past 10 years. As previously noted, assessment results for Cataract Creek and the North Fork of the Little Boulder River showed no nutrient impairments, therefore, nutrient TMDLs are not developed of these two streams and assessment information is not included in this document.

The assessment methodology uses two statistical tests (Exact Binomial Test and the One-Sample Student's T-test for the Mean) to evaluate water quality data for compliance with established target values. In general, compliance with water quality targets is <u>not</u> attained when nutrient chemistry data shows a target exceedance rate of >20% (Exact Binomial Test), when mean water quality nutrient chemistry exceeds target values (Student T-test), or when a single chlorophyll-*a* exceeds benthic algal target concentrations (125 mg/m^2 or 35 g AFDW/m^2). Where water chemistry and algae data do not provide a clear determination of impairment, or where other limitations exist, macroinvertebrate biometrics (HBI >4.0) are considered in further evaluating compliance with nutrient targets. Lastly, inherent to any impairment determination is the existence of human sources of pollutant loading. Human-caused sources of nutrients must be present for a stream to be considered impaired. Note: to ensure a higher degree of certainty for removing an impairment determination and making any new impairment determination, the statistical tests are configured differently for an unlisted nutrient form than for a listed nutrient form. This can result in a different number of allowable exceedances for nutrients within a single stream segment. Such tests help assure that assessment reaches do not vacillate between listed and delisted status by the change in results from a single additional sample.

Simple summary statistics are provided in tables in each of the subsequent sections. These tables show the minimum, maximum , mean and 80th percentile values of the data sets for each perspective waterbody. Percentile is the value below which the percent of the observations may be found. For example, if a score is in the 80th percentile, then this score is higher than 80 percent of the other values. The 80th percentile is shown to give the reader an idea of where the majority of the data lies.

7.4.3.1 Bison Creek

Bison Creek appears on the 2012 303(d) List as impaired for nitrates (equivalent to NO_3+NO_2 for all practical purposes). Bison Creek originates in Elk Park Pass in the Boulder Mountains and flows north-northwest for about 17.5 miles to the confluence with the Boulder River. The upper reach of Bison Creek consists of the first 10.5 miles from the origin to where it enters Bison Canyon. The lower reach of Bison Creek extends from Bison Canyon approximately 7 miles to the confluence with the Boulder River.

Bison Creek was broken into two reaches based on stream channel morphology and land use in the two reaches. The upper reach of Bison Creek is a gently sloping sinuous stream channel on the ElK Park valley floor. The upper reach sees a significant amount of grazing along its banks. The lower reach of Bison Creek is a straighter channel, more confined, existing on a steeper grade. Many of the riparian areas along Bison Creek in this reach do not appear to be as impacted as significantly by cattle grazing as the upper reach within Elk Park, although horses and other livestock have had significant negative impacts on riparian health in places. While the upper and lower reaches of Bison Creek were delineated for assessment purposes only, they are considered one segment for TMDL development. Partial reasoning for this is to aid Monitoring and Assessment staff in establishing spatial independence for sample collection in the different stream types. This process also aid in identification of contributing nutrient sources. Impairment for nutrients is consistent in both reaches of Bison Creek. The above mentioned reach breakouts will not affect TMDL development.

The nutrient impairment for Bison Creek is based on a total of 27 nutrient samples, collected from 2009 to 2010 and analyzed for TN, NO_3+NO_2 and TP **(Table 7-3).** Assessment evaluation results **(Tables 7-4 and 7-5)** for both the upper and lower reaches of Bison Creek indicated no exceedances of target values for NO_3+NO_2, 11 and 7 exceedances (respectively) for TN, and 9 and 1 exceedances (respectively) for TP. Biological data include a total of 10 Chlorophyll-*a* and 6 AFDW samples. Chlorophyll-*a* did not exceed target criteria (>125 mg/m^2) in any sample. One AFDW sample was above the target criteria (> 35 g/m^2) in the lower reach. Macroinvertebrate data were also collected and provide additional indication of impairment. Macroinvertebrate data were above the target criteria (HBI>4) in all six samples.

The high target exceedance rates for TN and TP, the exceedance of the AFDW target, along with the macroinvertebrate results justify TN and TP impairment determinations for Bison Creek. The data indicates that TN is a problem along both reaches of Bison Creek and that TP may only be a problem in the upper reach of Bison Creek. The results do not indicate a NO_3+NO_2 impairment and therefore the "nitrates" cause of impairment will be removed from the 303(d) List and no NO_3+NO_2 TMDL will be developed for Bison Creek. It is worth noting that development of a TN TMDL would effectively address any potential nitrate problems in Bison Creek

Table 7-3. Nutrient Data Summary for Bison Creek

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2009-2010	27	0.01	0.02	0.013	0.016
TN, mg/L	2009-2010	27	0.06	2.70	0.46	0.42
TP, mg/L	2009-2010	27	0.012	0.237	0.042	0.038
Chlorophyll-*a*, mg/m^2	2009-2010	10	4.40	101.0	18.75	14.35
AFDW, g/m^2	2009-2010	6	13.61	41.10	21.53	22.87
Macroinvertebrate HBI	2009-2010	6	4.2	6.4	5.1	5.73

Table 7-4. Assessment Method Evaluation Results for the upper reach of Bison Creek

Nutrient Parameter	Sample Size	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	AFDW Test Results	Chl-*a* Test Result	Indicates Impairment?
Nitrate+Nitrite	14	0.100	0	PASS	PASS			NO
TN	14	0.300	11	FAIL	FAIL	PASS	PASS	YES
TP	14	0.030	9	FAIL	PASS			YES

Table 7-5. Assessment Method Evaluation Results for the lower reach of Bison Creek

Nutrient Parameter	Sample Size	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	AFDW Test Results	Chl-*a* Test Result	Indicates Impairment?
Nitrate+Nitrite	13	0.100	0	PASS	PASS			NO
TN	13	0.300	7	FAIL	FAIL	FAIL	PASS	YES
TP	13	0.030	1	PASS	PASS			NO

7.4.3.2 Uncle Sam Gulch

Uncle Sam Gulch appears on the 2012 303(d) List as impaired for nitrate-nitrogen (equivalent to NO_3+NO_2 for all practical purposes). Uncle Sam Gulch originates at the base of Rocker Peak, immediately above the Crystal Mine. The streamflows south through the abandoned mine workings, and its total length is about 2.6 miles from the origin to the confluence with Cataract Creek. Cataract Creek is a tributary to the Boulder River and joins the Boulder River immediately downstream of the town of Basin. The likely cause of the nutrient impairment in Uncle Sam Gulch is the historical mining practices in the area.

Summary nutrient data statistics and assessment method evaluation results for Uncle Sam Gulch are provided in **Tables 7-6 and 7-7,** respectively. In 2009 and 2010, a total of 12 high-flow and low-flow samples were collected in Uncle Sam Gulch for TN, TP and NO_3+NO_2. NO_3+NO_2, TN, or TP samples collected during this time did not exceed target values.

Chlorophyll-*a* data was collected from 2009 to 2011. No samples collected during this time exceeded the target criteria (>125 mg/m^2). AFDW data was collected from 2009 to 2011; one value exceeded target criteria (>35g/m^2). On July 9, 2010, AFDW was 122.30 g/m^2. Field data sheets were reviewed to rule out irregularities in collection methods or sample QC/QC. Laboratory methods and QA/QC criteria were reviewed to ensure the value was accurate. Nothing was found to indicate the result was an anomaly. Visual observations from follow-up sampling in 2011 (and associated photographs) documented excessive algal growth. As a result of the initial listing, elevated AFDW, and the observed excessive algal growth, DEQ will continue with TMDL development for NO_3+NO_2.

Table 7-6. Nutrient Data Summary for Uncle Sam Gulch

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2009-2010	12	0.005	0.06	0.13	0.005
TN, mg/L	2009-2010	12	0.027	0.180	0.093	0.144
TP, mg/L	2009-2010	12	0.004	0.011	0.008	0.010
Chlorophyll-*a*, mg/m^2	2009-2011	5	1.34	10.90	4.84	6.80
AFDW, g/m^2	2009-2010	4	4.47	122.30	36.12	54.90
Macroinvertebrate HBI	2009-2010	3	2.27	3.75	3.24	3.37

Table 7-7. Assessment Method Evaluation Results for Uncle Sam Gulch

Nutrient Parameter	Sample Size	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	AFDW Test results	Chl-*a* Test Result	Indicates Impairment?
Nitrate+Nitrite	12	0.100	0	PASS	PASS			NO
TN	12	0.300	0	PASS	PASS	FAIL	PASS	NO
TP	12	0.030	0	PASS	PASS			NO

7.4.3.3 Nursery Creek

Nursery Creek appears on the 2012 303(d) List as impaired for NO_3+NO_2 and Total Kjehldahl Nitrogen. Nursery Creek is located in the northeast corner of the Boulder-Elkhorn TPA on the western-most extent of the Elkhorn Mountains. It originates in the foothills of the Elkhorn Mountains east of the intersection of Forest Service Road 7072 and the Forest Service boundary. The total stream length is about 1.2 miles from the origin to the confluence with Muskrat Creek, a tributary to the Boulder River. Muskrat Creek joins the Boulder River downstream and to the southeast of the town of Boulder. The likely cause of the elevated nutrient values in Nursery Creek is the result of fires that burned the sub-basin in 2000 and current cattle grazing in the area.

Summary nutrient data statistics and assessment method evaluation results for Nursery Creek are provided in **Tables 7-8 and 7-9**. From 2009 through 2011, a total of 12 high-flow and low-flow samples were collected on Nursery Creek. In addition, 12 samples were collected for NO_3+NO_2, TN, and TP. All 12 samples for NO_3+NO_2 were above the target criteria; 10 for TN were above target criteria; and 5 for TN were above target criteria. These results can be seen in **Table 7-8**.

Chlorophyll-*a* and AFDW data were also collected in 2010, none of which exceeded the target criteria of >125 mg/m^2 and >35g/m^2, respectively. From 2004 to 2010, four macroinvertebrate samples were collected, and two were above the target criteria (>4 HBI). The NO_3+NO_2 and TN impairment cause will be addressed through TMDLs for both TN and NO_3+NO_2 for Nursery Creek. The assessment methodology results also justify TP as a parameter of impairment; therefore, a TMDL for TP will also be developed for Nursery Creek. This impairment determination and associated TMDL development is complicated by the fact that the DEQ considers fire and resulting temporary water quality impacts as a natural condition. Nevertheless, there is sufficient grazing within this small sub-basin to justify the need for nutrient TMDL development. This decision is further supported by recently noted visual grazing affects to bank erosion along Nursery Creek whereas it has been 9 to 11 years between the 2000 fire and the nutrient sampling used to evaluate impairment.

Table 7-8. Nutrient Data Summary for Nursery Creek

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2009-2011	12	0.20	0.31	0.26	0.30
TN, mg/L	2009-2011	12	0.24	0.45	0.35	0.40
TP, mg/L	2009-2011	12	0.01	0.06	0.03	0.04
Chlorophyll-*a*, mg/m^2	2010	3	5.55	13.14	8.73	10.88
AFDW, g/m^2	2010	2	2.42	4.0	3.21	3.68
Macroinvertebrate HBI	2004-2010	4	3.92	4.59	4.15	4.31

Table 7-9. Assessment Method Evaluation Results for Nursery Creek

Nutrient Parameter	Sample Size	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	AFDW Test Result	Chl-*a* Test Result	Indicates Impairment?
Nitrate+Nitrite	12	0.1	12	FAIL	FAIL	PASS	PASS	YES
TN	12	0.3	10	FAIL	FAIL			YES
TP	12	0.03	5	FAIL	PASS			YES

7.4.3.4 McCarty Creek

McCarty Creek appears on the 2012 303(d) List as impaired for TP. McCarty Creek is located in the central portion of the Boulder-Elkhorn TPA on the western-most extent of the Elkhorn Mountains. McCarty Creek originates in foothills of the Elkhorn Mountains east of the town of Boulder. The total stream length is about 6.3 miles from the origin to the confluence with Muskrat Creek, downstream and southeast of the town of Boulder. The likely cause of the nutrient impairment is the result of cattle grazing and potential water quality impacts from two irrigation water storage reservoirs.

Summary nutrient data statistics and assessment method evaluation results for McCarty Creek are provided in **Tables 7-10 and 7-11.** From 2009 through 2011, a total of 17 high-flow and low-flow samples were collected and analyzed for NO_3+NO_2, TN, and TP. Of the 17 samples NO_3+NO_2 and TN each exceeded the target criteria 3 times. All 17 TP samples were above target criteria. Chlorophyll-*a* and AFDW data were collected in 2010. No Chlorophyll-*a* samples exceeded the target criteria of >125 mg/m^2. One AFDW sample exceeded the criteria of >35g/m^2. In 2010, three macroinvertebrate samples were collected and all were above the target criteria (>4 HBI). As a result of this assessment and the 2012 303(d) listing, DEQ will develop a TMDL for TP for McCarty Creek.

Table 7-10. Nutrient Data Summary for McCarty Creek

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2009-2011	17	0.005	0.40	0.055	0.034
TN, mg/L	2009-2011	17	0.140	0.650	0.248	0.256
TP, mg/L	2009-2011	17	0.035	0.309	0.081	0.096
Chlorophyll-*a*, mg/m^2	2010	3	3.09	5.36	4.42	5.14
AFDW, g/m^2	2010	2	3.76	40.58	22.17	33.22
Macroinvertebrate HBI	2010	3	4.37	6.96	6.04	6.88

Table 7-11. Assessment Method Evaluation Results for McCarty Creek

<table>
<tr><th>Nutrient Parameter</th><th>Sample Size</th><th>Target Value (mg/l)</th><th>Target Exceedances</th><th>Binomial Test Result</th><th>T-test Result</th><th>AFDW Test Results</th><th>Chl-a Test Result</th><th>Indicates Impairment?</th></tr>
<tr><td>Nitrate+Nitrite</td><td>17</td><td>0.1</td><td>3</td><td>PASS</td><td>PASS</td><td rowspan="3">FAIL</td><td rowspan="3">PASS</td><td>NO</td></tr>
<tr><td>TN</td><td>17</td><td>0.3</td><td>3</td><td>PASS</td><td>PASS</td><td>NO</td></tr>
<tr><td>TP</td><td>17</td><td>0.03</td><td>17</td><td>FAIL</td><td>FAIL</td><td>YES</td></tr>
</table>

7.4.4 Nutrient TMDL Development Summary

Table 7-12 summarizes the 2012 nutrient 303(d) listings for the Boulder-Elkhorn TPA, along with the summary of the nutrient pollutants for which TMDLs will be prepared based on DEQ's updated assessment for these stream. The changes from the 2012 303(d) List are because of limited data collection at the time the waterbody segments were initially listed (2000 through 2006) and the improved assessment method along with significant data collection since original impairment determinations. The updated impairment determinations will be reflected in the 2014 Water Quality Integrated Report. Note that as Per **Table 7-12** a total of 7 separate nutrient TMDLs will be developed for the 4 stream segments.

Table 7-12. Summary of Nutrient TMDL Development Determinations

Stream Segment	Waterbody ID	2012 303 (d) Nutrient Impairment(s)	TMDLs Prepared
Bison Creek, headwaters to mouth (Boulder River)	MT41E002_070	Nitrates	TN, TP
Uncle Sam Gulch, headwaters to mouth (Cataract Creek)	MT41E002_010	Nitrate, Nitrogen	NO_3+NO_2
Nursery Creek, headwaters to mouth (Muskrat Creek – Boulder River)	MT41E002_130	Nitrate + Nitrite, Total Nitrogen	NO_3+NO_2,TN and TP
McCarty Creek, headwaters to mouth (Boulder River)	MT41E002_110	Total Phosphorous	TP

7.5 Nutrient Sources, TMDLs, and Allocations

As described in **Section 7.4**, exceedances in water quality targets in the Boulder-Elkhorn TPA include total phosphorous (TP) and nitrogen fractions, total nitrogen (TN), and nitrate plus nitrite (NO_3+NO_2). Data results show TN target exceedances on Bison Creek (upper and lower reaches), Nursery Creek, and McCarty Creek. Data results also show NO_3+NO_2 target exceedances in Nursery Creek and McCarty Creek. TP exceedances were documented in Bison Creek (upper and lower reaches), Nursery Creek, and McCarty Creek.

Assessment of existing nutrient sources is needed to develop load allocations to specific source categories. Water quality sampling conducted from 2009 through 2011 provides the most recent data for determining existing nutrient water quality conditions in the Boulder River watershed. DEQ collected more than numerous samples from 19 sites during a 3-year period with the objective of 1) evaluating attainment of water quality targets and 2) assessing load contributions from nutrient sources within the watershed. These investigations form the primary dataset from which existing water quality conditions were evaluated and from which nutrient loading estimates are derived. Data used to conduct analyses and loading estimations is publicly available at http://deq.mt.gov/wqinfo/datamgmt/MTEWQX.mcpx .

This section characterizes the type, magnitude, and distribution of sources contributing to nitrogen (TN and NO_3+NO_2) and phosphorous loading to impaired streams, provides loading estimates for significant source types, and establishes TMDLs and allocations to specific source categories. Source types include natural and human-caused sources and are described in further detail for each stream. Source characterization links nutrient sources, nutrient loading to streams, and water quality response, and supports the formulation of the load allocation portion of the TMDL. As described in **Section 7.4.2**, TP, TN, and NO_3+NO_2 water quality targets are applicable during the summer growing season (i.e., July 1–Sept 30). Consequently, source characterizations are focused mainly on sources and mechanisms that influence nutrient contributions during this period. Similarly, loading estimates and subsequent load allocations are established for the growing season time period and are based on observed water quality data and typical flow conditions.

Source characterization and assessment was conducted primarily using extensive monitoring data collected in the watershed from 2005 through 2008 to determine temporal and spatial patterns in nutrient concentrations, loads, and biological response.

Land uses in the Boulder River watershed are primarily agriculture, mining, and residential. None of the nutrient impaired waterbodies in the watershed has contributing sources from sites with permits from the Montana Pollutant Discharge Elimination System (MPDES). Nutrient sources therefore consist primarily of 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering; and 2) human-caused sources (agriculture, mining, residential). These sources may include a variety of discrete and diffuse pollutant inputs related to agricultural and mining runoff, septic and wastewater infiltration, and other sources inherent in developed areas.

The below sections describe the most significant natural and human-caused sources in more detail, provide nutrient loading estimates for natural and human-caused source categories to nutrient-impaired stream segments, and establish TMDLs and load allocations to specific source categories for the following streams:

- Bison Creek
- Uncle Sam Gulch
- Nursery Creek
- McCarty Creek

7.5.1 Bison Creek (MT41E002_070)

Bison Creek flows into the Boulder River below Bison Canyon. Area land use is primarily agricultural and light residential development in the upper reaches. Land use on the lower reaches is primarily light residential, light agriculture, and past mining practices. As determined in **Section 7.4.3.1** the upper and lower reaches exceeded nutrient water quality targets for TN, and TP. TMDLs will be developed for both TN and TP

7.5.1.1 Bison Creek Source Assessment

The source assessment for Bison Creek includes an evaluation of TN and TP concentration, flow and loading data along the whole length of Bison Creek. This is followed by quantification of natural background and the two most significant human-caused sources of nutrients. The two human-caused nutrient sources include all forms of agriculture (grazing, pasture, crops) and septic systems. While there are a few abandoned mines in the Elk Park area and elsewhere in the Bison Creek watershed, the majority of the mining in the Boulder-Elk Horn TPA has taken place to the north and east of Bison Creek.

DEQ GIS coverage shows 6 abandoned mines for the 17 miles of Bison Creek stream channel as compared to the approximately 30 abandoned mines in along the 2.7 mile stretch of Uncle Sam Gulch. Furthermore, there are no priority mine sites like those found within the headwaters of Uncle Sam Gulch in Bison Creek. There is no record or indication of cyanide ore processing, and no record or indication of significant or recent mining where explosives were used. Therefore, mining is not considered a significant source of elevated nutrient loading to Bison Creek.

Instream TN and TP concentrations exceeded water quality targets at a number of sampling locations during the growing season. However, the majority of the TN and TP exceedances were in the upper reaches of Bison Creek. **Table 7-13** and **Figure 7-2** present summary statistics of TN concentrations at sampling sites in Bison Creek. **Table 7-14** and **Figure 7-3** present summary statistics of TP concentrations at sampling sites in Bison Creek. Included in **Tables 7-13 and 7-14 and in Figures 7-2 and 7-3** are data from 4th of July Creek, a tributary to Bison Creek that contributes the majority of flow in Bison Creek's uppermost reach.

Table 7-13. Growing Season TN Summary Statistics for Sampling Sites on Bison Creek & 4th of July Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	Median	75th percentile
4th of July Creek	2	0.18	0.39	0.28	0.23	0.29	0.34
Upper Bison Creek	3	1.47	2.70	1.97	1.61	1.75	2.23
Upper Elk Park (Bison Creek)	4	0.31	0.48	0.38	0.33	0.38	0.44
Lower Elk Park (Bison Creek)	10	0.14	0.43	0.31	0.21	0.36	0.40
Bison Canyon (Bison Creek)	6	0.17	0.37	0.29	0.22	0.34	0.36
Upstream of Confluence*	3	0.20	0.30	0.23	0.205	0.21	0.26

*Confluence of Bison Creek and Boulder River

In descriptive statistics, box plots are a convenient way of graphically depicting groups of numerical data through their five number summaries. Box plots depict the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3) and the largest observation (sample maximum). Box plots display differences between the data without making any assumptions of the underlying statistical distribution of the data. The spacing between the different parts of the box help to indicate the degree of dispersion and skewness in data and identify outliers. Concentration data for a given parameter and waterbody combination are presented in this section via box plots.

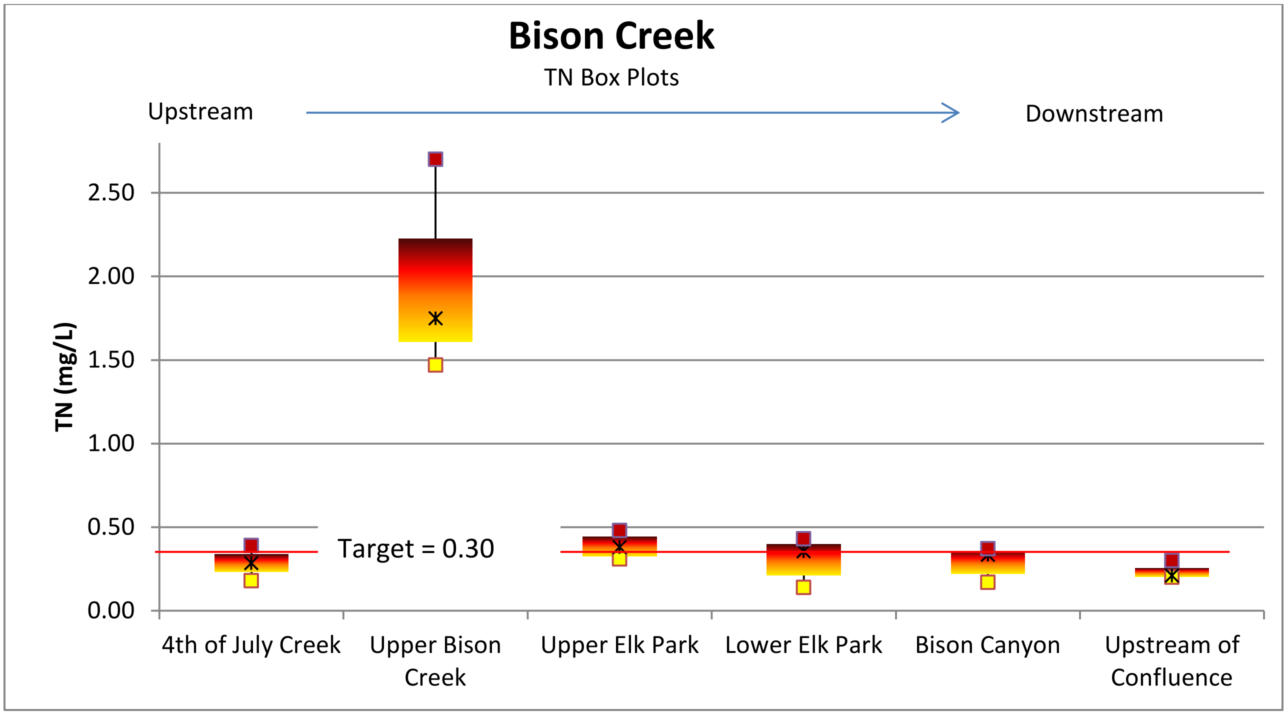

Figure 7-2. TN Box plots: Bison Creek

Table 7-14 Growing Season TP Summary Statistics for sampling sites on Bison Creek & 4th of July Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
4th of July Creek	2	0.012	0.029	0.021	0.016	0.021	0.025
Upper Bison Creek	3	0.012	0.23	0.180	0.029	0.138	0.171
Upper Elk Park (Bison Creek)	4	0.038	0.042	0.040	0.039	0.041	0.042
Lower Elk Park (Bison Creek)	10	0.02	0.034	0.027	0.023	0.026	0.031
Bison Canyon (Bison Creek)	6	0.023	0.030	0.026	0.0235	0.026	0.028
Upstream of Confluence*	3	0.025	0.030	0.027	0.0255	0.026	0.028

*Confluence of Bison Creek and Boulder River

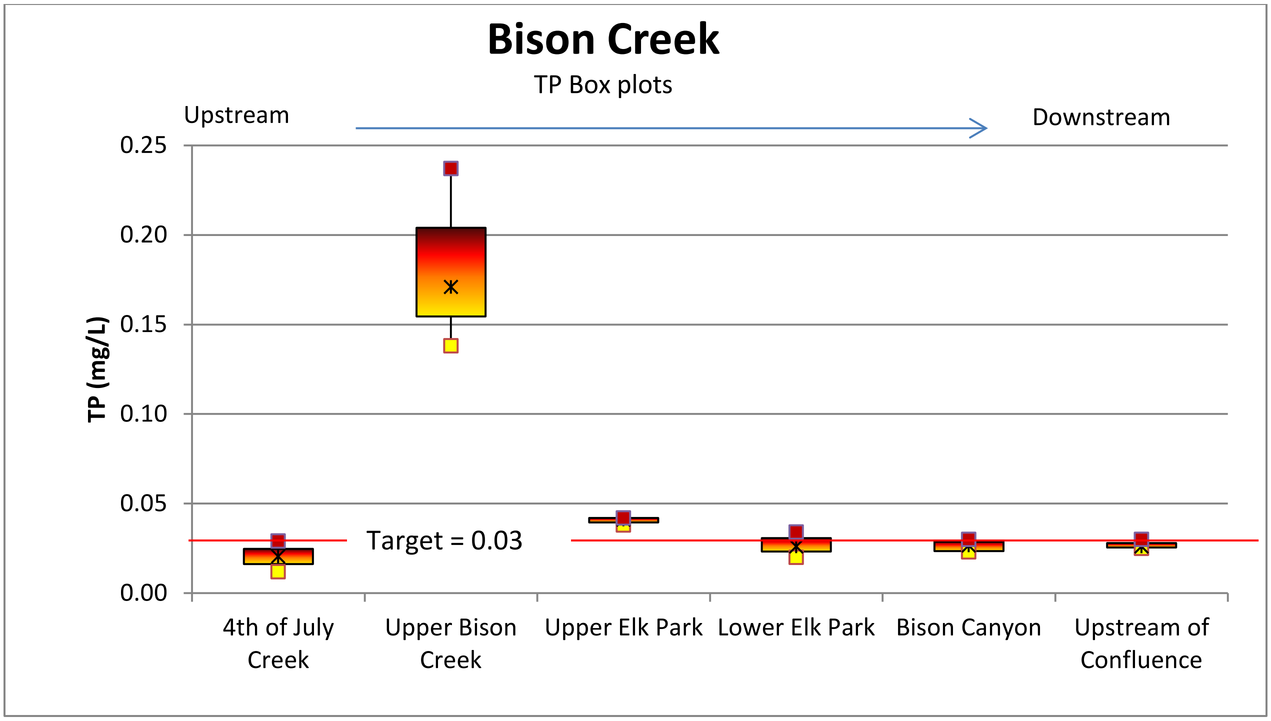

Figure 7-3. TP Box Plots: Bison Creek

Figures 7-2 and **7-3** shows very high concentrations and loads (respectively) of TN and TP in the upper Bison Creek area below 4th of July Creek, indicating a significant source of both TN and TP loading to Bison Creek in this area. Concentrations then decrease to values just above targets in upper Elk Park to mostly below targets in lower Elk Park for both TN and TP.

Average growing season TN loads increases from 2.9 lbs/day at 4th of July Creek to 32.2 lbs/day at Bison Canyon, an average increase of 29.3 lbs/day (90.9% increase). Average low-flow TP loads increased from 0.21 lb/day at 4th of July Creek to 2.99 lb/day . This is an average increase of 2.78 lbs/day (92.9% increase). TN and TP loads calculated from the 2009–2011 sampling events are depicted in **Figure 7-4 and 7-5**, respectively. Average TN and TP loads increase moving downstream from the headwaters of Bison Creek to the mouth, with relatively low loads originating from the 4th of July Creek portion of the headwaters. Note that there is a slight decrease in TN load from Bison Canyon to the confluence with the Boulder River. This loading decrease can be linked to the concentration decreases between these two sites shown in **Figure 7-2**. Cleaner tributary water could be contributing to the TN concentration decreases, although this would not cause a decrease in load, suggesting potential algal uptake. Note that the only AFDW value not meeting the target value is from this lower reach of Bison Creek.

The load increase in Bison Creek parallels the increase in flow in Bison Creek through Elk Park. The limited tributary network in this area suggests that much of this increased flow is via groundwater. The increased loading is likely due to TN and TP within the groundwater and/or could be linked to increased direct surface water nutrient input from cattle and other sources. Additionally the TN and TP concentrations **(Table 7-13)** tend to decrease along Bison Creek within Elk Park. This could be because the TN and TP concentrations in the ground and surface water entering Bison Creek within the Elk Park area are lower than (cleaner than) the concentrations in the uppermost sampled area of Bison Creek. The decreased concentrations could also indicate some algal nutrient uptake, although the relatively low Chlorophyll-*a* (live algae) results along Elk Park during the majority of sample events suggests that there was not significant algae uptake at the time of the sampling events. The AFDW values on the other hand are relatively high throughout the sampling events, suggesting increased algal uptake during some period of the growing season.

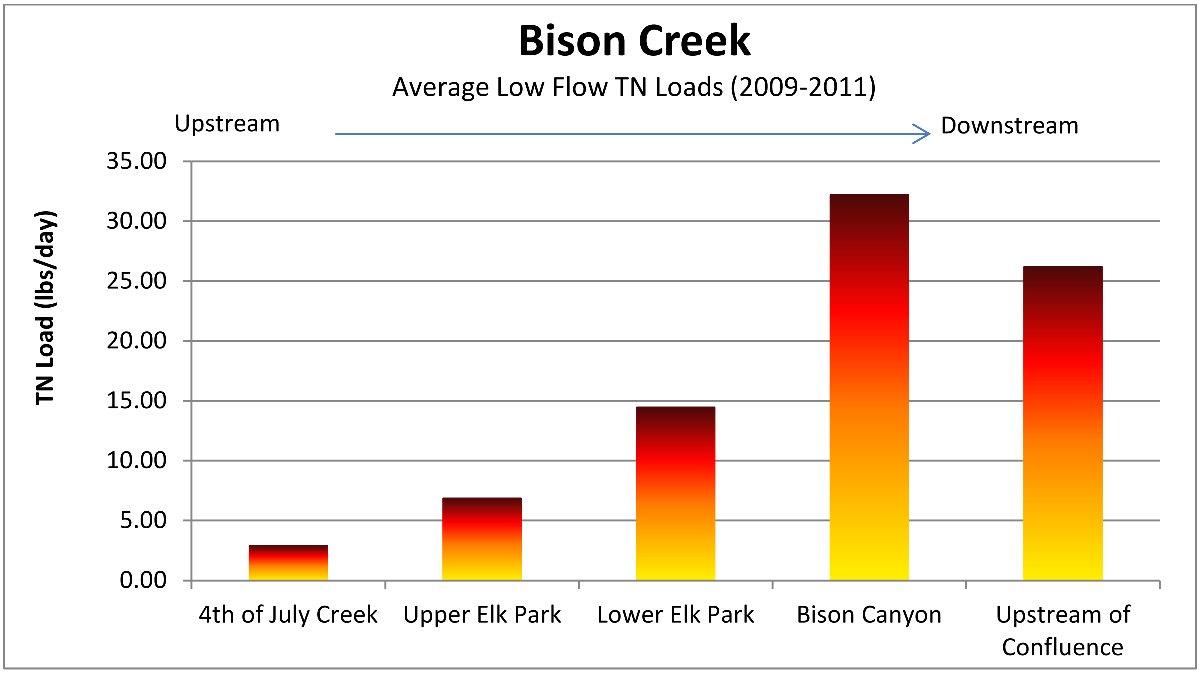

Figure 7-4. TN Load to Bison Creek

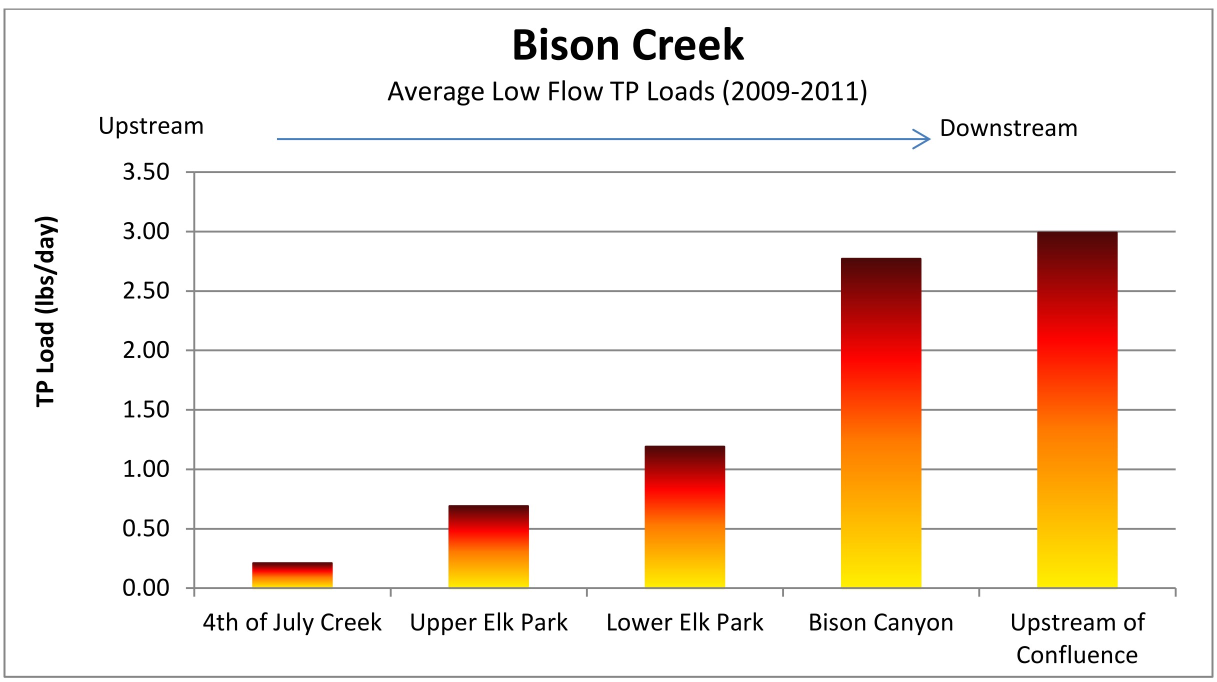

Figure 7-5. TP Load to Bison Creek

Natural Background Nutrient Loading
Natural background sources of nitrogen and phosphorus include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nutrients to the system. No background water quality data was available for Bison Creek.

Given this lack of data, and lack of data from reference streams in the Boulder –Elkhorn TPA, DEQ used values from reference streams in the Level III Middle Rockies Ecoregion. A study to develop nutrient criteria for streams in Montana (Suplee et al., 2007) provides the 25^{th}, 50^{th}, and 75^{th} percentile of the all-season reference dataset from wadeable streams to represent background conditions. This translates to background TN values ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25^{th}, 50^{th}, and 75^{th} percentiles, respectively. DEQ will use the 50^{th} percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median low-flow baseflow of 10.5 cfs, the average background TN load to the segment is calculated to be approximately 4.8 lbs/day. The Median low flow value was taken from flow measurements that coincided with water quality monitoring that is discussed in **Section 7.4.3**

Background TP values derived from Suplee (2007) for wadeable streams ranged from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25^{th}, 50^{th}, and 75^{th} percentiles, respectively. DEQ will use the 50^{th} percentile value (0.010mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TP of 0.010 mg/L and a median low-flow baseflow of 10.5 cfs, (see above comment) the average background TP load to the segment is calculated to be approximately 0.56 lb/day.

On-site Septic System Nutrient Loading
The number of on-site septic systems in the Bison Creek drainage is few, and they are located mainly in the stream reach above Bison Canyon. DEQ assessed TN and TP loads from on-site septic systems using a nutrient model designed to estimate TN and TP loading to streams from this source. The model estimates nutrients (nitrogen and phosphorus) discharged by septic systems that migrate to Bison Creek. Values are estimated using a simple spreadsheet assessment methodology. Results provide an estimation of the relative nutrient loads attributable to septic systems versus other nutrient sources. From the Lower Gallatin: "An outline of the MEANSS model may be found in Appendix A of Montana's DRAFT policy for nutrient trading at http://deq.mt.gov/wqinfo/NutrientWorkGroup/default.mcpx. " A brief summary is provided below.

The location of each septic system in the Bison Creek sub-basin is estimated by creating a GIS-coverage, plotting points in the centroid of every land parcel that is identified as "dwelling" or "mobile" in the cadastral database. GIS and STATSGO data is then used to estimate distances between each septic system to Bison Creek and to determine local soil types. The data derived from the GIS effort are then analyzed via an excel spreadsheet. Estimated attenuation factors are applied to each septic system based on the category it falls under, which in turn is based on soil type at the septic system, soil type at the nearby stream, and distance to the nearest stream. Only perennial streams were considered in the GIS assessment to determine proximity of septic systems to the surface waters because groundwater influence to surface water in non-perennial streams is likely low or non-existent. The assessment also assumes all septic systems are conventional treatment; it does not account for consideration of level 2 systems (systems with advanced treatment capability). This load estimate assumes that septic systems are functioning according to design specifications and does not assume septic failure or malfunction.

The results of this effort provide an estimated load of TN and TP entering Bison Creek.

Model results estimate that nitrogen and phosphorous will be reduced by 71.4% and 97.3%, respectively. That means that 28.6% and 2.7% (respectively) of the total load of on-site septic systems is expected to reach Bison Creek. These values are the average reductions from all systems in the area. Typical values for nitrogen and phosphorous loads from individual septic systems are 30.5 lbs/yr and 6.44 lbs/yr, respectively. The total number of on-site septic systems in the Bison Creek drainage is 74. This would yield nitrogen and phosphorous loads of 645.5 lbs/year and 12.8 lbs/year, respectively, or 1.77 lbs/day and 0.035 lb/day, respectively. Based on existing load values within Bison Creek (**Figures 7-4** and **7-5**) the septic contribution is estimated at about 5% of the total TN load to Bison Creek and about 1% to the total TP load to Bison Creek during summer baseflow conditions.

Agricultural Nutrient Loading

A large number of cattle are periodically grazed along Bison Creek within Elk Park, sometimes during the algal growing season. There is also a history of grazing within pastures adjacent to Bison Creek in the lower reaches above the Bear Creek tributary, as well as grazing along tributaries to Bison Creek. There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement and surface runoff and subsurface pathways, 2) delivery from grazed forest and rangeland during the growing season, 3) transport of fertilizer applied in late spring via overland flow and groundwater, 4) the increased mobility of nitrogen and phosphorus possibly caused by irrigation-related saturation of soils in pastures, (Green and Kauffman, 1989) and 5) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment discussion in **Section 5.4.3.2** and **5.5,** vegetation, habitat, and sedimentation in Bison Creek has been negatively affected from grazing. The impact of grazing and associated lack of riparian buffering likely has led to increased nutrient concentrations in Bison Creek.

7.5.1.2 Bison Creek Total Maximum Daily Loads: Total Nitrogen (TN) and Total Phosphorous (TP)

TN and TP Total Maximum Daily Loads are presented here for Bison Creek (MT41E002_070). The TMDLs (lbs/day) for TN and TP are the product of the water quality target values established in **Section 7.4** and streamflow. The TMDL loads for TN and TP apply during the summer growing season (July 1–Sept. 30). The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-6**). The TMDL for TP is based on an instream target value of 0.03 mg/L TN and streamflow (**Figure 7-7**).

TMDL calculations for TN and TP are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day

X= water quality target in mg/L (TN =0.30 mg/L or TP =0.030 mg/L)

Y= streamflow in cubic feet per second

5.393 = conversion factor

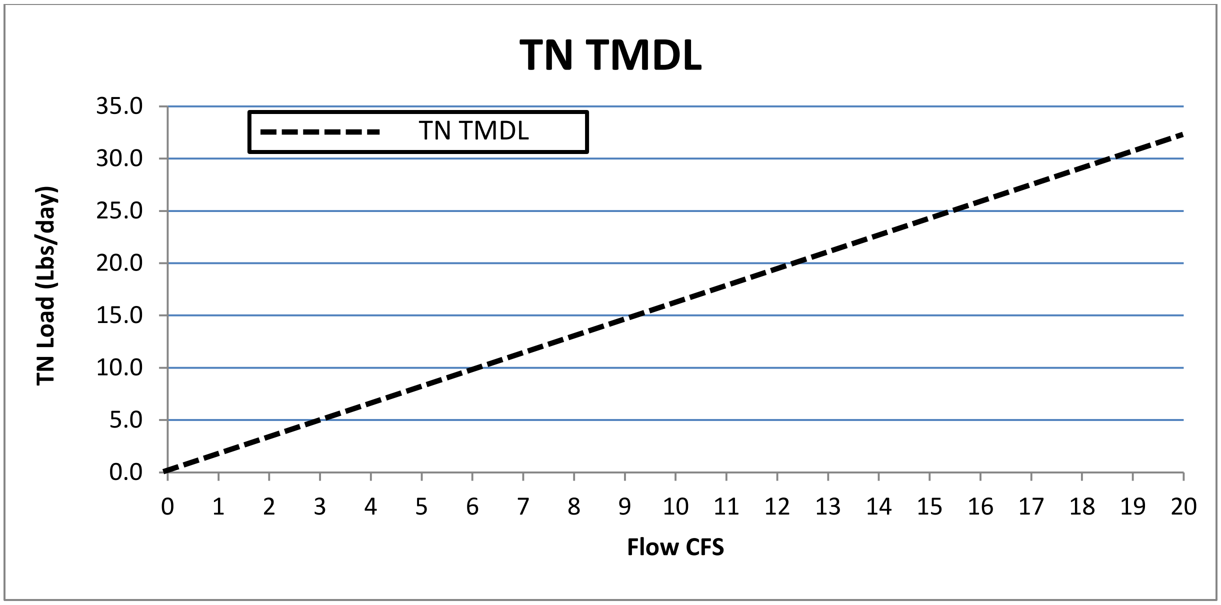

Figure 7-6. TMDL for TN as a function of flow: Bison Creek

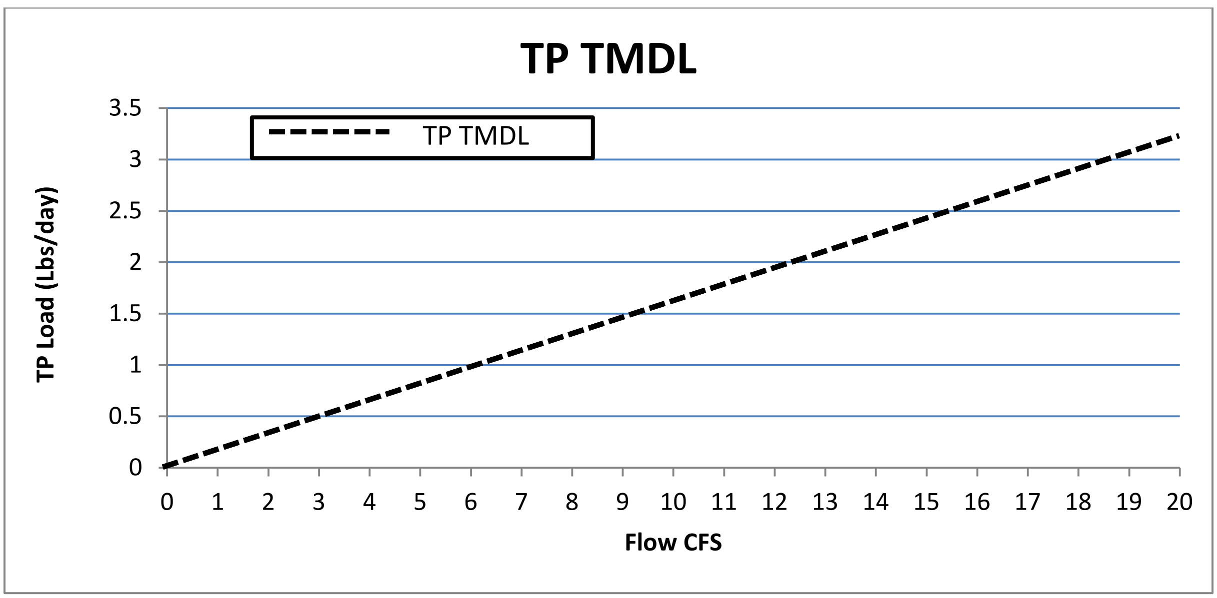

Figure 7-7. TMDL for TP as a function of flow: Bison Creek

7.5.1.3 Bison Creek Total Nitrogen (TN) and Total Phosphorus (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TN and TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. An implicit MOS, as defined within **Section 4.4**, is applied toward the Bison Creek TMDLs. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.1.3.1 Total Nitrogen (TN) Allocations

Bison Creek's TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TN nonpoint sources include natural background sources, agricultural, and septic systems.

Because of the relatively low percentage of nitrogen loading from septic systems (5%) along with the limited residential growth resulting in new septic systems within the watershed, the load allocations to on-site septic systems are included within the load allocation for agricultural land-use sources as a composite load allocation for human caused sources of nitrogen. Load allocations are therefore provided for 1) natural background sources and 2) cumulative on-site septic and agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TN in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{SEP+AG}$

LA_{NB} = Load Allocation to natural background sources

LA_{SEP+AG} = Load Allocation to the combination of agricultural land-use sources and on-site septic sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$LA_{NB} = (X) (Y) (5.393)$

LA_{NB}= TN load allocated to natural background sources

X= 0.085 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and On-site Septic Sources

The load allocation to the combination of agricultural sources and on-site septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{SEP+AG}= TMDL - LA_{NB}$

TN load allocations are summarized in **Table 7-15** and presented graphically in **Figure 7-8**.

Table 7-15. TN load allocation descriptions, Bison Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**$LA_{NB} = (X) (Y) (5.393)$**
Combination of Agricultural Land Use and On-site Septic	• domestic animal waste • loss of riparian and wetland vegetation along streambanks • on-site septic systems	**$LA_{SEP+AG} = TMDL - LA_{NB}$**

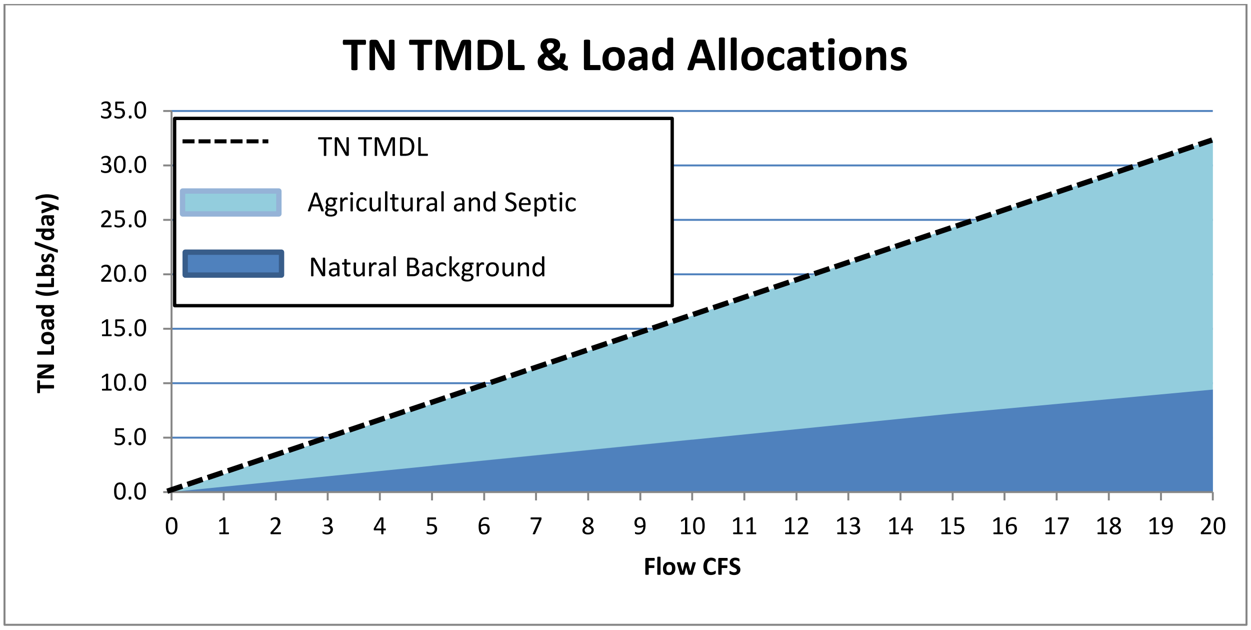

Figure 7-8. TMDL for TN and Load Allocations, Bison Creek

Table 7-16 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-16** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-16. Bison Creek TN Example load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	4.8	4.8	0%
Agricultural Land-Use Sources	27.5	12.1	59%
On-site Septic Systems	1.8		
	Total = 34.1**	**TMDL = 16.9**	**Total = 50%**

**based on a median growing season flow of 10.5 cfs*
*** based on 80th percentile of sample loads*

The example TMDL for TN in Bison Creek (presented in **Table 7-16**) is calculated to be 16.9 lbs/day. Existing TN loading to Bison Creek is estimated at 31.4 lbs/day, requiring a total load reduction of 50% in order to meet the TMDL for TN in Bison Creek. Load allocations and load reductions are specifically designated to the combination of 1) agricultural land use and 2) septic loads, which combined make up an estimated 85% of the TN load entering Bison Creek. Because septic loads associated with the allocation category are rather small (5%), and septic systems should have already have a minimum design/installation requirements that serves as the basic BMP, load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use, primarily grazing impacts along Bison Creek.

DEQ maintains that reducing loads from agricultural sources in Bison Creek and its tributaries will result in lower TN concentrations throughout Elk Park and at the mouth. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.1.3.2 Total Phosphorous (TP) Load Allocations

Bison Creek's TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations, and relevant TP nonpoint sources include natural background sources, agricultural, and septic systems.

Because of the relatively low percentage of phosphorus loading from septic systems (1%) along with the limited residential growth resulting in new septic systems within this watershed, the load allocations to on-site septic systems are included within the load allocation for agricultural land-use sources. Load allocations are therefore provided for 1) natural background sources and 2) cumulative on-site septic and agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TP in the watershed are equal to the sum of the individual load allocations as follows:

$$\mathbf{TMDL = LA_{NB} + LA_{SEP+AG}}$$

LA_{NB} = Load Allocation to natural background sources
LA_{SEP+AG} = Load Allocation to the combination of agricultural land use sources and on-site septic sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.010 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$$LA_{NB} = (X)\,(Y)\,(5.393)$$

LA_{NB}= TP load allocated to natural background sources
X= 0.010 mg/L natural background concentration
Y= median growing season streamflow in cubic feet per second
5.393 = conversion factor

Agriculture and On-site Septic Sources

The load allocation to the combination of agricultural sources and on-site septic sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$\mathbf{LA_{SEP+AG} = TMDL - LA_{NB}}$$

TP Load Allocation

TP load allocations are provided for Bison Creek (**Table 7-17**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the combination of agricultural land-use and on-site septic sources (LA_{AG+SEP}). TP load allocations are summarized in **Table 7-17** and presented graphically in **Figure 7-9**.

Table 7-17. TP load allocation descriptions, Bison Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Combination of Agricultural Land Use and On-site Septic	• vegetative decay from detritus derived from animal feeding operations • domestic animal waste • general refuse inherent in agricultural practices • on-site septic systems	**LA_{AG+SEP} = TMDL - LA_{NB}**

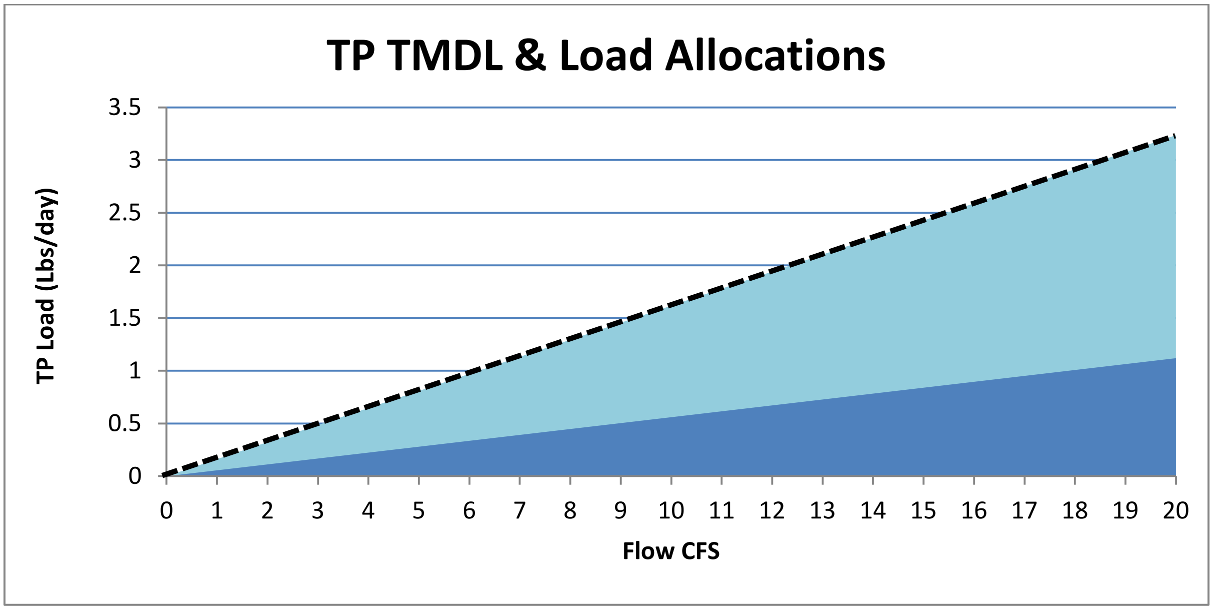

Figure 7-9. TMDL for TP and Load Allocations, Bison Creek

Table 7-18 provides an example TMDL and example allocations for a typical summer baseflow condition. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-18** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-18. Bison Creek Example TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.57	0.57	0%
Agricultural Land Use Sources	2.16	1.13	48.5%
On-site Septic Systems	0.035		
	Total = 2.77**	**TMDL = 1.7**	**Total = 39%**

**based on a median growing season flow of 10.5 cfs*
*** based on 80th percentile of sample loads*

The example TMDL for TP in Bison Creek is calculated to be 1.7 lbs/day. Existing TP loading to Bison Creek is estimated at 2.77 lbs/day, requiring a total load reduction of 39% in order to meet the TMDL for TP in Bison Creek. Load allocations and load reductions are specifically designated to the combination of 1) agricultural land use and 2) septic loads, which combined make up an estimated 79% of the TP load entering Bison Creek. Because septic loads associated with the allocation category are rather small (1.3%), and septic systems should already have a minimum design/installation requirements that serves as the basic BMP, load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use, primarily grazing impacts along Bison Creek.

DEQ maintains that reducing loads from agricultural sources in Bison Creek and its tributaries will result in lower TP concentrations throughout Elk Park and at the mouth. Reducing loads of this nature will mitigate elevated TP loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.2 Uncle Sam Gulch (MT41E002_010)

Uncle Sam Gulch originates in a saddle between Rocker Peak and Jack Mountain. Uncle Sam Gulch flows into Cataract Creek approximately 4 miles upstream from the confluence with the Boulder River. Land use along Uncle Sam Gulch consists primarily of historical mining in the upper segment and general silvicultural activities throughout the basin. As determined in **Section 7.4.3.2,** Uncle Sam Gulch did not exceed nutrient water quality targets for NO_3+NO_2, TN, and TP. However, one AFDW sample exceeded target criteria (>35 g/m^2). AFDW measured on July 9, 2010, had a result of 122.30 g/m^2. During DEQ sampling efforts, field staff observed and documented excessive algal growth in the upper segments of Uncle Sam Gulch. As a result of the existing NO_3+NO_2 impairment cause status (**Table 7-1**), elevated AFDW, the potential for nitrate loading form the use of explosives during past mining, and visual assessment, DEQ has chosen to continue with TMDL development for NO_3+NO_2, and a TMDL is presented here.

Complicating estimation of NO_3+NO_2, TN, and TP loads in Uncle Sam Gulch is instream assimilation and retention of these nutrient loads by algae. High algal densities through the reach indicate that some NO_3+NO_2, TN, and TP load is being taken up by algal growth and converted to biomass. This suggests that actual loads may be greater than loads measured instream.

7.5.2.1 Uncle Sam Gulch Source Assessment

The source assessment for Uncle Sam Gulch includes the evaluation of NO_3+NO_2 and TN concentrations as well as flow and loading data along the whole length of Uncle Sam Gulch. This is followed by the quantification of natural background and the most significant human caused sources of nutrients. The human caused nutrient sources in Uncle Sam Gulch are most likely the result of historical mining practices at the Crystal Mine.

DEQ sampled water quality on Uncle Sam Gulch during the low-flow summer seasons of 2009 and 2010. Samples were analyzed for TN and NO_3+NO_2. The data set for NO_3+NO_2 was significantly limited, as the majority of the analytical results were non-detect. For the purpose of data analysis a value of 0.005 mg/L was used where data were reported as non-detect. All NO_3+NO_2 concentrations were below target values. **Table 7-19** and **Figure 7-10** present summary statistics of NO_3+NO_2 concentrations at sampling sites in Uncle Sam Gulch.

Table 7-19. Growing Season NO_3 + NO_2 Summary Statistics for sampling sites on Uncle Sam Gulch (units in mg/L)

Site	n	min	max	mean	25^{th} percentile	median	75^{th} percentile
Headwaters	3	0.005	0.04	0.017	0.005	0.005	0.225
Below Mine	4	0.005	0.06	0.019	0.005	0.005	0.005
Mouth	5	0.005	0.005	0.005	0.005	0.005	0.005

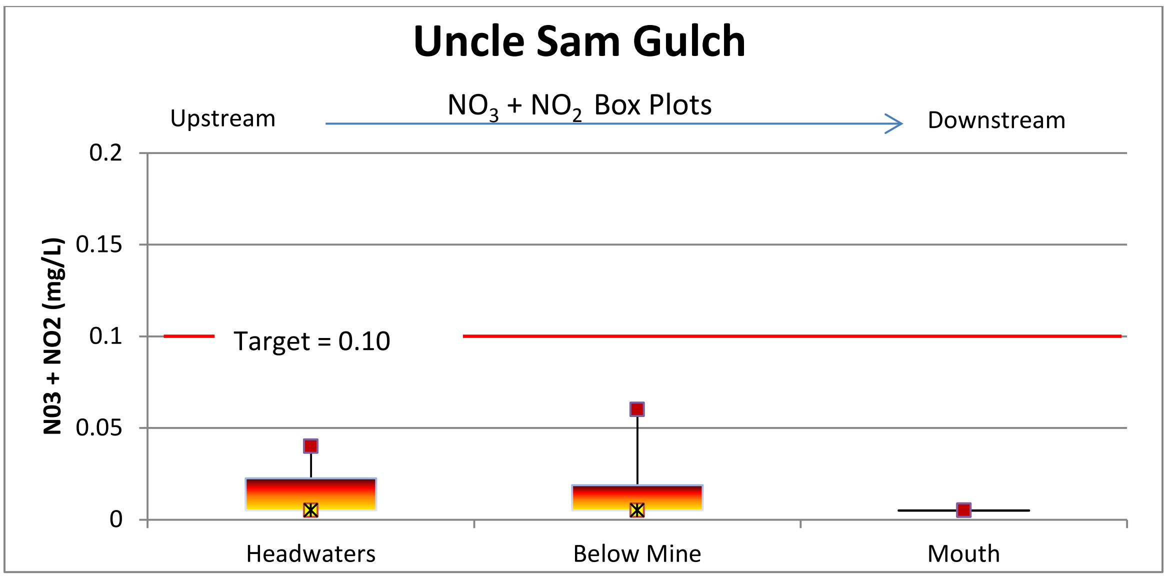

Figure 7-10. NO_2 + NO_3 Box plots: Uncle Sam Gulch

Natural background Nutrient loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. DEQ did not sample the origin of Uncle Sam Gulch. Given the historical disturbances in the area it is not clear whether or not the headwaters sample location is under the influence of previous mining activities. Consequently, no certain background water quality data was collected for Uncle Sam Gulch Creek.

Given the lack of data in Uncle Sam Gulch and lack of data in the Boulder-Elkhorn TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion for background concentrations.

Background NO_3+NO_2 values derived from Suplee (Suplee et al., 2007) for wadeable streams ranged from 0.005 mg/L, 0.020 mg/L , and 0.040 mg/L at the 25^{th}, 50^{th}, and 75^{th} percentiles, respectively. DEQ will use the 50^{th} percentile value (0.020mg/L) as it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration of 0.020 mg/L NO_3+NO_2 and a median low-flow baseflow of 1.3 cfs, the average background NO_3+NO_2 load to the segment is calculated to be approximately 0.14 lb/day. The Median low flow value was taken from flow measurements that coincided with water quality monitoring that is discussed in **Section 7.4.3**

Historical Mining Nutrient Loading

Mining within the Basin Mining District began in the mid- to late 1800s and continued sporadically into the 1960s. Early placer mining activities concentrated on Basin and Cataract Creeks. Lode mining followed in the 1870s with the Crystal Mine in Uncle Sam Gulch(CH2MHill, 2011). Miners primarily sought gold and silver. The Crystal Mine site covers approximately 22 disturbed acres. Site disturbances include an east–west trending linear trench feature, waste rock piles, two lined settling ponds built over a waste rock dump, and mine adits, all within close proximity (10's to 100's of feet) of Uncle Sam Gulch. In some cases waste rock dumps and their associated erosion are directly contributing to Uncle Sam Gulch.

Surface water quality can be degraded by releases of contaminants from mine waste material or from co-mingling with acid mine drainage from mine adits. Concentration of contaminants depends on the mechanism of chemical release, streamflow, and water chemistry. Degradation of surface water quality can be more severe during low-flow stream condition if the release of contaminants into the stream from an adit, for instance, remains constant. High flow events such as spring runoff or storm events can erode waste rock material into nearby streams where it contributes to water quality degradation.

Historical water quality reporting in the area of Uncle Sam Gulch at the Crystal Mine indicated water in Uncle Sam Gulch was degraded more significantly by the Crystal Mine than by any other influence down to its confluence with Cataract Creek (Martin, 1992).

Nitrates may be present in mine discharge water as a result of 1) residuals from ammonium nitrate and fuel oil (ANFO) used in blasting, 2) microbial mediates cyanide degradation, 3) leaching of ANFO contamination from waste rock or from rock with natural background nitrate, and 4) residuals from fertilizer used in reclamation (Environmental Protection Agency,1996). Some nitrate may be the result of nitric acid commonly used in the gold recovery process.

Nitrate pollution is likely not a result of ANFO, considering the time that has lapsed since these chemicals were used in the mining process. However, given the presence of large amounts of disturbed areas, and acid mine drainage from adits, nitrate pollution may be attributable nitrate leaching from waste rock or to the breakdown of cyanide from leaching. Nitrate polluted groundwater in the area is another possible source of nitrates. Depending on the hydrogeologic flow regime, groundwater affected by historical mining activities may be upwelling in the area and contributing to excessive nitrates in Uncle Sam Gulch.

DEQ is unaware of any other potential nutrient sources in Uncle Sam Gulch that would cause or contribute to an exceedance of water quality targets.

7.5.2.2 Uncle Sam Gulch Total Maximum Daily Loads: Nitrate plus Nitrite (NO_3 + NO_2)

As established in **Section 7.4** TMDLs for NO_3+NO_2 are presented here for Uncle Sam Gulch (MT41E002_010). The TMDLs (lbs/day) for NO_3+NO_2 are calculated using the water quality target values established in **Section 7.4** and applied during the summer season (July 1–Sept. 30). The TMDL for

NO_3+NO_2 is based on an instream target value of 0.10 mg/L NO_3+NO_2 multiplied by the streamflow (**Figure 7-11**).

TMDL calculations for NO_3+NO_2 are based on the following formula:

TMDL = (X) (Y) (5.393)
TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (NO_3+NO_2 =0.10 mg)
Y= streamflow in cubic feet per second
5.393 = conversion factor

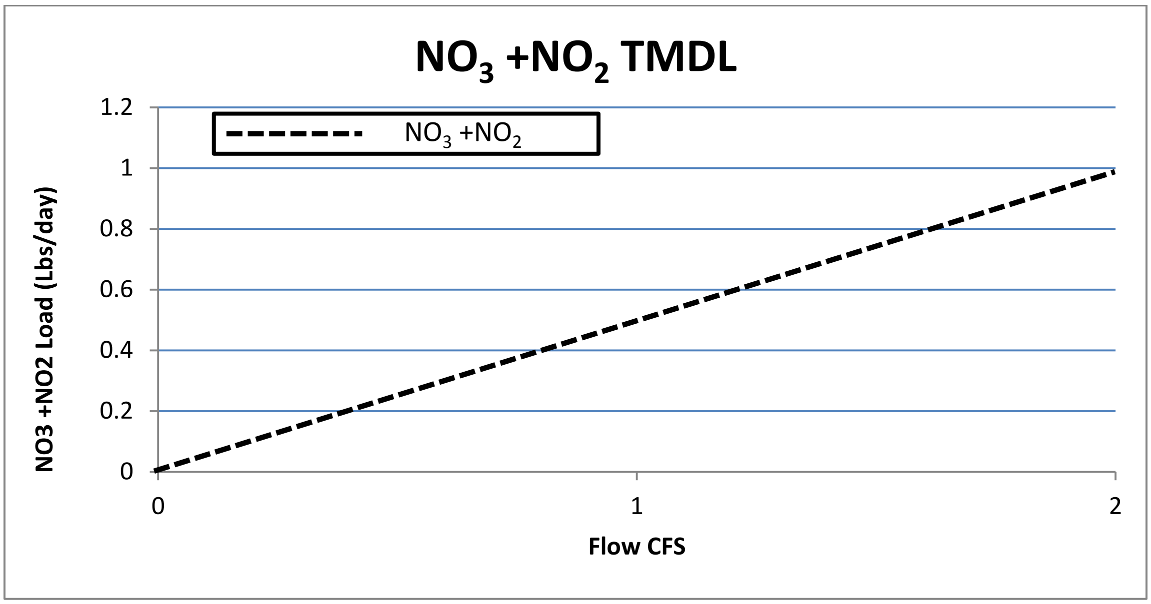

Figure 7-11. TMDL for NO_3+NO_2 as a function of flow: Uncle Sam Gulch

7.5.2.3 Uncle Sam Gulch Nitrate plus Nitrite (NO_2 + NO_3) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) NO_3+NO_2 sources. A TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. An implicit MOS is defined within **Section 4.4**, is applied toward the Uncle Sam Gulch TMDL. In addition to pollutant load allocations, a TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.2.3.1 Nitrate plus Nitrite (NO_2 + NO_3) Allocation

For Uncle Sam Gulch the TMDL for NO_3+NO_2 comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to Uncle Sam Gulch that would require wasteload allocations, and relevant NO_3+NO_2 nonpoint sources include natural background sources and historical mining activities. Load allocations are therefore provided for 1) natural background sources and 2) historical mining sources. In the absence of individual WLAs and an explicit MOS, the TMDL for NO_3+NO_2 in the watershed is equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + LA_{Mine}
LA_{NB} = Load Allocation to natural background sources

LA_{Mine} = Load Allocation to historical mining sources

Natural Background Source

Load allocations for natural background sources are based on a natural background NO_3+NO_2 concentration of 0.020 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= NO_3+NO_2 load allocated to natural background sources
X= 0.020 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Historical Mining Source

The load allocation to the historical mining sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

LA_{Mine}= TMDL - LA_{NB}

NO_3+NO_2 Load Allocation

NO_3+NO_2 load allocations (**Table 7-20**) are provided for Uncle Sam Gulch and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) historical mining (LA_{Mine}). **Figure 7-12** provides a graphical depiction of the TMDL and allocations**.**

Table 7-20. NO_3+NO_2 load allocation descriptions, Uncle Sam Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Historical Mining	• Cyanide breakdown from leaching • Runoff from exposed rock with containing natural background nitrate • Residual chemicals left over from mining practices (primarily from use of explosives)	**LA_{Mine} = TMDL - LA_{NB}**

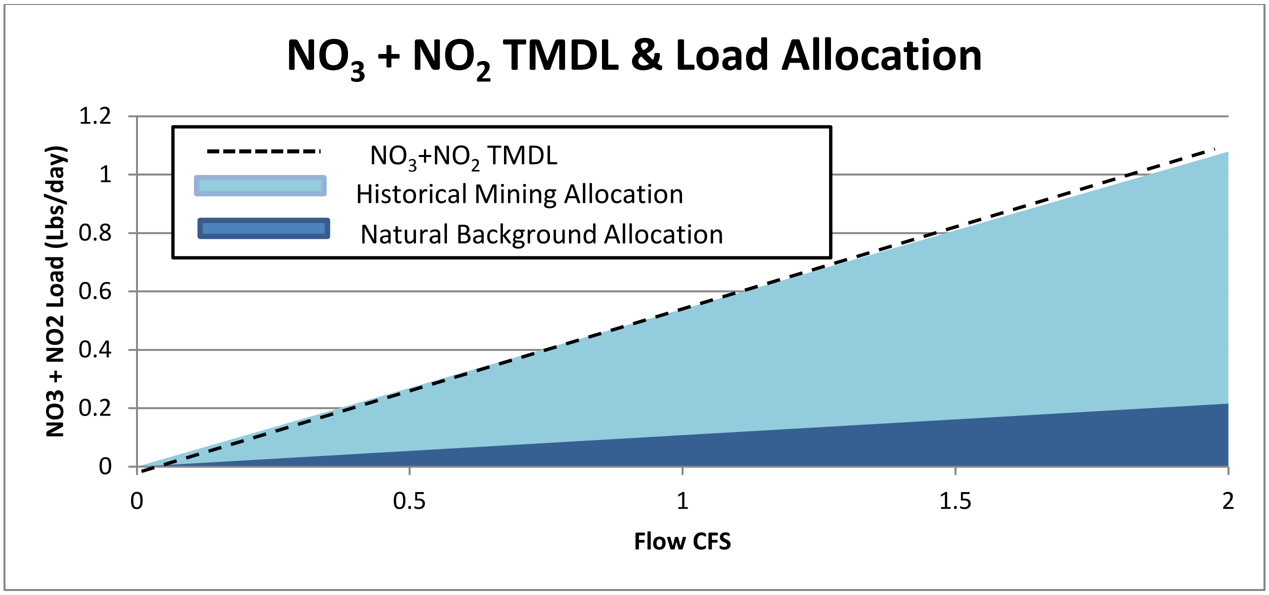

Figure 7-12. TMDL for NO_3+NO_2 and Load Allocations, Uncle Sam Gulch

Because measured instream NO_3+NO_2 concentrations are within natural background conditions and below target concentrations, water quality data precludes calculating NO_3+NO_2 load reductions to specific source categories using empirical data. As such no existing loads are provided in **Table 7-21.** Load allocations, however, incorporate allowed loading from general source categories and establish allowable NO_3+NO_2 loads. **Table 7-21** presents an example TMDL and NO_3+NO_2 load allocations as a function of streamflow in accordance with the allocation scheme presented in **Table 7-20**; load allocations are presented at summer baseflow conditions in Uncle Sam Gulch.

Reducing nitrate loads from historic mining sources will likely mitigate the effects of algal growth, although the uncertainty regarding background conditions and nutrient contributions from past mining makes it difficult to predict the extent of necessary nitrate reduction to reduce excess algal growth. Uncle Sam Gulch also has several impairment causes linked to excess metals loading from historic mining. These impairment causes were addressed in a separate TMDL document (Montana Department of Environmental Quality, 2012a) where the need for mine reclamation work is identified as part of the solution to eliminate excess metals loading to the stream. Very high metals load reductions are necessary to meet the numeric water quality standards for metals, and it is likely that the actions to reduce metals loading will also reduce excess nitrate and other nutrient loading to Uncle Sam Gulch. This is discussed further in **Section 8.0**.

Table 7-21. Uncle Sam Gulch Example NO_3+NO_2 load allocations and TMDL*

Source Category	Example Allocations & TMDL (lbs/day)*
Natural Background	0.14
Historical Mining	0.54
TMDL	**0.68**

**based on a median growing season flow of 1.28 cfs*

7.5.3 Nursery Creek (MT4E002_130)

Nursery Creek flows into Muskrat Creek, which in turn flows into the Boulder River below the town of Boulder. Land use along Nursery Creek consists primarily of cattle grazing. As determined in **Section**

7.4.3.3, all sampling locations (three total) exceeded nutrient water quality targets for NO_3+NO_2, TN, and TP. TMDLs will be developed for NO_3+NO_2, TN, and TP.

7.5.3.1 Nursery Creek Source Assessment

The source assessment for Nursery Creek includes the evaluation of NO_3+NO_2, TN, and TP concentrations, flow and loading data along the whole length of Nursery Creek. This is followed by the quantification of natural background and the most significant human caused sources of nutrients. The most prolific human caused nutrient source in Nursery Creek is cattle grazing. Defining the specific impacts from cattle grazing is complicated by the fact that most of the Nursery Creek drainage burned during a 2000 fire, discussed in further detail below.

Instream NO_3+NO_2, TN, and TP concentrations exceeded water quality targets during four different low-flow events. TN target concentrations were exceeded at both sampling locations for all sampling events with the exception of one sample. **Table 7-22** and **Figure 7-13** present summary statistics of TN concentrations at sampling sites in Nursery Creek. NO_3+NO_2 values for all samples collected were well above target concentrations for all sampling events. **Table 7-23** and **Figure 7-14** present summary statistics of NO_3+NO_2 concentrations at sampling sites in Nursery Creek. TP concentrations at the headwaters sites were below target values for all sampling events; however, the majority of TP samples collected at the mouth of Nursery Creek were above target criteria. **Table 7-24** and **Figure 7-15** present summary statistics of TP concentrations at sampling sites in Nursery Creek.

Table 7-22. Growing Season TN Summary Statistics for sampling sites on Nursery Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
Nursery Creek (headwaters)	6	0.24	0.40	0.33	0.32	0.34	0.36
Nursery creek (mouth)	6	0.29	0.45	0.37	0.34	0.35	0.39

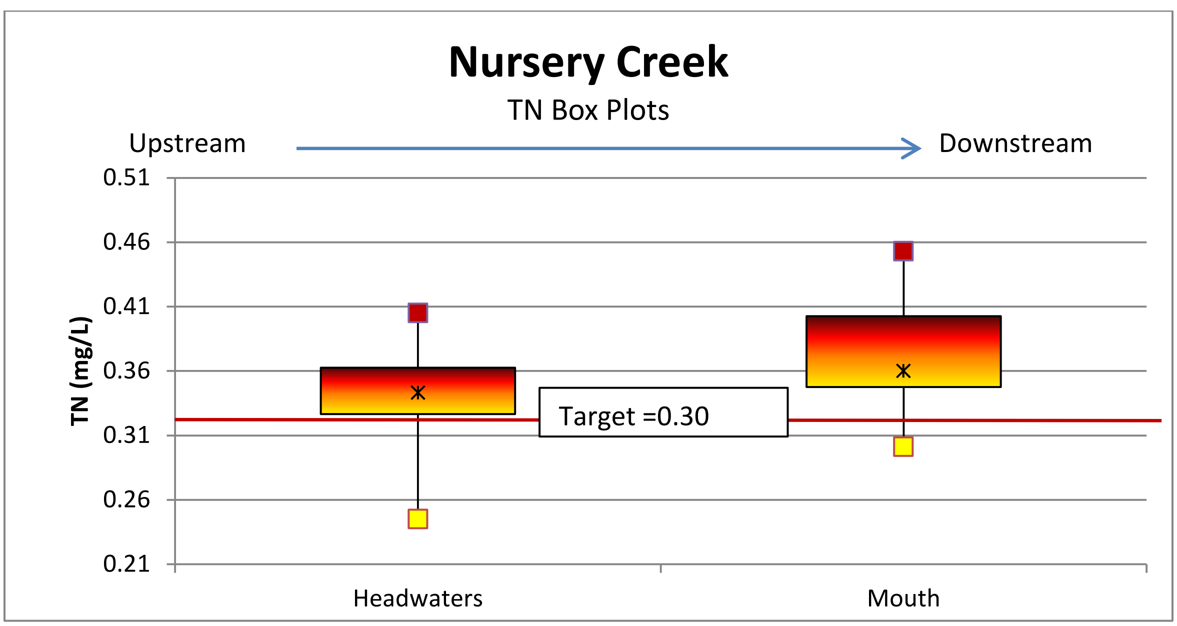

Figure 7-13. TN Box plots: Nursery Creek

Table 7-23. Growing Season NO_3+NO_2 Summary Statistics for sampling sites on Nursery Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
Nursery Creek (headwaters)	6	0.24	0.31	0.24	0.26	0.29	0.31
Nursery creek (mouth)	6	0.20	0.28	0.23	0.21	0.22	0.25

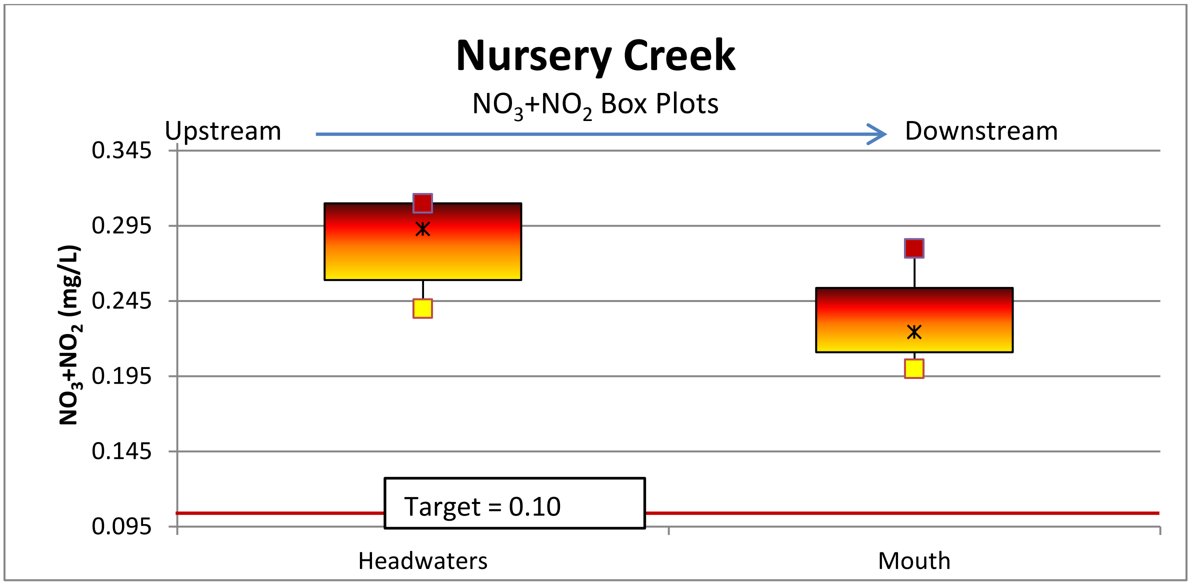

Figure 7-14. NO_3+NO_2 Box Plots: Nursery Creek

Table 7-24. Growing Season TP Summary Statistics for sampling sites on Nursery Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
Nursery Creek (headwaters)	6	0.009	0.028	0.017	0.01	0.016	0.019
Nursery creek (mouth)	6	0.028	0.056	0.38	0.32	0.036	0.043

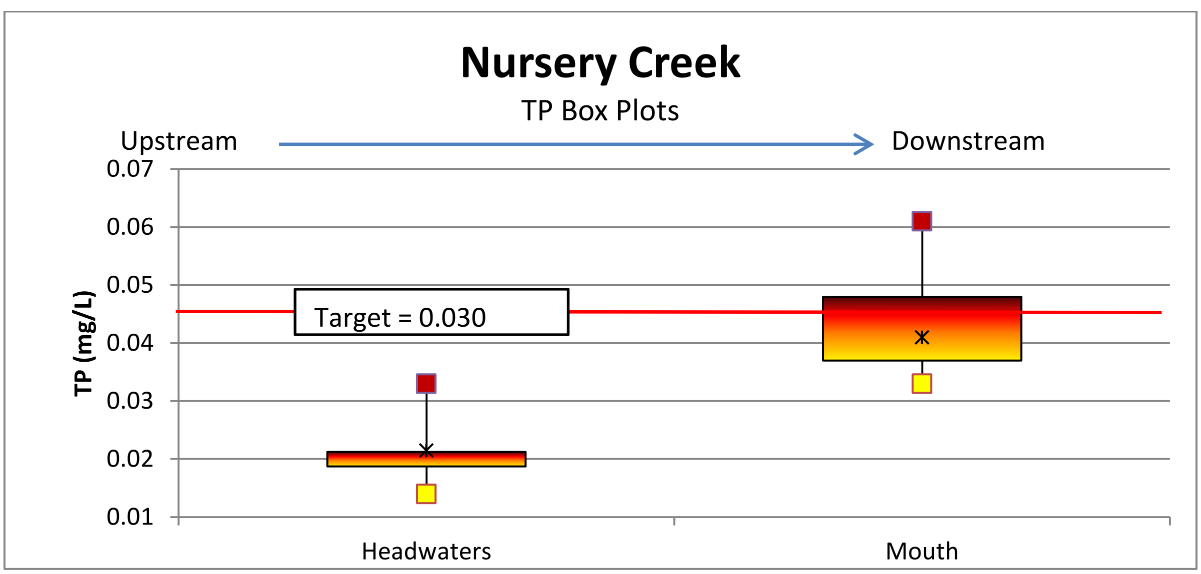

Figure 7-15. TP Box Plots: Nursery Creek

Average low-flow TN loads increase from 0.29 lb/day at the headwaters to 1.52 lbs/day at the mouth, an average increase of 1.23 lbs/day (80.9% increase). Average low-flow NO_3+NO_2 loads increased from 0.26 lb/day at the headwaters to 0.93 lb/day at the mouth, an average increase of 0.66 lb/day (72% increase). Average low-flow TP loads increased from 0.01 lb/day at the headwaters to 0.13 lb/day at the mouth. This is an average increase of 0.12 lb/day. TN, NO_3+NO_2, and TP loads calculated from the 2009–2010 sampling events are depicted in **Figures 7-16, 7-17, and 7-18**, respectively. Average TN, NO_3+NO_2, and TP loads increase moving downstream from the headwaters of Nursery Creek to the mouth.

Estimation of NO_3+NO_2, TN, and TP loads in Nursery Creek, instream assimilation and retention of NO_3+NO_2, TN, and TP loads by algae is relatively straight forward. The dramatic increase of TN, NO_3+NO_2, and TP loads from the headwaters site to sampling sites at the mouth, in conjunction with low algal densities throughout the reach, likely indicates that some NO_3+NO_2, TN, and TP load is being taken up by algal growth and converted to biomass. This may also suggests that NO_3+NO_2, TN, and TP loads entering the reach are likely close to the loads measured instream and are contributing high concentrations of nutrients to downstream waterbodies.

Natural and human-caused sources contributing to NO_3+NO_2, TN, and TP loads entering the reach are described below. Numeric load estimates to specific source categories are provided and form the basis for NO_3+NO_2, TN, and TP load allocations.

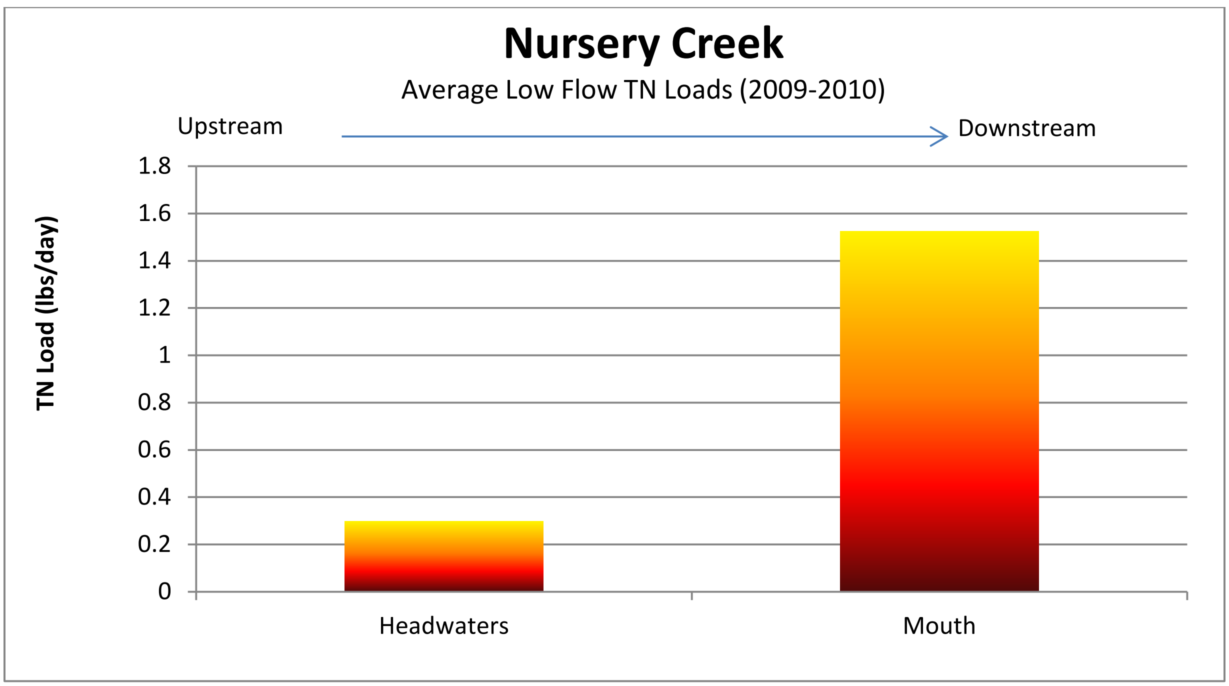

Figure 7-16. TN Load to Nursery Creek

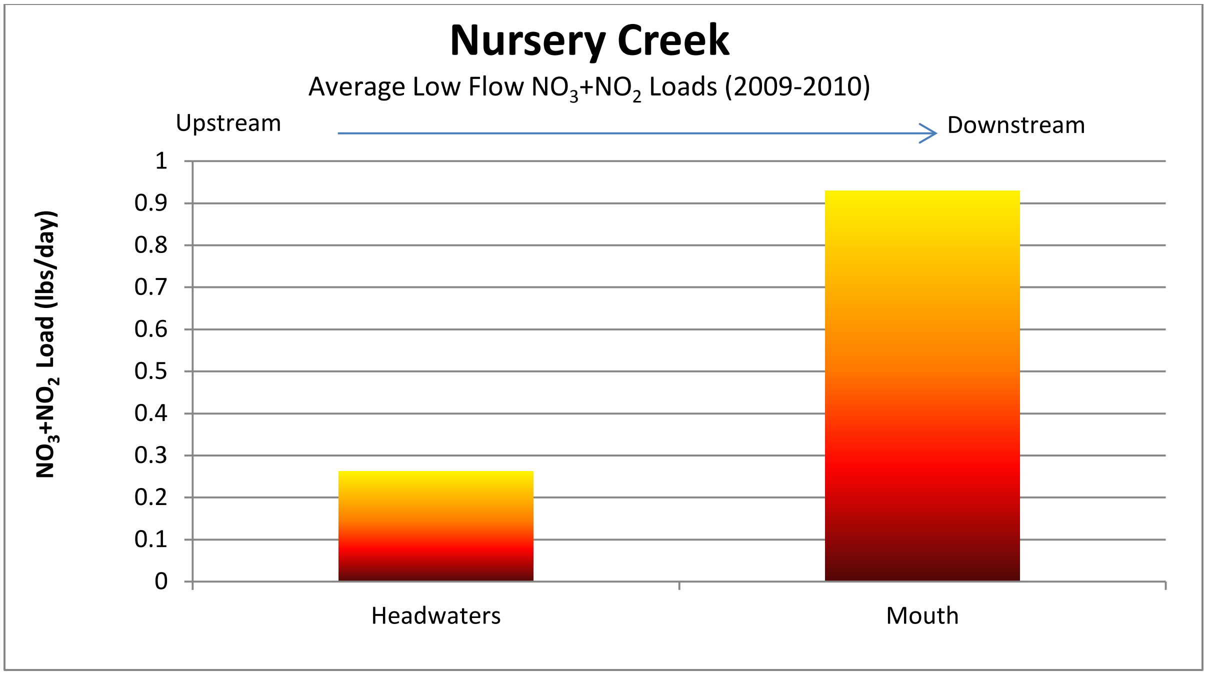

Figure 7-17. NO_3+NO_2 Load to Nursery Creek

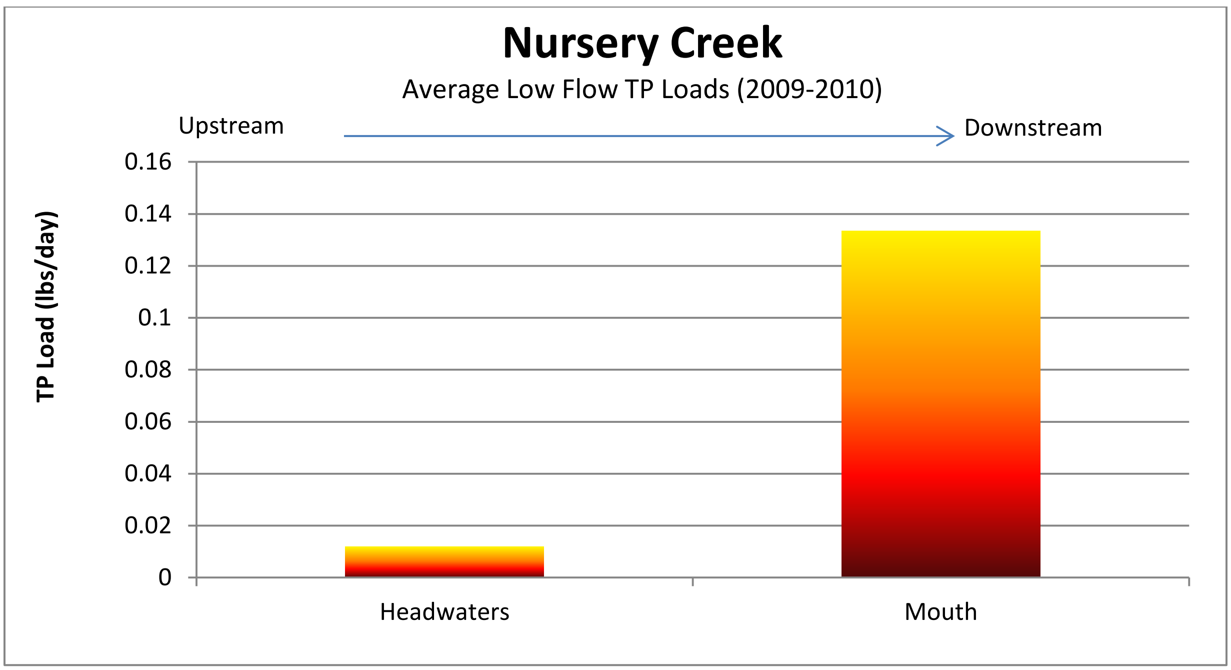

Figure 7-18. TP Load to Nursery Creek

Natural Background Nutrient Loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. No background water quality data was available for Nursery Creek. Because Nursery Creek is a small drainage (approximately 1 mile from origin to mouth), sampling locations were limited. Establishing locations that would be considered representative of background was difficult, thus no sampling locations representative of background water quality were established.

Given this lack of data and lack of a reference stream data in the Boulder-Elkhorn TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2007) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions. This translates to background TN values ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration of 0.085 mg/L TN and a median low-flow baseflow of 0.26 cfs, the average background TN load to the segment is calculated to be approximately 0.12 lb/day. The Median low flow value was taken from flow measurements that coincided with water quality monitoring that is discussed in **Section 7.4.3**

Reference NO_3+NO_2 values derived from Suplee (2007) for wadeable streams ranged from 0.005 mg/L, 0.020 mg/L , and 0.040 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.020mg/L) as it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration of 0.020 mg/L NO_3+NO_2 and a median low-flow baseflow of 0.26 cfs, the average background NO_3+NO_2 load to the segment is calculated to be approximately 0.03 lb/day.

Background TP values derived from Suplee (2007) for wadeable streams ranged from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.010mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration of 0.010 mg/L TP and a median low-flow baseflow of 0.26 cfs, the average background TP load to the segment is calculated to be approximately 0.01 lb/day.

The above natural background determinations do not account for the 2000 fire and represent the normal expected background nutrient concentrations prior to the fire or after full recovery from the fire.

Cattle Grazing Nutrient Loading

The Nursery Creek drainage is approximately 700 acres. Cattle grazing operations are conducted here through Bureau of Land Management (BLM) cattle allotment #20249. Approximately 65 % of the Nursery Creek drainage is known as the Nursery Creek Pasture and is allotted for grazing; about 54 cattle are allowed to graze on this and adjacent pastures from June 1 through September 30—the entire growing season.

Cattle are allowed to roam and are not deliberately concentrated along the valley bottoms during the growing season. There are several possible mechanisms for the transport of nutrients from grazed land to surface water during the growing season, including 1) direct loading via the breakdown of excrement and surface runoff and subsurface pathways, 2) delivery from grazed forest and rangeland during the growing season 3) the effects of grazing on vegetation and its ability to take up nutrients and 4) the effects of grazing on vegetation and its ability to minimize erosion in upland and riparian areas. The load from cattle grazing is the difference of the existing load and the background load. Explanation of how the existing load is calculated is provided further in this section.

In 2000 the Boulder Hill Wildfire severely burned all of the Nursery Creek drainage, leaving little overstory or understory vegetation. Wildfire effects on the nutrient cycle are highly dependent on the fire's severity. In high severe burns, overstory or ground fuels are consumed, leaving no plants capable of taking up nutrients. With high intensity wildfires, the capacity of microbial organisms and plants to incorporate nitrogen into their biomass is reduced and the levels of released nitrogen are therefore greater. The resulting effects on the nutrient cycle (limited nutrient uptake) are usually short term (on the order of 1–2 years after the fire) (Rhoads et al., 2011). Roades et al. also indicates these effects can be seen long term (5+ years). Further, Rhoades et al. concluded the lack of nitrate abatement was attributed to slow recovery of the overstory. While forest floor vegetation has rebounded in Nursery Creek, a large amount of the overstory has not yet rebounded. This indicates that nitrate export from the watershed may still be elevated as a result of the wildfire.

Effects of nutrient loading resulting from cattle grazing on the Nursery Creek watershed are likely exasperated by the 2000 wildfire. Nutrient loading is directly affected by increased erosion associated with the wildfire, lack of nutrient uptake by overstory vegetation and the decreased riparian vegetation along Nursery Creek. Wildfire is a natural process in the ecosystem, and the DEQ cannot allocate a load reduction, although it should be noted that activities within the watershed should not alter recovery time from a fire or contribute to the severity of the impacts from a fire. However, the effects of cattle grazing on the watershed may have been augmented as a result of the wildfire.

7.5.3.2 Nursery Creek Total Maximum Daily Loads: Total Nitrogen (TN), Nitrate plus Nitrite (NO_3 + NO_2), Total Phosphorous (TP)

As established in **Section 7.4**, TMDLs for TN, NO_3+NO_2, and TP are presented here for Nursery Creek (MT4E002_130). The TMDLs (lbs/day) for TN, NO_3+NO_2, and TP are calculated using the water quality target values established in **Section 7.4**. The TN, NO_3+NO_2, and TP TMDL loads apply during the summer growing season (July 1–Sept. 30). The TMDL for TN is based on an instream target value of 0.30 mg/L TN and the streamflow (**Figure 7-19**). The NO_3+NO_2 TMDL is based on an instream target value of 0.10 mg/L TN and the streamflow (**Figure 7-20**).The TMDL for TP is based on an instream target value of 0.03 mg/L TP and the streamflow (**Figure 7-21**).

TN, NO_3+NO_2, and TP TMDL calculations are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (TN =0.30 mg/L, NO_3+NO_2 *= 0.10 or TP =0.030 mg/L)*
Y= streamflow in cubic feet per second
5.393 = conversion factor

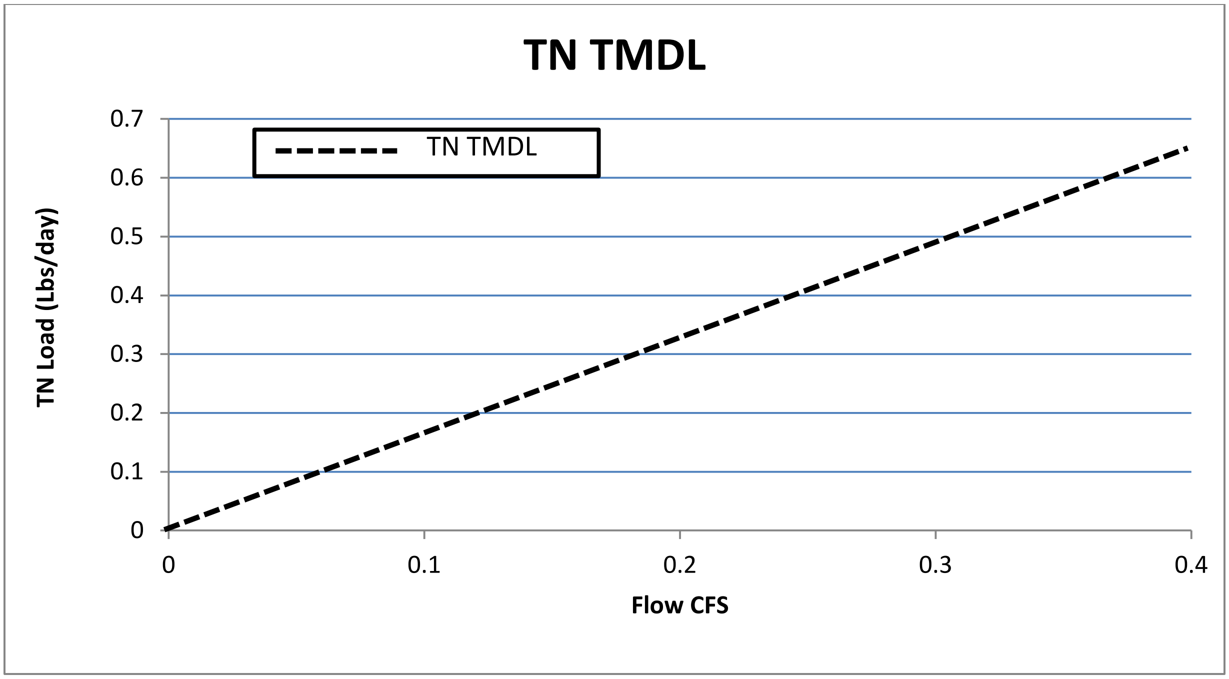

Figure 7-19. TMDL for TN as a function of flow: Nursery Creek

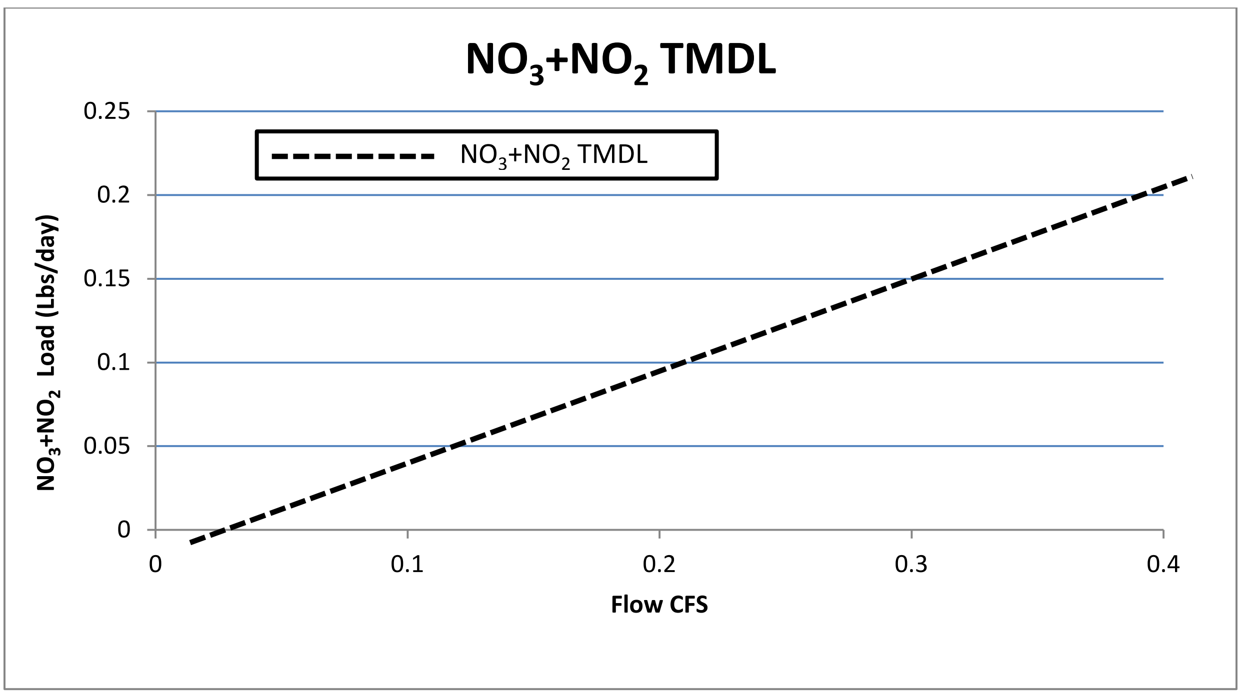

Figure 7-20. TMDL for NO_3+NO_2 as a function of flow: Nursery Creek

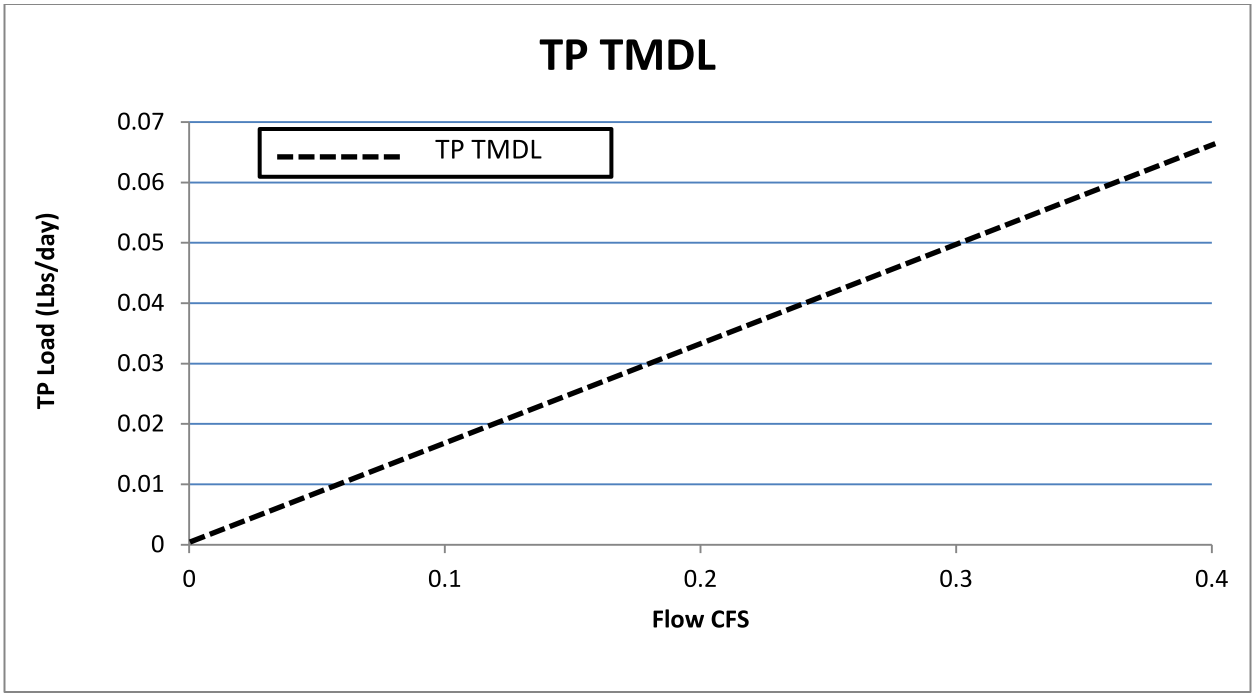

Figure 7-21. TMDL for TP as a function of flow: Nursery Creek

7.5.3.3 Nursery Creek Total Nitrogen (TN), Nitrate plus Nitrite (NO_3+NO_2) and Total Phosphorus (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TN, NO_3+NO_2 and TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. An implicit MOS is defined within **Section 4.4**, is applied toward the Nursery Creek TMDLs. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

All three nutrient TMDLs are written for a “normal” watershed condition not significantly influenced by wildfire. Given that the fire was about one decade prior to the water quality sampling, the extent of wildfire influence on pollutant loading is uncertain. It is possible that some elevated wildfire related loading still occurs and will need to be considered as part of adaptive management activities in this watershed.

7.5.3.3.1 Total Nitrogen (TN) Allocation

For Nursery Creek the TMDL for TN is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations, and relevant TN nonpoint sources include natural background sources and sources associated with cattle grazing. Load allocations are therefore provided for 1) natural background sources and 2) cumulative cattle grazing sources. In the absence of individual WLAs and an explicit MOS, TN TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + LA_{CTTL}

LA_{NB} = Load allocation to natural background sources

LA_{CTTL} = Load allocation to cattle grazing sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.3.1**) and are calculated as follows:

$$LA_{NB} = (X)(Y)(5.393)$$

LA_{NB}= TN load allocated to natural background sources
X= 0.085 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Cattle Grazing Sources

The load allocation to cattle grazing sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$LA_{CTTL} = TMDL - LA_{NB}$$

TN Load Allocation

TN load allocations are provided for Nursery Creek (**Table 7-25**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the cattle grazing (LA_{CTTL}). **Figure 7-22** provides a graphical depiction of the TMDL and allocations**.**

Table 7-25. TN load allocation descriptions, Nursery Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background (non-wildfire conditions)	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	$LA_{NB} = (X)(Y)(5.393)$
Cattle Grazing	• domestic animal waste • lack of riparian vegetation • vegetative decay from detritus derived from animal grazing • increased erosion associated with grazing in areas impacted by wildfire	$LA_{CTTL} = TMDL - LA_{NB}$

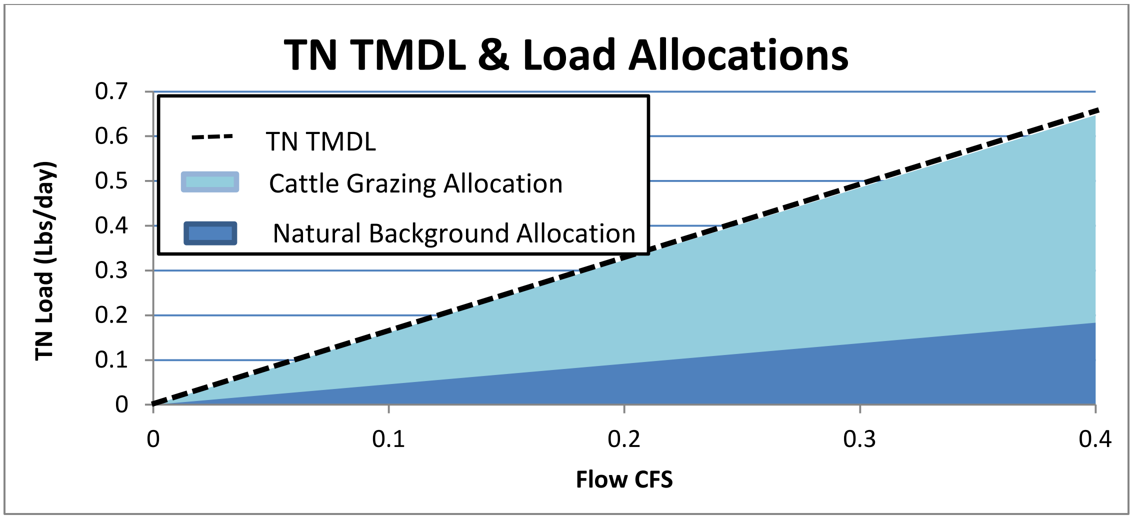

Figure 7-22. TMDL for TN and Load Allocations, Nursery Creek

Table 7-26 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-26** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-26. Nursery Creek Example TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background (non-wildfire conditions)	0.12	0.12	0%
Cattle Grazing Sources	1.40	0.3	79%**
	Total = 1.52	**TMDL = 0.42**	**Total = 72%**

**based on a median growing season flow of 0.26 cfs*
*** The percent reduction is provided for informational purposes and it should be recognized that the watershed may not be fully recovered from the 2000 fire. Therefore, the percent reduction needed to meet the cattle grazing load allocation could be smaller due to these potential lingering fire impacts.*

The TMDL for TN in Nursery Creek is calculated to be 0.42 lb/day. Existing TN loading to Nursery Creek is estimated at 1.52 lbs/day (**Section 7.5.3.1**), requiring a total load reduction of 72% in order to meet the TN TMDL for Nursery Creek. Load allocations and load reductions are specifically designated to the cattle grazing sources, which make up an estimated 92% of the TN load entering Nursery Creek. Loading associated with cattle grazing is complicated by the effects of wildfire and is difficult to quantify and differentiate potential remaining wildfire loads from loads associated with cattle grazing alone. Load reductions should focus on limiting and controlling TN loads from the sources associated with cattle grazing enhanced by the effects from wildfire.

The DEQ has determined that reducing loads from cattle grazing sources in Nursery Creek will result in lower TN concentrations at the mouth. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.3.3.2 Nitrate plus Nitrite (NO_3+NO_2) Allocation

For Nursery Creek the TMDL for NO_3+NO_2 is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations, and relevant NO_3+NO_2 nonpoint sources include natural background sources and sources associated with cattle grazing. Load allocations are therefore provided for 1) natural background sources and 2) cattle grazing sources. In the absence of individual WLAs and an explicit MOS, NO_3+NO_2 TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + LA_{CTTL}

LA_{NB} = Load allocation to natural background sources

LA_{CTTL} = Load allocation to cattle grazing sources

Natural Background Source

Load allocations for natural background sources are based on a natural background NO_3+NO_2 concentration of 0.10 mg/L (**see Section 7.5.3.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= NO_3+NO_2 *load allocated to natural background sources*

X= 0.020 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Cattle Grazing Sources

The load allocation to cattle grazing sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

LA_{CTTL}= TMDL - LA_{NB}

NO_3+NO_2 Load Allocation

NO_3+NO_2 load allocations are provided for Nursery Creek (**Table 7-27**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) cattle grazing sources (LA_{CTTL}). **Figure 7-23** provides a graphical depiction of the TMDL and allocations**.**

Table 7-27. NO_3+NO_2 load allocation descriptions, Nursery Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background (non-wildfire conditions)	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Cattle Grazing	• domestic animal waste • lack of riparian vegetation • vegetative decay from detritus derived from animal grazing • increased erosion associated with grazing in areas impacted by wildfire	**LA_{CTTL} = TMDL - LA_{NB}**

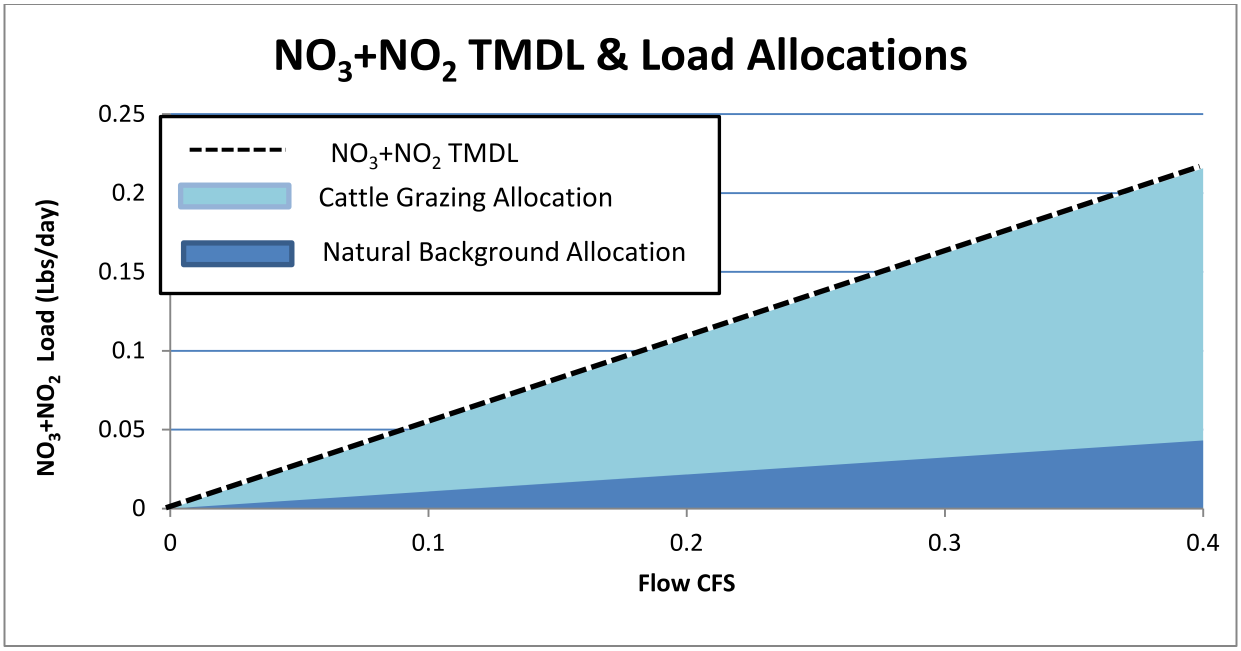

Figure 7-23. TMDL for NO_2+NO_3 and Load Allocations, Nursery Creek

Table 7-28 provides an example TMDL and example allocations for a typical summer baseflow condition. The NO_3+NO_2 load allocations and the NO_3+NO_2 TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-28** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-28. Nursery Creek Example NO_3+NO_2 load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background (non-wildfire conditions)	0.03	0.03	0%
Cattle Grazing Sources	0.90	0.11	88%**
	Total = 0.93	**TMDL = 0.14**	**Total = 85%**

**based on a median growing season flow of 0.26 cfs*
*** The percent reduction is provided for informational purposes and it should be recognized that the watershed may not be fully recovered from the 2000 fire. Therefore, the percent reduction needed to meet the cattle grazing load allocation could be smaller due to these potential lingering fire impacts.*

The TMDL for NO_3+NO_2 in Nursery Creek is calculated to be 0.14 lb/day. Existing NO_3+NO_2 loading to Nursery Creek is estimated at 0.93 lb/day (**Section 7.5.3.1**), requiring a total load reduction of 85% in order to meet the NO_3+NO_2 TMDL for Nursery Creek. Load allocations and load reductions are specifically designated to cattle grazing sources which makes up an estimated 97% of the NO_3+NO_2 load entering Nursery Creek. Loading associated with cattle grazing is complicated by the effects of wildfire and is difficult to quantify and differentiate potential remaining wildfire loads from loads associated with cattle grazing alone. Load reductions should focus on limiting and controlling NO_3+NO_2 loads from the sources associated with cattle grazing enhanced by the effects from wildfire.

The DEQ has determined that reducing loads from cattle grazing sources in Nursery Creek will result in lower NO_3+NO_2 concentrations at the mouth. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.3.3.3 Total Phosphorous (TP) Allocation

For Nursery Creek the TMDL for TP is comprised of the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations, and relevant TP nonpoint sources include natural background sources and sources associated with cattle grazing. Load allocations are therefore provided for 1) natural background sources and 2) cattle grazing sources. In the absence of individual WLAs and an explicit MOS, TP TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

$$\mathbf{TMDL = LA_{NB} + LA_{CTTL}}$$

LA_{NB} = Load allocation to natural background sources
$LA_{CTTL+WLDFR}$ = Load allocation to cattle grazing sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.080 mg/L (**see Section 7.5.3.1**), and are calculated as follows:

$$LA_{NB} = (X)\,(Y)\,(5.393)$$

LA_{NB}= TP load allocated to natural background sources
X= 0.010 mg/L natural background concentration
Y= median growing season streamflow in cubic feet per second
5.393 = conversion factor

Cattle Grazing Sources

The load allocation to cattle grazing sources and is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$\mathbf{LA_{CTTL} = TMDL - LA_{NB}}$$

TP Load Allocation

TP load allocations are provided for Nursery Creek (**Table 7-29**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) cattle grazing sources (LA_{CTTL}). **Figure 7-24** provides a graphical depiction of the TMDL and allocations**.**

Table 7-29. TP load allocation descriptions, Nursery Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background (non-wildfire conditions)	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute phosphorous to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Cattle Grazing	• domestic animal waste • lack of riparian vegetation • vegetative decay from detritus derived from animal grazing • increased erosion associated with grazing in areas impacted by wildfire	**LA_{CTTL} = TMDL - LA_{NB}**

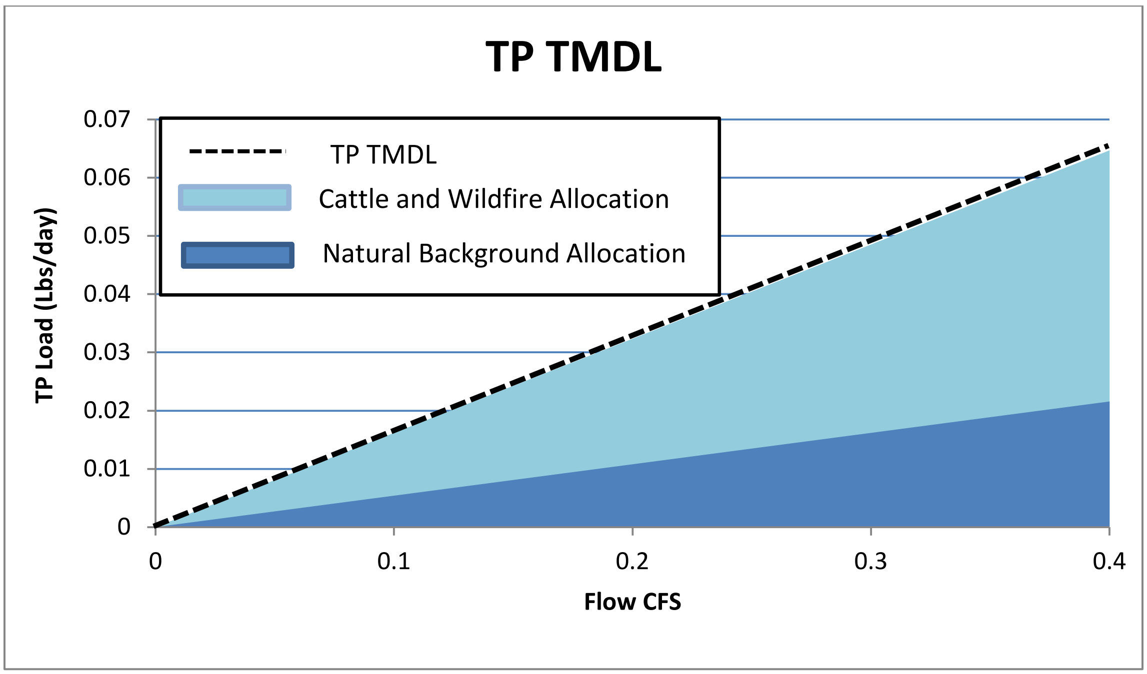

Figure 7-24. TMDL for TP and Load Allocations, Nursery Creek

Table 7-30 provides an example TMDL and example allocations for a typical summer baseflow condition. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-30** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-30. Nursery Creek Example TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background (non-wildfire conditions)	0.01	0.01	0%
Cattle Grazing	0.12	0.03	75%**
	Total = 0.13	**TMDL = 0.04**	**Total = 69%**

**based on a median growing season flow of 0.26 cfs*
*** The percent reduction is provided for informational purposes and it should be recognized that the watershed may not be fully recovered from the 2000 fire. Therefore, the percent reduction needed to meet the cattle grazing load allocation could be smaller due to these potential lingering fire impacts.*

The TMDL for TP in Nursery Creek is calculated to be 0.04 lb/day. Existing TP loading to Nursery Creek is estimated at 0.13 lb/day (**Section 7.5.3.1**), requiring a total load reduction of 69% in order to meet the TP TMDL for Nursery Creek. Load allocations and load reductions are specifically designated to cattle grazing sources, which make up an estimated 92% of the TP load entering Nursery Creek. Loading associated with cattle grazing is complicated by the effects of wildfire and it is difficult to quantify and differentiate potential remaining wildfire loads from loads associated with cattle grazing alone. Load reductions should focus on limiting and controlling TP loads from the sources associated with cattle grazing enhanced by the effects from wildfire.

The DEQ has determined that reducing loads from cattle grazing sources in Nursery Creek will result in lower TP concentrations at the mouth. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.4 McCarty Creek (MT41E002_110)

McCarty Creek flows into the Boulder River downstream and south of the town of Boulder. Land use along McCarty Creek consists primarily of light cattle grazing and silvicultural practices. Sites were sampled during four different low-flow events between 2009 and 2010. As determined in **Section 7.4.3.4**, sampling conducted at the five sampling sites indicated that 3 NO_3+NO_2 and 3 TN results were above target criteria. All sampling locations exceeded nutrient water quality targets for TP. As such TMDL will be developed for TP.

7.5.4.1 McCarty Creek Source Assessment

The source assessment for McCarty Creek includes the evaluation of the TP concentration, flow and loading data along the whole length of McCarty Creek. This is followed by the quantification of natural background and the most significant human caused sources of nutrients. The human cause nutrient sources include cattle grazing and irrigation water storage reservoirs.

As determined in **Section 7.4.3.3**, all sampling locations for all sampling events exceeded nutrient water quality targets for TP. As a result of the initial impairment listing and assessment monitoring data collection conducted in 2009 and 2010, McCarty Creek was found to remain impaired for TP and will be addressed through a TMDL for TP. **Table 7-31** and **Figure 7-25** present summary statistics of TP concentrations at sampling sites in McCarty Creek.

Table 7-31. Growing Season TP Summary Statistics for sampling sites on McCarty Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
McCarty Creek (Headwaters)	6	0.035	0.046	0.041	0.038	0.041	0.044
McCarty Creek (At Reservoirs)	7	0.047	0.092	0.069	0.059	0.070	0.079
McCarty Creek (At Mouth)	4	0.097	0.309	0.162	0.109	0.122	0.175

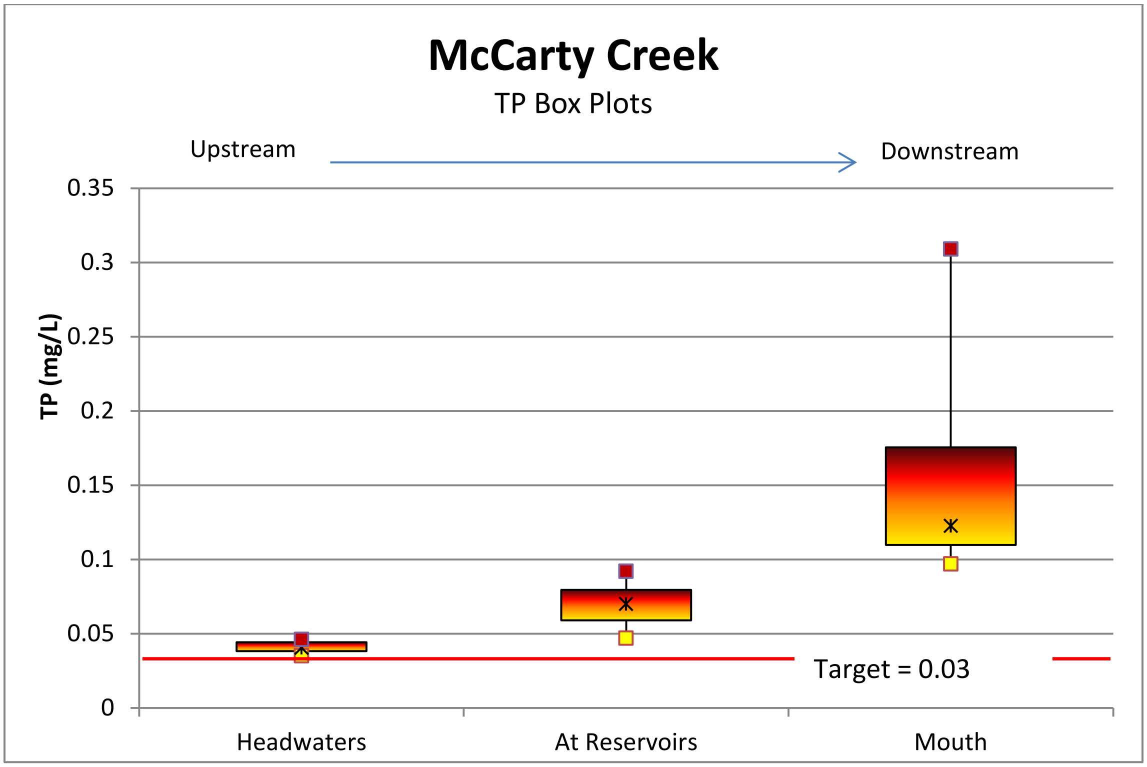

Figure 7-25. TP Box plots: McCarty Creek

Average low-flow TP loads decrease from 0.023 lb/day at the headwaters to 0.015 lb/day at the mouth, an average decrease of 0.0083 lb/day (decrease of 98.5%). TP loads calculated from the 2009–2010 sampling events are depicted in **Figure 7-26**. In general, TP loads are relatively uniform from the headwaters to the sampling locations at the irrigation water storage reservoirs. There is a slight decrease in loading below the reservoirs. The decrease of TP load from the headwaters sampling sites to sampling sites at the mouth in McCarty Creek can be attributed only to the decrease of the flow volume. During low-flow conditions, McCarty Creek often does not flow at all below the lower-most reservoir. While concentration values get higher moving downstream, the load stays constant or decreases as a result of low flow volumes recorded at downstream sampling locations.

Natural and human-caused sources contributing to TP loads entering the reach are described below. Numeric load estimates to specific source categories are provided and form the basis for TP load allocations.

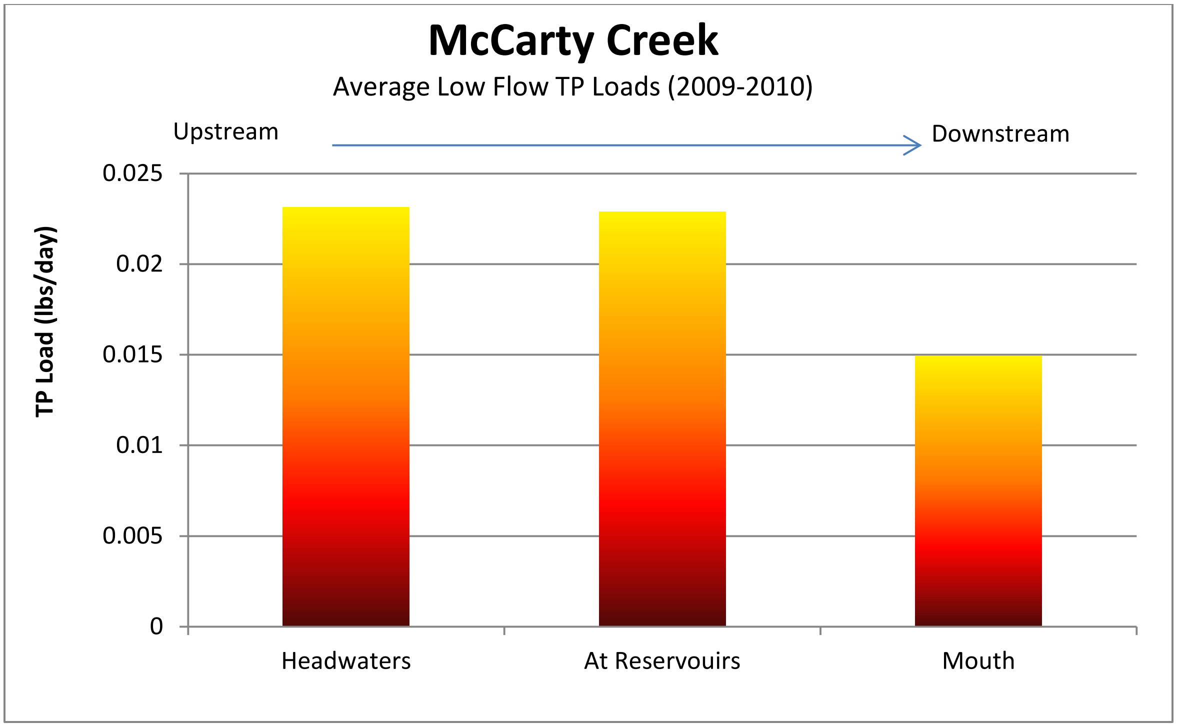

Figure 7-26. TP Load to McCarty Creek

Natural Background Nutrient Loading

Natural background sources of phosphorus include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute phosphorus to this system. Headwaters sampling did occur; however, the upstream-most samples were collected approximately 2 miles downstream of the origin of McCarty Creek because this was the only accessible sampling location. While these samples are the upstream-most, realistically they represent water from the middle of the stream channel; therefore, no accurate background water quality data was collected for McCarty Creek.

Given the lack of data in McCarty Creek and lack of data in the Boulder-Elkhorn TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion for background concentrations. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2007) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions. This translates to background TP values ranging from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.010 mg/L) as it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration of 0.010 mg/L TP and a median low-flow baseflow of 0.060 cfs, the average background TN load to the segment is calculated to be approximately 0.0032 lb/day. The Median low flow value was taken from flow measurements that coincided with water quality monitoring that is discussed in **Section 7.4.3**

The ultimate source of some of the natural background phosphorus in McCarty Creek is the acres of land in the headwaters where granitic and volcanic rocks form the bedrock. Igneous intrusive and volcanic rocks are the most common bedrock in McCarty Creek, and pedogenic weathering of these rocks forms the soils, which contribute phosphorus to the creek. Phosphorus is a common element in igneous rocks (Hem, 1985). The average phosphorus content of basalts and andesites (basic volcanic rocks) can be as much as 0.10–0.12 weight percent (as P); and for granodiorites (intrusive igneous rocks) 0.09 percent (Hyndman, 1972).

Because a portion of the geology within McCarty Creek drainage includes volcanic rocks, the natural background levels for TP might be higher in McCarty Creek than for other streams in the Boulder-Elkhorn TPA, although there is not enough data to provide a more detailed natural background estimate given TP impacts from grazing as well as potential impacts from the two irrigation reservoirs within the watershed. As such, DEQ has decided to use the same natural background concentration for all streams given the inherent uncertainties with estimating natural background conditions

Irrigation Water Storage Reservoir Phosphorous loading

High phosphorous concentrations (and the resultant loading) in McCarty Creek is likely influenced by the result of a number of effects of multiple small surface water impoundments (irrigation water storage reservoirs) in the drainage. These effects include the lack of flushing of the reservoir and the latent effects of the phosphorous cycle.

Flushing rate is directly tied to nutrient loading capacity. Lakes and reservoirs have low flushing rates compared with rivers and streams, which are constantly replenishing their water volume. A reservoir is more vulnerable to the accumulation of pollutants and nutrients both in its water column and in its organisms than a river or stream (Chapman, 1992). Low flushing rates exacerbate nutrient loading problems and accelerate eutrophication because the water is not replenished often enough to prevent accumulation of nutrient-rich runoff from the watershed, leading to increased amounts of nutrients in the sediments.

Organic matter in anoxic sediments is continuously being decomposed with the release of dissolved reactive phosphorus (DRP) into the sediment pore waters (Smolders et al., 2006). When a waterbody is stratified and the hypolimnion (bottom waters) becomes anoxic, substantial amounts of nutrients, particularly DRP and ammoniacal nitrogen (NH4-N), diffuse into the overlying waters (Burger et al., 2007). The N and P loads from these internal nutrient sources are recycled and do not contribute to the external nutrient budget of a lake (Nurnberg, 1984) But in summer, they can be considerably greater than the external N and P loads from river inputs (e.g., (Burger et al., 2007)) and thus may be a significant source of nutrients to McCarty Creek.

DEQ recognizes that the purpose of the irrigation water storage reservoirs is to provide irrigation and that some elevated nutrient loading from reservoir discharges may be extremely difficult to avoid. In fact, DEQ's definition of "naturally occurring" provided in Appendix C includes consideration of reservoirs if operated reasonably. Reduced upstream loading to meet the TP target values would likely, over time, reduce TP loads downstream of each reservoirs. It is difficult at this time to determine the achievable TP loading reductions via a combination of grazing improvements and potential improvements to reservoir operations under conditions where the reservoirs are still able to provide irrigation water per their intended purpose.

Cattle Grazing Nutrient Loading

The McCarty Creek drainage is approximately 4,000 acres. Cattle grazing operations are conducted on a number of sections of federal and private land. Approximately 138 cattle are allowed to graze on the West Elkhorn Grazing Allotment, currently comprised of three permittees. Cattle are allowed to grave in the McCarty Creek watershed from June 16 through October 15—the entire growing season.

Cattle are allowed to roam and are not deliberately concentrated along the valley bottoms during the growing season. There are several possible mechanisms for the transport of nutrients from grazed land to surface water during the growing season. The potential pathways include including 1) direct loading via the breakdown of excrement and surface runoff and subsurface pathways, 2) delivery from grazed forest and rangeland during the growing season 3) the effects of winter grazing on vegetation and its ability to take up nutrients and 4) the effects of grazing on vegetation and its ability to minimize erosion in upland and riparian areas.

Empirical water quality data does not allow differentiation of phosphorus loads to specific sources. Consequently, load estimates to specific cattle grazing pathways are not provided but are addressed in the allocation scheme in **Section 7.5.4.3.**

7.5.4.2 McCarty Creek Total Maximum Daily Loads: Total Phosphorous (TP)

As established in **Section 7.4**, TP Total Maximum Daily Loads are presented here for McCarty Creek (MT41E002_110). The TMDLs (lbs/day) for TP are calculated using the water quality target values established in **Section 7.4** and apply during the summer growing season (July 1–Sept. 30). The TMDL for TP is based on an instream target value of 0.030 mg/L TP and the streamflow (**Figure 7-27**).

TMDL for TP calculations are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (TP =0.030 mg)
Y= streamflow in cubic feet per second
5.393 = conversion factor

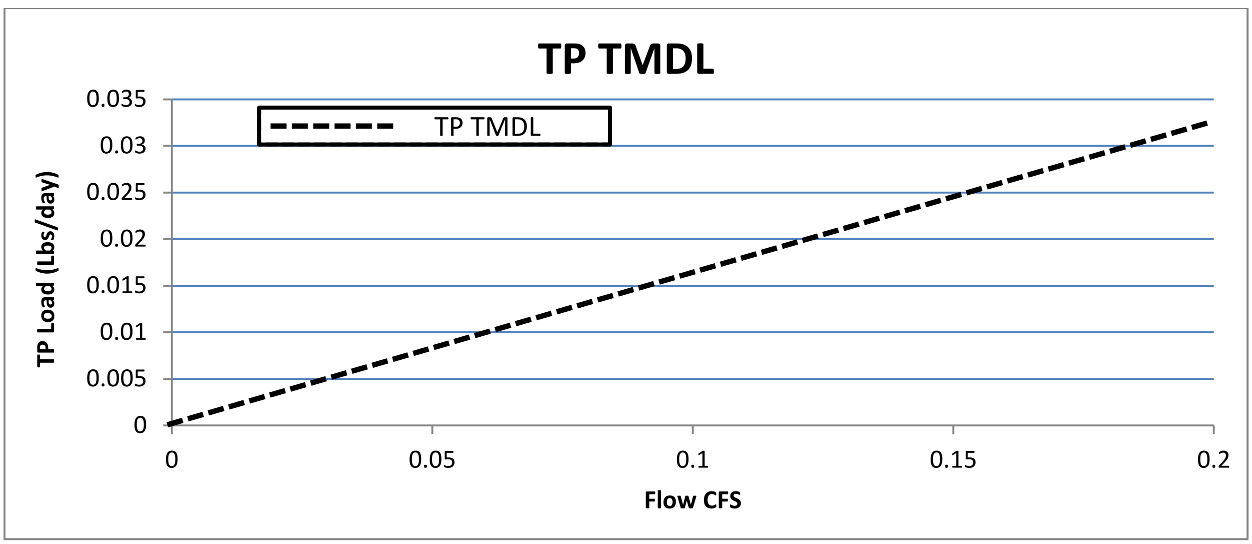

Figure 7-27. TMDL for TP as a function of flow: McCarty Creek

7.5.4.3 McCarty Creek Total Phosphorus (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. An implicit MOS is defined within **Section 4.4**, is applied toward the McCarty Creek TMDL. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.4.3.1 Total Phosphorous (TP) Load Allocations

For McCarty Creek the TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations, and relevant TP nonpoint sources include natural background sources, cattle grazing, and sources associated with reservoirs. Because DEQ could not differentiate phosphorous pollution caused by cattle grazing from sources associated with the irrigation water storage reservoirs, load allocations for cattle grazing sources are included within the load allocations for sources associated with the reservoirs. Load allocations are therefore provided for 1) natural background sources and 2) cumulative cattle grazing sources and sources associated with the reservoir. In the absence of individual WLAs and an explicit MOS, TP TMDLs in the watershed are equal to the sum of the individual load allocations as follows:

$$\mathbf{TMDL = LA_{NB} + LA_{CTTL+RES}}$$

LA_{NB} = Load Allocation to natural background sources
$LA_{CTTL+RES}$ = Load Allocation to the combination of cattle grazing sources and sources associated with the reservoirs

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.010 mg/L (**see Section 7.5.4.1**) and are calculated as follows:

$$LA_{NB} = (X)(Y)(5.393)$$

LA_{NB}= TP load allocated to natural background sources
X= 0.010 mg/L natural background concentration
Y= median growing season streamflow in cubic feet per second
5.393 = conversion factor

Reservoir Cattle and Grazing Sources

The load allocation to the combination of cattle grazing sources and sources associated with reservoirs is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$\mathbf{LA_{CTTL+RES} = TMDL - LA_{NB}}$$

TP Load Allocation

TP load allocations are provided for McCarty Creek (**Table 7-32**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the combination of cattle grazing and sources associated with the reservoirs ($LA_{CTTL+RES}$). **Figure 7-28** provides a graphical depiction of the TMDL and allocations**.**

Table 7-32. TP load allocation descriptions, McCarty Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils & local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute phosphorous to nearby waterbodies.	LA_{NB} = (X) (Y) (5.393)
Combination of Cattle Grazing and Reservoirs	• vegetative decay from detritus derived from animal grazing • domestic animal waste • lack of flushing flows through reservoirs • contributions of phosphorous from reservoir sediments	$LA_{CTTL+RES}$ = TMDL - LA_{NB}

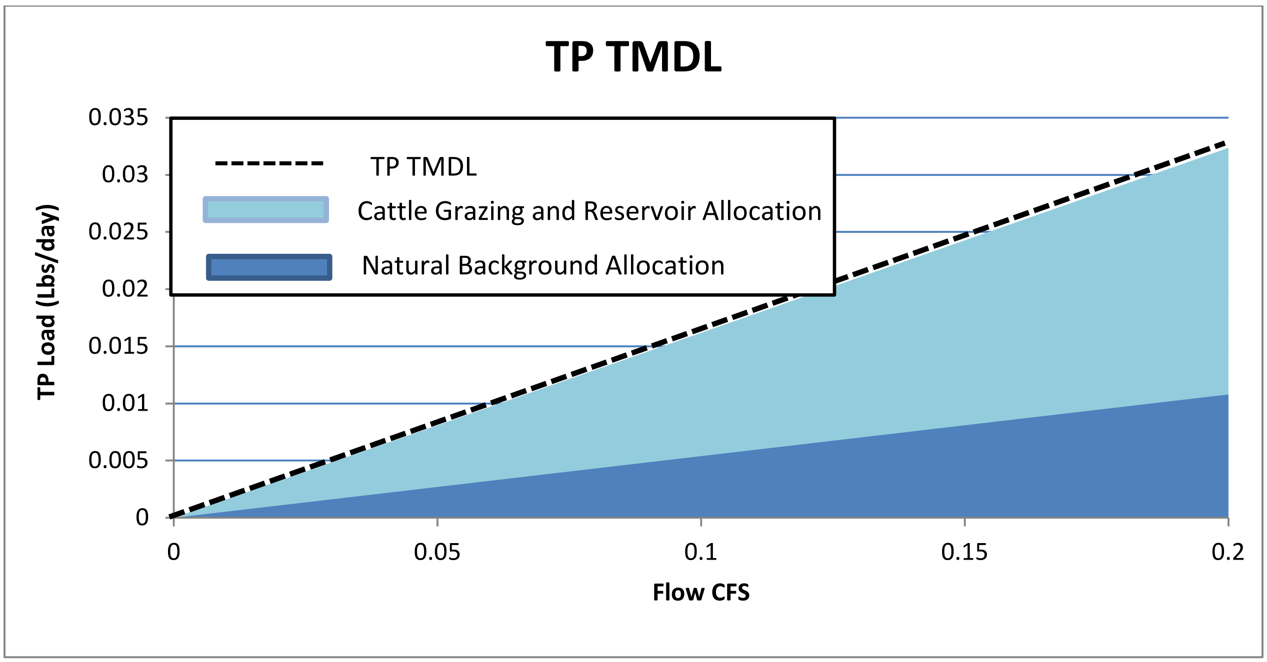

Figure 7-28. TMDL for TP and Load Allocations, Nursery Creek

Table 7-33 provides an example TMDL and example allocations for a typical summer baseflow condition. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-33** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80^{th} percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80^{th} percentile of these loads is then used as the existing load.

Table 7-33. McCarty Creek Example TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Example Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.0032	0.0032	0%
Cattle Grazing Sources	0.019	0.0065	66%
Reservoir Sources			
	Total = 0.023	**TMDL = 0.0097**	**Total = 58%**

**based on a median growing season flow of 0.060 cfs*

The TMDL for TP in McCarty Creek is calculated to be 0.0097 lb/day. Existing TP loading to McCarty Creek is estimated at 0.023 lb/day (**Section 7.5.4)**, requiring a total load reduction of 58% in order to meet the TP TMDL for McCarty Creek. Load allocations and load reductions are specifically designated to the combination of 1) cattle grazing sources and 2) sources associated with the irrigation water storage reservoirs, which make up an estimated 82% of the TP load entering McCarty Creek. As loading associated with sources from the reservoirs are difficult to quantify and differentiate from loads associated with cattle grazing, load reductions should focus on limiting and controlling TP loads from the variety of sources associated with both cattle grazing and effects from reservoirs.

DEQ believes that reducing loads from cattle grazing and sources associated from area irrigation water storage reservoirs in McCarty Creek will result in lower TP concentrations throughout McCarty Creek. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**. DEQ recognizes that the purpose of the reservoirs is to provide irrigation water and that some elevated nutrient loading from reservoir discharges may be extremely difficult to avoid while at the same time meeting the intended purpose of each reservoir. This will need to be considered as part of TMDL adaptive management.

7.6 Seasonality, Margin of Safety, and Adaptive Management

In developing TMDLs, DEQ must consider the seasonal variability, or seasonality, on water quality impairment conditions, TMDLs, and load allocations. DEQ must also incorporate a margin of safety to account for uncertainties between pollutant sources and the quality of the receiving waterbody, and to ensure (to the degree practicable) that the TMDL components and requirements sufficiently protect water quality and beneficial uses. This section describes seasonality, margin of safety, and adaptive management in developing TMDLs for nutrients in the Boulder-Elkhorn TPA.

7.6.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development; throughout this plan seasonality is an integral consideration. Water quality, and particularly nitrogen concentrations, have seasonal cycles. Specific examples of how seasonality has been addressed within this document include the following:

- Water quality targets, TMDLs and subsequent allocations apply to the summer growing season (July 1–Sept 30) to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads was collected during summer to coincide with applicable nutrient targets.
- Nutrient data and sources were evaluated based on an understanding of the sources and seasonal effects on the presence or absences of nutrients.

7.6.2 Margin of Safety

A margin of safety (MOS) is a required component of TMDL development. MOS accounts for the uncertainty about the pollutant loads and the quality of the receiving water; it's intended to protect beneficial uses in the face of this uncertainty. 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 (U.S. Environmental Protection Agency, 1999). This plan addresses MOS implicitly in a variety of ways:

- Nutrient target values (0.100 mg/L NO_3+NO_2, 0.30 mg/L TN, and 0.030 mg/L TN) were used to calculate allowable nutrient TMDLs. Allowable exceedances of nutrient targets (see **Section 7.4.3**) were not incorporated into the calculation of allowable loads, thereby adding an MOS to established nutrient allocations.
- The 50th percentile value of the all season natural background concentrations was used to establish a natural background concentration for load allocations. This acceptable approach provides an MOS for background nutrient loads during most conditions.
- Seasonality and variability were considered in nutrient loading.
- An adaptive management approach will be used to evaluate target attainment and allow for refinement of load allocation, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development.
- A TMDL for TN was developed for Uncle Sam Gulch because of high chlorophyll-*a* concentrations, and in the absence of elevated nitrogen concentrations. This provides a protective approach to water quality for the Boulder-Elkhorn TPA and the Boulder River by proactively allocating loads to sources thought to be contributing to algal growth.

7.6.3 Adaptive Management

Uncertainties in the accuracy of field data, target development, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are a fact of TMDL development, mitigating uncertainties through adaptive management is a key component of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations are applied throughout this document and point to the need to refine analysis, conduct further monitoring, and address unknowns in order to develop a better understanding of nutrient impairment conditions and the processes that affect impairment.

Adaptive management assumes that TMDL targets, allocations, and the analyses supporting them are not static but are processes subject to adjustment as new information and relationships are understood. For instance, numeric nutrient targets provided in **Table 7-2** are based on the best information and analyses available at the time and represent water quality concentrations believed to limit algal growth below nuisance or harmful levels within the Boulder-Elkhorn TPA.

Uncertainties associated with the assumptions and considerations may be mitigated, and loading estimates refined, to more accurately portray watershed conditions. As further monitoring of water quality and source loading conditions is conducted, an adaptive management approach, land use activities, nutrient management and control should be tracked. Changes in land use or management may change nutrient dynamics and may trigger a need for additional monitoring. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP assessments to a complete measure of target parameters above and below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration as nutrient sources are ubiquitous in the Boulder-Elkhorn TPA. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed.

Uncertainties in assessments and assumptions should not paralyze, but should point to the need to be flexible in our understanding of complex systems, and to adjust our thinking and analysis in response to this need. Implementation and monitoring recommendations presented in **Section 8.0** provide a basic framework for reducing uncertainty and furthering understanding of these issues.

There are several specific Boulder – Elkhorn TPA nutrient TMDL uncertainties that will need to be addressed via adaptive management. These include:

- the uncertainties regarding the elevated algae levels and impairment conditions for nitrate or other nutrients in Uncle Sam Gulch;
- the potential for remaining residual nutrient inputs from the 2000 forest fire in the Nursery Creek drainage; and
- the uncertainty regarding achievable TP load reductions below the reservoirs within McCarty Creek.

8.0 Other Identified Issues or Concerns

8.1 Non-Pollutant Listings

Water quality issues are not limited simply to those streams where TMDLs are developed. In some cases, streams have not yet been reviewed through the assessment process and do not appear on the 303(d) list. In other cases, streams in Boulder-Elkhorn TPA may appear on the 303(d) list but may not always require TMDL development for a pollutant, but do have non-pollutant listings such as "alteration in streamside or littoral vegetation covers" that could be linked to a pollutant. These habitat related non-pollutant causes are often associated with sediment issues, may be associated with nutrient or temperature issues, or may be having a deleterious effect on a beneficial use without a clearly defined quantitative measurement or direct linkage to a pollutant to describe that impact. Nevertheless, the issues associated with these streams are still important to consider when improving water quality conditions in individual streams, and the Boulder River watershed as a whole. In some cases, pollutant and *non-pollutant* causes are listed for a waterbody, and the management strategies as incorporated through the TMDL development for the pollutant, inherently address some or all of the non-pollutant listings. **Table 8-1** presents only the *non-pollutant* listings in the Boulder-Elkhorn TPA. Streams for which no TMDLs have been developed are presented in bold italics.

Table 8-1. Waterbody Segments in the Boulder-Elkhorn TPA with Sediment Related Pollutant and/or Non-pollutant (Pollution) Listings on the 2012 303(d) List

Waterbody ID	Stream Segment	2012 Probable Causes of Impairment
MT41E002_030	BASIN CREEK, headwaters to mouth (Boulder River)	Alteration in stream-ide or littoral vegetation covers
MT41E002_070	BISON CREEK, headwaters to mouth (Boulder River)	Alteration in streamside or littoral vegetative covers
MT41E001_021	***BOULDER RIVER***, Basin Creek to Town of Boulder	Alteration in streamside or littoral vegetation covers
MT41E001_022	BOULDER RIVER, Town of Boulder to Cottonwood Creek	Alteration in streamside or littoral vegetation covers; Low flow alterations
MT41E001_030	BOULDER RIVER, Cottonwood Creek to the mouth (Jefferson Slough), T9N R3W S2	Alteration in streamside or littoral vegetation covers; Low flow alterations
MT41E002_061	ELKHORN CREEK, headwaters to Wood Gulch	Alteration in streamside or littoral vegetation covers, Low flow alterations
MT41E002_062	ELKHORN CREEK, Wood Gulch to mouth (Unnamed Canal/Ditch), T5N R3W S21	Low flow alterations
MT41E002_040	HIGH ORE CREEK, headwaters to mouth (Boulder River)	Alteration in streamside or littoral vegetation covers
MT41E002_080	***LITTLE BOULDER RIVER***, North Fork to mouth (Boulder River)	Alteration in streamside or littoral vegetative covers, Physical substrate habitat alterations
MT41E002_050	***LOWLAND CREEK***, headwaters to mouth (Boulder River)	Alteration in streamside or littoral vegetative covers, Physical substrate habitat alterations

Table 8-1. Waterbody Segments in the Boulder-Elkhorn TPA with Sediment Related Pollutant and/or Non-pollutant (Pollution) Listings on the 2012 303(d) List

Waterbody ID	Stream Segment	2012 Probable Causes of Impairment
MT41E002_110	McCARTY CREEK, headwaters to mouth (Boulder River)	Alteration in streamside or littoral vegetative covers, Fish passage barrier; Low flow alterations
MT41E002_100	MUSKRAT CREEK, headwaters to mouth (Boulder River)	Alteration in streamside or littoral vegetative covers
MT41E002_090	NORTH FORK LITTLE BOULDER RIVER, headwaters to mouth (Little Boulder River)	Alteration in streamside or littoral vegetative covers
MT41E002_010	UNCLE SAM GULCH, headwaters to mouth (Cataract Creek)	Alteration in streamside or littoral vegetative covers; Other flow regime alterations

8.2 Non-Pollutant Causes of Impairment Determination

Non-pollutant listings are often used as a probable cause of impairment when available data at the time of assessment does not necessarily provide a direct quantifiable linkage to a specific pollutant, however non-pollutant sources or indicators do indicate impairment. In some cases the pollutant and non-pollutant categories are linked and appear together in the cause listings, however a non-pollutant category may appear independent of a pollutant listing. The following discussion provides some rationale for the application of the identified non-pollutant causes to a waterbody, and thereby provides additional insight into possible factors in need of additional investigation or remediation.

Alteration in Streamside or Littoral Vegetation Covers

Alteration in streamside or littoral vegetation covers refers to circumstances where practices along the stream channel have altered or removed riparian vegetation and subsequently affected channel geomorphology and/or stream temperature. This may include riparian vegetation removal for a road or utility corridor, effects of streamside mine tailings or placer mining remnants, or overgrazing by livestock along the stream. As a result of altering the streamside vegetation, destabilized banks from loss of vegetative root mass could lead to overwidened stream channel conditions and elevated sediment loads, in addition to elevated stream temperature from loss of canopy shade.

Physical Substrate Habitat Alterations

Physical substrate habitat alterations generally describe cases where the stream channel has been physically altered or manipulated, such as through the straightening of the channel or from human-influenced channel downcutting, resulting in a reduction of morphological complexity and loss of habitat (riffles and pools) for fish and aquatic life. For example, this may occur when a stream channel has been straightened to accommodate roads, agricultural fields, or through placer mine operations.

Fish Passage Barrier

Impairment caused by fish passage barriers is most often related to channel obstacles such as impoundments or perched culverts at road crossings. The impairments are addressed by modification or removal of the barriers or operational changes to allow migration of fish and other aquatic life. Any fish barrier removal must be done in coordination with state and federal fishery representatives since fish passage barriers can beneficially isolate native fish populations, protecting them from non-native invasive species. For example, the Montana FWP has worked with the USFS and the BLM on two projects to improve native cutthroat trout isolation by constructing physical barriers in Muskrat Creek and High Ore Creek.

In the Boulder watershed toxic barriers due to mine discharge create another form of fish barrier. Toxic fish barriers have been identified within at least three tributaries where the toxic barrier isolates native cutthroat from non-native trout (Jack Creek, High Ore Creek, and Little Boulder River).

Although maintenance of toxic stream conditions does not represent a desirable method for isolating native fish species, future projects to address toxic stream conditions should incorporate necessary barrier construction or other methods to maintain appropriate native fish isolation. For example, mine reclamation work associated with Jack Creek was conducted in a manner to improve distribution of native cutthroat while maintaining the isolated fishery upstream of the toxic reach of stream.

Low Flow Alterations

Streams are typically listed for low flow alterations when local water use management leads to base flows that are too low to fully support the beneficial uses designated for that system. This could result in dry channels or extreme low flow conditions harmful to fish and aquatic life.

Other Flow Regime Alterations

Other flow regime alterations may refer to scenarios where land or water management has led to flows that would not be typical under naturally occurring flow conditions. This could be related to irrigation practices, or dam release operations, or even groundwater use that has subsequently altered stream recharge.

In situations where causes of impairment are linked to flow conditions, it is the prerogative of local water users, agencies, and other associated entities to evaluate water and land management practices and address flow related concerns. The goal in addressing flow related causes of impairment is to improve conditions for aquatic life, while maintaining the needs and associated legal obligations of water right holders.

8.3 Monitoring and BMPs for Non-Pollutant Affected Streams

Two forms of habitat alteration (alteration in streamside or littoral vegetation covers and physical substrate habitat alterations) can be linked to the sediment TMDL development, where there is overlap between the two. It is likely that meeting the sediment targets will also equate to addressing the habitat impairment conditions in each of these streams. For the streams with no developed TMDL, meeting the sediment targets applied to streams of similar size will likely equate to addressing the habitat impairment condition for each stream.

Streams listed for *non-pollutants* as opposed to a pollutant should not be overlooked when developing watershed management plans. Attempts should be made to collect sediment, nutrient, and temperature information where data is minimal and the linkage between probable cause, non-pollutant listing, and effects to the beneficial uses are not well defined. Watershed management planning should also include strategies to help increase streamflows, particularly during summer low flow periods for those streams with low flow alteration impairment causes. The monitoring and restoration strategies that follow in **Sections 9.0** and **10.0** are presented to address both pollutant and non-pollutant issues for streams in the Boulder-Elkhorn TPA with TMDLs in this document, and they are equally applicable to streams listed for the above non-pollutant categories.

9.0 Framework Water Quality Restoration Strategy

9.1 Summary of Restoration Strategy

This section describes an overall strategy and specific on-the-ground measures designed to restore beneficial water uses and attain water quality standards in Boulder-Elkhorn TPA streams. The strategy includes general measures for reducing loading from each significant identified pollutant source.

This section should assist stakeholders in developing a more detailed adaptive Watershed Restoration Plan (WRP) in the future. The locally-developed WRP will likely provide more detailed information about restoration goals and spatial considerations within the watershed. The WRP may also encompass broader goals than the focused water quality restoration strategy outlined in this document. The intent of the WRP is to serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing types of projects, and funding sources towards achieving local watershed goals, including water quality improvements. Within this plan, the local stakeholders would identify and prioritize streams, tasks, resources, and schedules for applying Best Management Practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

The recommendations presented in this section are not necessarily appropriate for every situation or condition encountered in the watershed, nor do they suggest that the watershed is universally in need of restoration. In fact, some of the strategies described may currently be in use and undoubtedly there are land managers in the watershed who have made, and continue to make, conscious efforts for improvements to land use and water quality. This section is simply meant as a guide and introduction to measures that can be taken to facilitate improvement where needed. Application of the restoration strategy is with the discretion of the stakeholders.

9.2 Role of DEQ, Other Agencies, and Stakeholders

The DEQ does not implement TMDL pollutant reduction projects for nonpoint source activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally-driven WRPs, administer funding specifically to help support water quality improvement and pollution prevention projects, and can help identify other sources of funding.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers work collaboratively with local and state agencies to achieve water quality restoration to meet TMDL targets and load reductions. Specific stakeholders and agencies that have been, and will likely continue to be, vital to restoration efforts include the Lower Jefferson River Watershed Council, Jefferson Conservation District, USFS, USFWS, NRCS, DNRC, FWP, EPA, and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include the Montana Water Trust, Montana Water Center, University of Montana Watershed Health Clinic, Montana Bureau of Mines and Geology, Montana Aquatic Resources Services (MARS), and MSU Extension Water Quality Program.

9.3 Water Quality Restoration Objective

The following are general water quality goals provided in this TMDL document:

- Provide general technical guidance for full recovery of aquatic life beneficial uses to all impaired streams within the Boulder-Elkhorn TPA by improving pollutant and non-pollutant related water quality conditions. This technical guidance is provided by the TMDL components in the document which include:
  - water quality targets,
  - pollutant source assessments, and
  - a broad restoration and TMDL implementation strategy to meet TMDL allocations

A watershed restoration plan (WRP) can provide a framework strategy for water quality restoration and monitoring in the Boulder-Elkhorn TPA, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document, as well as other water quality issues of interest to local communities and stakeholders. Watershed restoration plans identify considerations that should be addressed during TMDL implementation and should assist stakeholders in developing a more detailed adaptive plan in the future. A locally developed WRP will likely provide more detailed information about restoration goals and spatial considerations but may also encompass more broad goals than this framework includes. A WRP would serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements. The WRP is intended to be a living document that can be revised based on new information related to restoration effectiveness, monitoring results, and stakeholder priorities. The following are key elements suggested for the WRP:

- Support for implementing restoration projects to protect water conditions so that all streams and aquatic resources in the watershed maintain good water quality, with an emphasis on waters with TMDLs completed.
- Detailed cost/benefit analysis and spatial considerations for water quality improvement projects.
- Develop an approach for future BMP installment and efficiency results tracking.
- Provide information and education components to assist with stakeholder outreach about restoration approaches, benefits, and funding assistance.
- Other various watershed health goals, such as weed control initiatives and wetland restoration.
- Other local watershed based issues.

Water quality goals for the various pollutants are detailed in **Sections 5.0, 6.0, and 7.0**. These goals include water quality and habitat targets as a measure for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of waterbodies in the Boulder-Elkhorn TPA. It is presumed that the meeting of all water quality and habitat targets will signal the achievement of water quality goals for a given stream. **Section 10.0** identifies a general monitoring strategy and recommendations to track post-implementation water quality conditions and measure restoration successes.

9.4 Overview of Management Recommendations

TMDLs were completed for thirteen waterbody segments for sediment, three waterbody segments for temperature, and five waterbody segments for nutrients. Metals impairments are discussed in a separate document. Other streams in the watershed may be in need of restoration or pollutant reduction, but insufficient about them precludes TMDL formation at this time. The following subsections describe some generalized recommendations for implementing projects to achieve the TMDL. Details specific to each stream, and therefore which of the following strategies may be most appropriate, are found within **Section 5.0, 6.0,** and **7.0**.

9.4.1 Sediment Restoration Approach

Streamside riparian and wetland vegetation restoration and long term riparian area and wetland management are vital restoration practices that must be implemented across the watershed to achieve the sediment TMDLs. Native streamside riparian and wetland vegetation provides root mass which hold streambanks together. Suitable root mass density ultimately slows bank erosion. Riparian and wetland vegetation filters pollutants from upland runoff. Therefore, improving riparian and wetland vegetation will decrease bank erosion by improving streambank stability and will also reduce pollutant delivery from upland sources. Suspended sediment is also deposited more effectively in healthy riparian zones and wetland areas during flooding because water velocities slow in these areas enough for excess sediment to settle out.

Riparian and wetland disturbance has occurred throughout the Boulder-Elkhorn TPA as a result of many influencing factors. Riparian timber harvest and the conversion of forest and valley bottoms for agriculture, mining, livestock production, and residential development have all had varying degrees of impact, depending on the drainage. Restoration recommendations involve the promotion of riparian and wetland recovery through improved grazing and land management (including the timing and duration of grazing, the development of multi-pasture systems that include riparian pastures, and the development of off-site watering areas), application of timber harvest best management practices, restoration of streams affected by mining activity, and floodplain and streambank stabilization and revegetation efforts where necessary. In general, natural recovery of disturbed systems is preferred however it is acknowledged that existing conditions may not readily allow for unassisted recovery in some areas where disturbance has occurred. Active vegetation planting and bank or stream channel reshaping may increase costs, but may be a reasonable and relatively cost effective restoration approach, depending on the site. When stream channel restoration work is needed because of altered stream channels, cost increases and projects should be assessed on a case by case basis. The implementation of BMPs should aim to prevent the availability, transport, and delivery of a pollutant through the most natural or natural-like means possible. Appropriate BMPs will differ by location and are recommended to be included and prioritized as part of a comprehensive watershed scale plan (e.g. WRP).

Although roads may be a small source of sediment at the watershed scale, sediment derived from roads may cause significant localized impact in some stream reaches. Restoration approaches for unpaved roads near streams should be to divert water off of roads and ditches before it enters the stream. The diverted water should be routed through natural healthy vegetation, which will act as filter zones for the sediment laden runoff before it enters streams. In addition, routine maintenance and upkeep of unpaved roads is a crucial component to limiting sediment production from roads. Sediment loads from culvert failure and culvert caused scour were not assessed by the TMDL source assessment, but should be considered in road sediment restoration approaches.

Assistance from resource professionals from various local, state, and federal agencies or non-profit groups should be available in the Boulder-Elkhorn TPA. In particular, the Jefferson Conservation District in Boulder and the NRCS are two resources that are valuable aids for assisting with investigating, developing, and implementing measures to improve conditions in the Boulder River watershed.

9.4.2 Temperature Restoration Approach

The goal of the temperature restoration approach is to reduce water temperatures where possible to be consistent with naturally occurring conditions. The most significant mechanisms for reducing water temperature are increasing shade and increasing flow. Secondarily, recovery of over-widened stream channels to a more natural morphology may also aid in reducing temperatures.

Increase in shade can be accomplished through the restoration and protection of shade-providing vegetation within the riparian corridor. This type of vegetation can also have the added benefit of serving as a stabilizing component to streambanks to reduce bank erosion, slow lateral river migration, and buffer pollutants from upland sources from entering the stream. In some cases, this can be achieved by limiting the frequency and duration of livestock access to the riparian corridor, or through other grazing related BMPs such as installing water gaps or off-site watering. Other areas may require planting, active bank restoration, and protection from browse to establish vegetation.

Increasing instream summer flows can be achieved through a thorough investigation of water use practices and water conveyance infrastructure, and a willingness and ability of local water users to keep more water instream. This TMDL document cannot, nor is it intended to, prescribe limitations on individual water rights owners and users. However, it is understood that increased summer instream flows could improve summer water temperatures, and in addition improve quality and connectivity among instream features used by aquatic life. Local water users should work collectively and with local, state, and federal resource management professionals to review water use options and available assistance programs.

Recovery of stream channel morphology in most cases, and in particular for the Boulder River, will occur slowly over time and follow the improvement of riparian condition, stabilization of streambanks, and reduction in overall sediment load. For smaller streams, there may be discrete locations or portions of reaches that demand a more rapid intervention through physical restoration, but size, scale, and cost of restoration in most cases are limiting factors to applying a constructed remedy. In addition, the effects of channel morphology on temperature are probably more significant for small streams such as High Ore Creek, rather than large and naturally wide streams like the Boulder River.

The above approaches give only the broadest description of activities to help reduce water temperatures. The temperature assessment described in **Section 6.0** looked at possible scenarios based on limited information at the watershed scale. Those scenarios showed that improvements in stream temperatures can be made through increased shade and flow, but site-specific analysis and detailed review of current land management and water use practices was not included in the assessment. Therefore, it is not suggested that every operator and water user in the basin need to change their practices in order to reduce stream temperatures; there may be some who currently manage their land and water use consistent with all reasonable land, soil, and water conservation practices, and there may be others for whom changing their practices at this stage is not a viable option due to economic or other constraints. Nevertheless, it is strongly encouraged that continued investigations be conducted by resource managers and land owners to identify all potential areas of improvement and develop projects and practices to reduce stream temperatures in the Boulder River and High Ore Creek watersheds.

9.4.3 Nutrients Restoration Approach

The goal of the nutrient restoration strategy is to reduce nutrient input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients from rangeland , cropland and historically impacted areas (mining).

Cropland filter strip extension, vegetative restoration, and long-term filter area maintenance are vital BMPs for achieving nutrient TMDLs in predominantly agricultural watersheds. Grazing systems with the explicit goal of increased vegetative post-grazing ground cover are needed to address the same nutrient loading from rangelands. Grazing prescriptions that enhance the filtering capacity of riparian filter areas offer a second tier of controls on the sediment content of upland runoff. Grazing and pasture management adjustments should consider:

- The timing and duration of near-stream grazing
- The spacing and exposure duration of on-stream watering locations
- Provision of off-stream site watering areas to minimize near-stream damage and allow impoundment operations that minimize salt accumulations
- Active reseeding and rest rotation of locally damaged vegetation stands
- Improved management of irrigation systems and fertilizer applications
- Incorporation of streamside vegetation buffer to irrigated croplands and animal feeding areas

In addition to the agricultural related BMPs, a reduction of sediment delivery from roads and eroding streambanks is another component of the nutrient reduction restoration plan. Additional sediment related BMPs are presented in **Section 9.4.1**

In general, these are sustainable grazing and cropping practices that can reduce nutrient inputs while meeting production goals. The appropriate combination of BMPs will differ according to landowner preferences and equipment but are recommended as components of comprehensive plan for farm and ranch operators. Sound planning combined with effective conservation BMPs should be sought whenever possible and applied to croplands, pastures and livestock handling facilities. Assistance from resource professionals from various local, state, and federal agencies or non-profit groups is widely available in Montana. The local USDA Service Center and county Conservation District offices are geared to offer both planning and implementation assistance.

Potential nutrient loading sources associated with historical mining practices include discharging mine adits and mine waste materials on-site and in-channel. The goal of the nutrient restoration strategy is to limit the input of nutrients to stream channels from abandoned mine sites and other mining related sources. For most of the mining-related sources, additional analysis and identification will likely be required to identify site-specific delivery pathways and to develop mitigation plans.

Goals and objectives for future restoration work include the following:

- Prevent contaminants or nutrients contaminated solid materials in the waste rock and tailings materials/sediments from migrating into adjacent surface waters to the extent practicable
- Reduce or eliminate concentrated runoff and discharges that generate sediment and/or heavy contamination to adjacent surface waters and groundwater to the extent practicable
- Identify, prioritize, and select response and restoration actions based on a comprehensive source assessment and streamlined risk analysis of areas affected by historical mining.

9.4.4 Pollution Restoration Approach

Although TMDL development is not required for pollution listings, they are frequently linked to pollutants, and addressing pollution sources is an important component of TMDL implementation. Pollution listings within the Boulder-Elkhorn TPA are described in **Section 8.0**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Therefore, if restoration goals within the Boulder-Elkhorn TPA are not also addressing pollution impairments, additional pollution-related BMP implementation should be considered.

9.5 Restoration Approaches by Source

Generalized management recommendations are outlined below for the major sources of human caused pollutant loads in the Boulder-Elkhorn TPA: grazing, upland sources, riparian and wetland vegetation removal, irrigation, roads and historical mining practices. Applying BMPs are the core of the pollutant reduction strategy, but are only part of a watershed restoration strategy. Restoration activities may also address other current pollution-causing uses and management practices. In some cases, efforts beyond implementing new BMPs may be required to address key pollutant sources. In these cases, BMPs are usually identified as a first effort and an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is also an important part of the restoration process. Monitoring recommendations are outlined in **Section 10.0**.

9.5.1 Agriculture Sources

Reduction of pollutants from upland agricultural sources can be done by limiting the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil and runoff before it enters a waterbody. The main BMP recommendations for the Boulder River watershed are riparian buffers, wetland restoration, and vegetated filter strips, where appropriate. These methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept pollutants. Filter strips and buffers are even more effective for reducing upland agricultural related sediment when used in conjunction with BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, and stripcropping (although currently there is very little cropping activity that occurs in the Boulder River watershed). Additional BMP information, design standards and effectiveness, and details on the suggested BMPs can be obtained from your local USDA Agricultural Service Center and in Montana's NPS Management Plan (Montana Department of Environmental Quality, 2012b).

An additional benefit of reducing sediment input to the stream is a decrease in sediment-bound nutrients. Reductions in sediment loads may help address some nutrient related problems. Nutrient management considers the amount, source, placement, form, and timing of plant nutrients and soil amendments. Conservation plans should include the following information (NRCS MT 590-1):

- Field maps and soil maps
- Planned crop rotation or sequence
- Results of soil, water, plant, and organic materials sample analysis
- Realistic expected yields
- Sources of all nutrients to be applied
- A detailed nutrient budget
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns

- Location of designated sensitive areas
- Guidelines for operation and maintenance

9.5.1.1 Grazing

Development of riparian grazing management plans should be a goal for any landowner in the watershed who operates livestock and does 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 riparian corridors. Nevertheless, in some areas, a more limited management strategy may be necessary for a period of time in order to accelerate re-establishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The plan should at least include the following elements:

- A map of the operation showing fields, riparian and wetland areas, winter feeding areas, water sources, animal shelters, etc.
- The number and type of livestock
- Realistic estimates of forage needs and forage availability
- The size and productivity of each grazing unit (pasture/field/allotment)
- The duration and time of grazing
- Practices that will prevent overgrazing and allow for appropriate regrowth
- Practices that will protect riparian and wetland areas and associated water quality
- Procedures for monitoring forage use on an ongoing basis
- Development plan for off-site watering areas

Reducing grazing pressure in riparian and wetland areas and improving forage stand health are the two keys to preventing nonpoint source pollution from grazing. Grazing operations should use some or all of the following practices:

- Minimizing or preventing livestock grazing in riparian and wetland areas
- Providing off-stream watering facilities or using low-impact water gaps to prevent 'loafing' in wet areas
- Managing riparian pastures separately from upland pastures
- Installing salt licks, feeding stations, and shelter fences to prevent 'loafing' in riparian areas
- Replanting trodden down banks and riparian and wetland areas with native vegetation (this should always be coupled with a reduction in grazing pressure)
- Rotational grazing or intensive pasture management

The following resources may be able to help you prevent pollution and maximize productivity from your grazing operation:

- USDA, Natural Resources Conservation Service. You can find your local USDA Agricultural Service Center listed in your phone directory or on the Internet at www.nrcs.usda.gov
- Montana State University Extension Service www.extn.msu.montana.edu
- DEQ Watershed Protection Section, Nonpoint Source Program www.deq.mt.gov/wqinfo/nonpoint/NonpointSourceProgram

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian and wetland vegetation and minimize disturbance of the streambank and channel. The primary recommended BMPs for the Boulder River watershed are limiting livestock access to streams and stabilizing the stream at access points, providing off-site watering sources when and where appropriate, planting native stabilizing vegetation along streambanks, and establishing and maintaining riparian buffers. Although bank re-vegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation.

9.5.1.2 Animal Feeding Operations

Animal feeding operations (AFOs) can pose a number of risks to water quality and public health if the animal manure and wastewater they generate contaminates nearby waters. To minimize water quality and public health concerns from AFOs and land applications of animal waste, the USDA and EPA released the Unified National Strategy for AFOs in 1999 (United States Department of Agriculture, Natural Resources Conservation Service, 2005). This strategy encouraged owners of AFOs of any size or number of animals to voluntarily develop and implement site-specific Comprehensive Nutrient Management Plans (CNMPs). A CNMP is a written document detailing manure storage and handling systems, surface runoff control measures, mortality management, chemical handling, manure application rates, schedules to meet crop nutrient needs, land management practices, and other options for manure disposal.

An AFO that meets certain specified criteria is referred to as a Concentrated Animal Feeding Operation (CAFO). CAFOs may be required to obtain a Montana Pollution Discharge Elimination System (MPDES) permit as a point source. Montana's AFO compliance strategy is based on federal law and has voluntary, as well as, regulatory components. If voluntary efforts can eliminate discharges to state waters, no direct regulation is necessary through a permit.

Operators of AFOs may take advantage of effective, low cost practices to reduce potential runoff to state waters. In addition to water quality benefits, these practices may help to increase property values and operation productivity. Properly installed vegetative filter strips, in conjunction with other practices to reduce wasteloads and runoff volume, are very effective at trapping and detaining sediment and reducing transport of nutrients and pathogens to surface waters, with removal rates approaching 90 percent (United States Department of Agriculture, Natural Resources Conservation Service, 2005). Other options may include clean water diversions, roof gutters, berms, sediment traps, fencing, structures for temporary manure storage, shaping, and grading. Animal health and productivity also benefit when clean, alternative water sources are installed to prevent contamination of surface water. Studies have shown benefits in red meat and milk production of 10 to 20 percent by livestock and dairy animals when good quality drinking water is substituted for contaminated surface water.

Opportunities for financial and technical assistance (including CNMP development) in achieving voluntary AFO and CAFO compliance may be available from conservation districts, NRCS field offices, or the Montana DEQ Watershed Protection Section (among other sources). Further information on CAFO discharge permitting may be obtained from the DEQ website at:
www.deq.mt.gov/wqinfo/mpdes/cafo.mcpx

Montana's NPS pollution control strategies for addressing AFOs are summarized in the bullets below:

- Work with producers to prevent NPS pollution from AFOs.
- Promote use of State Revolving Fund for implementing AFO BMPs.

- Collaborate with MSU Extension Service, NRCS, and agriculture organizations in providing resources and training in whole farm planning to farmers, ranchers, conservation districts, watershed groups and other resource agencies.
- Encourage inspectors to refer farmers and ranchers with potential nonpoint source discharges to DEQ watershed protection staff for assistance with locating funding sources and grant opportunities for BMPs that meet their needs. (This is in addition to funds available through NRCS and the Farm Bill).
- Develop early intervention of education & outreach programs for small farms and ranches that have potential to discharge nonpoint source pollutants from animal management activities. This includes assistance from the DEQ Permitting Division, as well as external entities such as DNRC, local watershed groups, conservation districts, and MSU Extension.

9.5.1.3 Flow and Irrigation

Flow alteration and dewatering are commonly considered water quantity rather than water quality issues. However, changes to streamflow can have a profound effect on the ability of a stream to attenuate pollutants, especially nutrients, metals and heat. Flow reduction may increase water temperature, allow sediment to accumulate in stream channels, reduce available habitat for fish and other aquatic life, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation if flood flows are reduced (Andrews and Nankervis, 1995; Schmidt and Potyondy, 2004). Restoration targets and implementation strategies recognize the need for specific flow regimes, and may suggest flow-related improvements as a means to achieve full support of beneficial uses. However, local coordination and planning are especially important for flow management because State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705).

Irrigation management is a critical component of attaining both coldwater fishery conservation and TMDL goals. Management practices for irrigation efficiency in the Boulder River watershed should investigate reducing the amount of stream water diverted during July and August, while still maintaining healthy crops or forage. It may also be desirable to investigate irrigation practices earlier in the year that promote groundwater return during July, August, and September. Understanding irrigation water, groundwater and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons.

Some irrigation practices in western Montana are based in flood irrigation methods. Occasionally, head gates and ditches leak, which can decrease the amount of water in diversion flows. The following recommended activities could result in notable water savings.

- Install upgraded head gates for more exact control of diversion flow and to minimize leakage when not in operation.
- Develop more efficient means to supply water to livestock.
- Determine necessary diversion flows and timeframes that would reduce over watering and improve forage quality and production.
- Where appropriate, redesign or reconfigure irrigation systems.
- Upgrade ditches (including possible lining) to increase ditch conveyance efficiency.

Future studies could investigate irrigation water return flow timeframes from specific areas along the Boulder River watershed. Some water from spring and early summer flood irrigation likely returns as cool groundwater to the streams during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas where year round irrigation efficiencies could be more beneficial than seasonal management practices. Winter baseflow should also be considered during these investigations.

9.5.1.4 Small Acreages

Throughout Montana, the number of small acreage properties is growing rapidly, and many small acreage owners own horses or cattle. Animals grazing in small acreages can lead to overgrazing and a shortage of grass cover, leaving the soil subject to erosion and runoff to surface waters. General BMP recommendations for small acreage lots with animals include creating drylots, developing a rotational grazing system, and maintaining healthy riparian buffers. Small acreage owners should collaborate with MSU Extension Service, NRCS, conservation districts and agricultural organizations to develop management plans for their lots. Further information may be obtained from the Montana Nonpoint Source Management Plan (Montana Department of Environmental Quality, 2012b) or the MSU extension website at: http://www.msuextension.org/ruralliving/Index.html.

9.5.1.5 Cropland

The primary strategy of the recommended cropland BMPs is to reduce sediment inputs. The major factors involved in decreasing sediment loads are reducing the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil before it enters waterbodies. The main BMP recommendations for the Boulder-Elkhorn TPA are vegetated filter strips (VFS) and riparian buffers. Both of these methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70 percent for the filter strips and 50 percent for the buffers (Montana Department of Environmental Quality, 2012b). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, strip cropping, and precision farming. Filter strips along streams should be composed of natural vegetative communities. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in Appendix A of Montana's NPS Management Plan (Montana Department of Environmental Quality, 2012b).

9.5.2 Forestry and Timber Harvest

Currently, active timber harvest is not significantly affecting sediment or nutrient loads in the Boulder - Elkhorn TPA, but harvesting will likely continue in the future within the Beaverhead-Deer Lodge National Forest, and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University, Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a waterbody), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. The DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

Timber harvest should not increase the peak water yield by more than 10 percent of historic conditions. If a natural disturbance, such as a forest fire, increases peak water yield, the increase should be accounted for as part of timber harvest management.

In addition to the BMPs identified above, effects that timber harvest may have on yearly streamflow levels, such as peak flow, should be considered. Water yield and peak flow increases should be modeled in areas of continued timber harvest and potential effects should be evaluated. Furthermore, noxious weed control should be actively pursued in all harvest areas and along all forest roads.

9.5.3 Riparian Areas, Wetlands, and Floodplains

Riparian areas, wetlands, and floodplains are critical for wildlife habitat, groundwater recharge, reducing the severity of floods and upland and streambank erosion, and filtering pollutants from runoff. The performance of the above named functions is dependent on the connectivity of riparian areas, wetlands and floodplains to both the stream channel and upland areas. Anthropogenic activities affecting the quality of these transitional habitats or their connectivity can alter their performance and greatly affect the transport of water, sediments, and contaminants (e.g. channelization, increased stream power, bank erosion, and habitat loss or degradation). Therefore, restoring maintaining, and protecting riparian areas, wetlands, and floodplains within the watershed should be a priority of TMDL implementation in the Boulder- Elkhorn TPA.

Reduction of riparian and wetland vegetative cover by various land management activities is a principal cause of water quality and habitat degradation in watersheds throughout Montana. Although implementation of passive BMPs that allow riparian and wetland vegetation to recover at natural rates is typically the most cost-effective approach, active restoration (i.e. plantings) may be necessary in some instances. The primary advantage of riparian and wetland plantings is that installation can be accomplished with minimum impact to the stream channel, existing vegetation, and private property.

Factors influencing the appropriate riparian and wetland restoration would include severity of degradation, site-potential for various species, and availability of local sources for native transplant materials. In general, riparian and wetland plantings would promote establishment of functioning stands of native species. The following recommended restoration measures would allow for stabilization of the soil, decrease sediment delivery to the stream, and increase absorption of nutrients from overland runoff.

- Harvest and transplant locally available sod mats with an existing dense root mass which provide immediate promotion of bank stability and filtering nutrients and sediments.
- Transplanting mature native shrubs, particularly willows (*Salix* sp.), provides rapid restoration of instream habitat and water quality through overhead cover and stream shading as well as uptake of nutrients.
- Seeding with native graminoids (grasses and sedges) and forbs is a low cost activity at locations where lower bank shear stresses would be unlikely to cause erosion.
- Willow sprigging expedites vegetative recovery, but involves harvest of dormant willow stakes from local sources.

Note: Before transplanting *Salix* from one location to another it is important to determine the exact species so that we do not propagate the spread of non-native species. There are several non-native willow species that are similar to our native species and commonly present in Montana watersheds.

In addition to the benefits noted above, it should be noted that in some cases wetlands act as areas of shallow subsurface groundwater recharge and/or storage areas, and can have added benefits to the issues discussed in **Section 6.0**. The captured water via wetlands is then generally discharged to the stream later in the season and contributes to the maintenance of base flows and stream temperatures. Restoring ditched or drained wetlands can have a substantial effect on the quantity, temperature, and timing of water returning to a stream, as well as the pollutant filtering capacity that improved riparian and wetlands provide.

9.5.4 Unpaved Roads

The road sediment reductions in this document represent a gross estimation of the sediment load that would remain once road BMPs were applied, assuming no current BMPs are in place. In general, a road with associated BMPs assumes contributing road treads, cutslopes, and fillslopes were reduced to 100 feet (from each side of a crossing). This distance is selected as an example to illustrate the potential for sediment reduction through BMP application and is not a formal goal at every crossing. For example, many roads may easily allow for a smaller contributing length, while others may not be able to meet a 100ft goal. Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana's NPS Management Plan (Montana Department of Environmental Quality, 2007). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, and up-grade of stream crossings.
- Use rolling dips on downhill grades with an embankment on one side to direct flow to the ditch.
- Inslope roads along steep banks with the use of cross slopes and cross culverts.
- Outslope low traffic roads on gently sloping terrain with the use of a cross slope.
- Use ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches.
- For maintenance, grade materials to the center of the road and avoid removing the toe of the cutslope.
- Prevent disturbance to vulnerable slopes.
- Use topography to filter sediments; flat, vegetated areas are more effective sediment filters.
- Where possible, limit road access during wet periods when drainage features could be damaged.

9.5.4.1 Culverts

Although culverts were not part of the source assessment, they can be large sources of sediment, and should be included in the restoration strategy. A field survey should be conducted and combined with local knowledge to prioritize culverts for restoration. As culverts fail, they should be replaced with culverts that pass a 100 year flood on fish bearing streams and at least 25 year events on non-fish bearing streams. Culverts should be installed at grade with the streambed, and inlets and outlets should be vegetated and armored. Some road crossings may not pose a feasible situation for size upgrades because of road bed configuration; in those circumstances, the largest size culvert feasible should be used.

Another consideration for culvert upgrades will be to provide fish passage. During the assessment and prioritization of culverts, additional crossings should be assessed for streams where fish passage is a concern. Each fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana FWP can aid in determining if a fish passage barrier should be mitigated, and, if so, they should be involved in culvert design. If funding is available, culverts should be prioritized and replaced prior to failure.

9.5.4.2 Traction Sand

Severe winter weather and mountainous roads in the Boulder-Elkhorn TPA will require the continued use of relatively large quantities of traction sand. Nevertheless, closer evaluation of and adjustments to existing practices should be done to reduce traction sand loading to streams the extent practicable. The necessary BMPs may vary throughout the watershed and particularly between state and private roads but may include the following:

- Utilize a snow blower to directionally place snow and traction sand on cutslopes/fillslopes away from sensitive environments.
- Increase the use of chemical deicers and decrease the use of road sand, as long as doing so does not create a safety hazard or cause undue degradation to vegetation and water quality.
- Improve maintenance records to better estimate the use of road sand and chemicals, as well as to estimate the amount of sand recovered in sensitive areas.
- Continue to fund MDT research projects that will identify the best designs and procedures for minimizing road sand impacts to adjacent bodies of water and incorporate those findings into additional BMPs.
- Street sweeping and sand reclamation.
- Identify areas where the buffer could be improved or structural control measures may be needed.
- Improved maintenance of existing BMPs.
- Increase availability of traction sand BMP training to both permanent and seasonal MDT employees as well as private contractors.

9.5.5 Bank Hardening/Riprap/Revetment/Floodplain Development

The use of riprap or other “hard” approaches is not recommended and is not consistent with water quality protection or implementation of this plan. Although it is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated threat to infrastructure. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of the upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit threats to infrastructure by reducing floodplain development through land use planning initiatives.

Bank stabilization using natural channel design techniques can provide both bank stability and habitat potential. The primary recommended structures include natural or “natural-like” structures, such as 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 together, woody debris jams and straight log vanes can benefit the stream and fishery by improving bank stability, reducing bank erosion rates, adding protection to fillslopes and/or embankments, reducing near-bank shear stress, and enhancing aquatic habitat and lateral channel margin complexity.

9.5.6 Mining

Metals pollutants and associated TMDLs are addressed in detail in the “Boulder-Elkhorn Metals TMDLs and Framework Water Quality Improvement Plan” (Montana Department of Environmental Quality, 2012a). Restoration approaches that deal with the impacts from mining are discussed within that document. Mining activities may have impacts that extend beyond increased metal concentrations in the water however; channel alteration, riparian degradation, and runoff and erosion associated with mining can lead to sediment, habitat, nutrient, and temperature impacts as well. The need for further characterization of impairment conditions and loading sources is addressed through the framework monitoring plan in **Section 10.0**. Since the 2012 Boulder-Elkhorn Metals TMDL discusses the mining affects in greater detail, this section will simply describe a number of potential funding sources that can be used to address reclamation or restoration of lands effected from mining.

A number of state and federal regulatory programs have been developed over the years to address water quality problems stemming from historic mines, associated disturbances, and metal refining impacts. Some regulatory programs and approaches that may be applicable to the Boulder River watershed include:

- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA),
- The State of Montana Mine Waste Cleanup Bureau's Abandoned Mine Lands (AML) Reclamation Program,
- The Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA), which incorporates additional cleanup options under the Controlled Allocation of Liability Act (CALA) and the Voluntary Cleanup and Redevelopment Act (VCRA).

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
CERCLA, which is also common referred to as Superfund, is a Federal law that addresses cleanup on sites, such as historic mining areas, where there has been a hazardous substance release or threat of release. Sites are prioritized on the National Priority List (NPL) using a hazard ranking system with significant focus on human health. Under CERCLA, the potentially responsible party or parties must pay for all remediation efforts based upon a liability approach whereby any existing or historical land owner can be held liable for restoration costs. Where viable landowners are not available to fund cleanup, funding can be provided under Superfund authority. Federal agencies can be delegated Superfund authority, but cannot access funding from Superfund.

Cleanup actions under CERCLA must be based on professionally developed plans and can be categorized as either Removal or Remedial. Removal actions can be used to address the immediate need to stabilize or remove a threat where an emergency exists. Removal actions can also be non-time critical.

Once removal activities are completed, a site can then undergo Remedial Actions or may end up being scored low enough from a risk perspective that it no longer qualifies to be on the NPL for Remedial Action. Under these conditions the site is released back to the state for a "no further action" determination. At this point there may still be a need for additional cleanup since there may still be significant environmental threats or impacts, although the threats or impacts are not significant enough to justify Remedial Action under CERCLA. Any remaining threats or impacts would tend to be associated with wildlife, aquatic life, or aesthetic impacts to the environment or aesthetic impacts to drinking water supplies versus threats or impacts to human health. A site could, therefore, still be a concern from a water quality restoration perspective, even after CERCLA removal activities have been completed.

Remedial actions may or may not be associated with or subsequent to removal activities. A remedial action involves cleanup efforts whereby Applicable or Relevant and Appropriate Requirements and Standards (ARARS), which include state water quality standards, are satisfied. Once ARARS are satisfied, then a site can receive a "no further action" determination.

Montana Mine Waste Cleanup Bureau Abandoned Mine Reclamation Program (AML)
The Mine Waste Cleanup Bureau (MWCB), which is part of the DEQ Remediation Division, is responsible for reclamation of historical mining disturbances associated with abandoned mines in Montana.

The MWCB abandoned mine reclamation program is funded through the Surface Mining Control and Reclamation Act of 1977 (SMCRA) with SMCRA funds distributed to states by the federal government. In order to be eligible for SMCRA funding, a site must have been mined or affected by mining processes, and abandoned or inadequately reclaimed, prior to August 3, 1977 for private lands, August 28, 1974 for Forest Service administered lands, and prior to 1980 for lands administered by the U.S. Bureau of Reclamation. Furthermore, there must be no party (owner, operator, other) who may be responsible for reclamation requirements, and the site must not be located within an area designated for remedial action under the federal Superfund program or certain other programs.

Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA)
Reclamation of historic mining-related disturbances administered by the State of Montana and not addressed under SMCRA, are typically addressed through the DEQ State Superfund or CECRA program. The CECRA program maintains a list of facilities potentially requiring response actions based on the confirmed release or substantial threat of a release of a hazardous or deleterious substance that may pose an imminent and substantial threat to public health, safety or welfare or the environment (ARM 17.55.108). Listed facilities are prioritized as maximum, high, medium, or low priority or in operation and maintenance status based on the potential threat posed.

CECRA also encourages the implementation of voluntary cleanup activities under the VCRA and CALA. It is possible that any historic mining-related metals loading sources identified in the watershed in the future could be added to the CECRA list and addressed through CECRA, with or without the VCRA and/or CALA process. A site can be added to the CECRA list at DEQ's initiative, or in response to a written request made by any person to the department containing the required information.

9.5.7 Storm Water Construction Permitting and BMPs

Construction activities disturb the soil, and if not managed properly, they can be substantial sources of sediment. Construction activity disturbing one acre or greater is required to obtain permit coverage through DEQ under the Storm Water Permit for Construction Activities. A Storm Water Pollution Prevention Plan (SWPPP) must be developed and submitted to obtain a permit. A SWPPP identifies pollutants of concern, which is most commonly sediment, construction related sources of those pollutants, any nearby waterbodies that could be affected by construction activities, and BMPs that will be implemented to minimize erosion and discharge of pollutants to waterbodies. The SWPPP must be implemented for the duration of the project, including final stabilization of disturbed areas, which is a vegetative cover of at least 70% of the pre-disturbance level or an equivalent permanent stabilization measure. Development and implementation of a thorough SWPPP should ensure WLAs within this document are met.

Land disturbance activities that are smaller than an acre (and exempt from permitting requirements) also have the potential to be substantial pollutant sources, and BMPs should be used to prevent and control erosion consistent with the upland erosion allocations. Potential BMPs for all construction activities include construction sequencing, permanent seeding with the aid of mulches or geotextiles, check dams, retaining walls, drain inlet protection, rock outlet protection, drainage swales, sediment basin/traps, earth dikes, erosion control structures, grassed waterways, infiltration basins, terraced slopes, tree/shrub planting, and vegetative buffer strips. An EPA support document for the construction permits has extensive information about construction related BMPs, including limitations, costs, and effectiveness (U.S. Environmental Protection Agency, 2009).

9.5.8 Urban Area Stormwater BMPs

Although towns like Boulder and Basin do not have a large enough population to require a municipal stormwater permit, activities to reduce pollutant loading from new development or redevelopment should be pursued consistent with the upland erosion allocations and efforts to avoid future water quality problems. Any BMPs which promote onsite or after collection infiltration, evaporation, transpiration or reuse of the initial flush stormwater should be implemented as practicable on all new or redevelopment projects. EPA provides more comprehensive information about stormwater best management practices on their website at:
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

9.6 Potential Funding Sources

Funding and prioritization of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies fund watershed or water quality improvement projects. Below is a brief summary of potential funding sources to assist with TMDL implementation.

9.6.1 Section 319 Nonpoint Source Grant Program

Section 319 grant funds are typically used to help identify, prioritize, and implement water quality protection projects with focus on TMDL development and implementation of nonpoint source projects. Individual contracts under the yearly grant typically range from $20,000 to $150,000, with a 40 percent match requirement. 319 projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

9.6.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by FWP and offers funding for on-the-ground projects that focus on habitat restoration to benefit wild and native fish. Anyone ranging from a landowner or community-based group to a state or local agency is eligible to apply. Applications are reviewed annually in December and June. Projects that may be applicable to the Boulder River watershed include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats.

9.6.3 Watershed Planning and Assistance Grants

The MT DNRC administers Watershed Planning and Assistance Grants to watershed groups that are sponsored by a conservation district. Funding is capped at $10,000 per project and the application cycle is quarterly. The grant focuses on locally developed watershed planning activities; eligible activities include developing a watershed plan, group coordination costs, data collection, and educational activities.

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and

Assistance Division, Water Quality Planning Bureau, 2012) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

9.6.4 Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is administered by NRCS and offers financial (i.e., incentive payments and cost-share grants) and technical assistance to farmers and ranchers to help plan and implement conservation practices that improve soil, water, air and other natural resources on their land. The program is based on the concept of balancing agricultural production and forest management with environmental quality, and is also used to help producers meet environmental regulations. EQIP offers contracts with a minimum length of one year after project implementation to a maximum of 10 years. Each county receives an annual EQIP allocation and applications are accepted continually during the year; payments may not exceed $300,000 within a six-year period.

9.6.5 Resource Indemnity Trust/Reclamation and Development Grants Program

The Resource Indemnity Trust/Reclamation and Development Grants Program (RIT/RDG) is an annual program administered by MT DNRC that can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the AML priority list, but of low enough priority where cleanup under AML is uncertain. RIT/RDG program funds can also be used for conducting site assessment/characterization activities such as identifying specific sources of water quality impairment. RIT/RDG projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

10.0 MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

10.1 INTRODUCTION

The monitoring strategies discussed in this section are an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis, however the scale of the watershed coupled with constraints on time and resources often result in compromises that must be made that include estimations, extrapolation, and a level of uncertainty. The margin of safety (MOS) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy presented in this section provides a starting point for the development of more detailed and specific planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet aforementioned goals. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on stakeholder priorities for restoration and funding opportunities.

10.2 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach is recommended to control costs and meet the water quality standards to support all beneficial uses. This approach works in cooperation with the monitoring strategy, and as new information is collected, it allows for adjustments to restoration goals or pollutant targets, TMDLs, and/or allocations, as necessary.

10.3 FUTURE MONITORING GUIDANCE

The objectives for future monitoring in the Boulder River watershed include: 1) strengthen the spatial understanding of sources for future restoration work, which will also strengthen source assessment analysis for future TMDL review, 2) gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development, 3) gather consistent information among agencies and watershed groups that is comparable to targets and allows for common threads in discussion and analysis, 4) expand the understanding of streams throughout the Boulder River watershed beyond those where TMDL have been developed and address issues if necessary, and 5) track restoration projects as they are implemented and assess their effectiveness.

10.3.1 Strengthening Source Assessment

In the Boulder-Elkhorn TMDL Planning Area (TPA), the identification of sources was conducted largely through watershed field tours, aerial assessment, the incorporation of GIS information, available data and literature review, with limited field verification and on-the-ground analysis. In many cases, assumptions were made based on overall TPA conditions and extrapolated throughout the watershed. As a result, the level of detail often does not provide specific areas by which to focus restoration efforts, only broad source categories to reduce sediment loads from each of the discussed subwatersheds. Strategies for strengthening source assessments for each of the pollutants may include:

Sediment
Field surveys of road and road crossing to identify specific contributing road crossings, their associated loads, and prioritize those road segments/crossings of most concern.

Review of land use practices specific to subwatersheds of concern to determine where the greatest potential for improvement and likelihood of sediment reduction can occur for the identified major land use categories.

More thorough examinations of bank erosion conditions and investigation of related contributing factors for each subwatershed of concern through site visits and subwatershed scale BEHI assessments. Additionally, the development of bank erosion retreat rates specific to the Boulder-Elkhorn TPA would provide a more accurate quantification of sediment loading from bank erosion. Bank retreat rates can be determined by installing bank pins at different positions on the streambank at several transects across a range of landscapes and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions.\

Temperature
Field surveys to better identify riparian area conditions and potential for improvement.

Additional temperature data logger recordings throughout the Boulder River and at major tributary or irrigation return inputs to better discern temperature fluctuations and causes.

Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in the valley.

Assessment of water use in the valley and potential for improvements in water use that would result in increased in streamflows.

Flow measurements at all temperature data locations at the time of data collection.

Nutrients
Nutrient-related information that could help strengthen the source assessment is as follows:

- a better understanding of septic contributions to nutrient loads
    - for Bison Creek which has the greatest potential for contributions from septic systems
- a better understanding of nutrient concentrations in groundwater and spatial variability
- a better understand on nutrient contributions from mining sources
    - particularly in Uncle Sam Gulch
- a better understanding of irrigation networks and their effect on hydrology and nutrient concentrations
    - for Basin Creek which may receive runoff from surface irrigation
    - for McCarty Creek and the surface water impoundment structure
- a more detailed understanding of fertilization practices within the watershed

- a review of land management practices specific to sub-watersheds of concern to determine where the greatest potential for improvement can occur for the major land use categories,
- additional sampling in all streams, particularly those with limited or no data

10.3.2 Increase Available Data

While the Boulder River watershed has been the recipient of significant remediation and restoration activities, data is still often limited depending on the stream and pollutant of interest. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition, however regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change.

Sediment

For sediment investigation in the Boulder River watershed, each of the streams of interest were stratified into unique reaches based on physical characteristics and anthropogenic influence. A total of 25 sites were sampled throughout the watershed, however this equates to only a small percentage of the total number of stratified reaches, and even less on a stream by stream basis. Sampling additional monitoring locations to represent some of the various reach categories that occur would provide additional data to assess existing conditions, and provide more specific information on a per stream basis as well as the TPA as a whole, by which to assess reach by reach comparisons and the potential influencing factors and resultant outcomes that exist throughout the watershed.

Temperature

Temperature investigation for the Boulder River included over 20 data loggers that were deployed throughout the river and at a few key tributary inputs. Increasing the number of data logger locations and the number of years of data, and collecting associated flow data, would improve our understanding of instream temperature changes in the river, and better identify influencing factors on those changes.

Nutrients

Water quality sampling for nutrients was distributed spatially along each assessment unit in order to best delineate nutrient sources. Over multiple sample seasons, sampling locations were refined to better quantify loading sources to the impaired waterbodies.

Source refinement and nutrient loading dynamics will continue to be necessary on streams with TMDLs and those that have not yet been assessed in the Boulder Elkhorn TPA. It will also be important to continually assess nutrient sources in a watershed with changing land uses and/or new MPDES permitted discharges to surface waters.

10.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Boulder River watershed for many years and by many different agencies and entities, however the type and quality of information is often variable. Where ever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

The Montana Department of Environmental Quality (DEQ) is the lead agency for developing and conducting impairment status monitoring. However, other agencies or entities may work closely with DEQ to provide compatible data if interest arises. Impairment determinations are conducted by the state but can use data collected from other sources. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, State and Federal laws. For example, reclamation of a mining related source of metals under CERCLA and CECRA typically requires source-specific sampling requirements, which cannot be defined at this time, to determine the extent of and the risk posed by contamination, and to evaluate the success of specific remedial actions.

Sediment

Sediment and habitat assessment protocols consistent with DEQ field methodologies and that serve as the basis for sediment targets and assessment within this TMDL should be conducted whenever possible. Current protocols are identified within Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (Montana Department of Environmental Quality, 2010). It is acknowledged that various agencies and entities have differing objectives, as well as time and resources available to achieve those objectives. However, when possible, when collecting sediment and habitat data in the Boulder River watershed it is recommended that at a minimum the following parameters be collected to allow for comparison to TMDL targets:

- Riffle Cross Section; using Rosgen methodology
- Riffle Pebble Count; using Wolman Pebble Count methodology
- Pool Assessment; Count and Residual Pool Depth Measurements
- Greenline Assessment; NRCS methodology

Additional information will undoubtedly be useful and assist DEQ with TMDL effectiveness monitoring in the future. Macroinvertebrate studies, McNeil core sediment samples, and fish population surveys and redd counts are examples of additional useful information used in impairment status monitoring and TMDL effectiveness monitoring which were not developed as targets but reviewed where available during the development of this TMDL.

Temperature

Consistency in temperature data collection is not as significant for what is collected as much as how and where it is collected. Data loggers should be deployed at the same locations through the years to accurately represent the site-specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and method.

Nutrients

For those watershed groups and/or government agencies that monitor water quality, it is recommended that the same analytical procedures and reporting limits are used in order that water quality data may be compared to TMDL targets (**Table 10-1**). In addition, stream discharge should be measured at time of sampling.

Table 10-1. DEQ Monitoring Parameter Requirements

Analyte	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-NC	A4500-N B	40	28	250mL HDPE	≤6°C (7d HT); Freeze (28d HT)
Total Phosphorus as P	EPA-365.1	A4500-P F	3			H2S04, ≤6°C of Freeze
Nitrate-Nitrite as N	EPA-353.2	A4500-N03 F	10			

10.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, watershed-scale monitoring may be valuable in determining if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

As restoration activities begin throughout the watershed, pre and post monitoring to understand the change that follows implementation will be necessary to track the effectiveness of specific projects. Monitoring activities should be selected such that they directly investigate those subjects that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL. For example, is bank erosion is to be addressed, pre and post BEHI analysis on the subject banks will be valuable to understand the extent of improvement and the amount of sediment reduced.

10.3.5 Watershed Wide Analyses

Recommendations for monitoring in the Boulder River watershed should not be confined to only those streams addressed within this document. The water quality targets presented herein are applicable to all streams in the watershed, and the absence of a stream from the State's 303(d) list does not necessarily imply a stream that fully supports all beneficial uses. Furthermore, as conditions change over time and land management evolves, consistent data collection methods throughout the watershed will allow resource professionals to identify problems as they occur, and to track improvements over time.

11.0 STAKEHOLDER AND PUBLIC INVOLVEMENT

Public and stakeholder involvement is a component of TMDL planning efforts. Stakeholders included the Jefferson Valley Conservation District; Lower Jefferson River Watershed Council; City of Boulder; Jefferson County; USDA Natural Resource Conservation Service; US Environmental Protection Agency; US Forest Service (Beaverhead-Deerlodge National Forest); Bureau of Land Management; Montana Fish, Wildlife, and Parks; Montana Department of Natural Resources; Montana Bureau of Mines and Geology; Montana Department of Transportation; Montana Department of Environmental Quality (DEQ), as well as private landowners in the watershed. In addition, Watershed Advisory Group meetings and other outreach and education efforts conducted by the DEQ provided opportunities to review and comment on technical documents. Stakeholder review drafts were provided throughout the process to the Boulder-Elkhorn TMDL Advisory Group which included all of the entities listed above, and also made available to the public. Stakeholder comments, both verbal and written, were accepted and are addressed within the document.

The public comment period provided an additional opportunity for public. This public review period was initiated on June 5, 2012 and ended on July 12, 2013. At a public meeting on June 27th in Boulder, MT, DEQ provided an overview of the TMDLs for sediment, temperature, and nutrients in the Boulder-Elkhorn TMDL Planning Area, made copies of the document available to the public, and solicited public input and comment on the plan. The announcement for that meeting was distributed among the Boulder-Elkhorn TMDL Watershed Advisory Group, and advertised in the following newspapers: the Boulder Monitor, the Montana Standard (Butte), and the Helena Independent Record. This section includes DEQ's response to all official public comments received during the public comment period. This final document was updated, based on public input and comment.

RESPONSE TO PUBLIC COMMENTS

The formal public comment period for the Boulder-Elkhorn TMDL Planning Area Sediment, Temperature, and Nutrients TMDLs extended from June 5, 2013 to July 12, 2013. One letter was received by DEQ during the public comment period. The format below breaks the letter into its individual comments, followed by responses to each. Responses prepared by DEQ follow each of the individual comments and where applicable, the text of the Final document has been modified to address these comments. Original comment letters are held on file at the DEQ are may be viewed upon request.

Comment #1
As a landowner within the Boulder River Watershed, I am compelled to comment on the Boulder Elkhorn TMDL. After viewing the draft and finding what I think are false statements, I wonder how much of this study might not be true. In 2.2.4, one figure that stands out is 849.5 acres of row crops. I would doubt there is that much in all of Jefferson County. Berkas (2005) reports 3500 acres irrigated upstream of Boulder gage and 6754 total irrigated acres. Something is not adding up.

Response #1
The purpose of **Section 2.0** as a whole is to provide general information that characterizes the watershed and puts geography, history, ecology, land use, etc. into context. To do this, we reference a variety of sources of information. Because the information we use may not all come from the same reference document or source material, there may be slight inconsistencies in numbers or percentages.

Your comment brought to our attention that an earlier version of Land Use/Land Cover data was used in the watershed characterization than was used for the Land Cover/Land Use analysis as part of the USLE modeling for sediment later in the document. We have updated the watershed characterization **Section 2.2.4** to be consistent with the land use information used in the sediment source assessment.

Table 2-4 is based on information provided through the 2001 National Land Cover Dataset mapping completed by the USGS, which serves as a well-used and vetted source of land cover/land use information. However, that dataset is based on interpretation of aerial photographs. We have observed in other watersheds in western Montana that the NLCD cover sometimes over represents cultivated crop acreage, and may potentially be classifying a small percentage of Pasture/Hay as cultivated crop.

Table 2-4 identifies 13,108 acres of Pasture/Hay. If we assume that cultivated crops were misclassified and should be considered Pasture/Hay then there would be a total of 14,486 acres of Pasture/Hay classified according to the NLCD. Pasture/Hay is also often observed to be irrigated land in western Montana. Berkas (2005) reports a total of 6,754 acres of irrigated land. *At the watershed scale*, that is a difference of 1.73% between the two source classifications (the Boulder watershed's estimated area is 446,891.3 acres). In addition, not all Pasture/Hay land is irrigated and therefore the discrepancy between Berkas and the NLCD is likely even less. This difference we deem as acceptable in order to describe the general watershed characteristics.

The 2001 NLCD information was also used to assist with the modeling of upland sediment contribution in this TMDL planning area. Although there may be some slight discrepancies between the NLCD land cover interpretations and the local understanding of land use in the watershed, again, when viewed at the watershed scale, these discrepancies in the Boulder Elkhorn TPA amount to very slight difference in sediment loading values. In this case, these differences are negligible as it pertains to pollutant estimation, TMDL calculation, and load allocations.

Comment #2

Also, the study seems to be biased against agriculture. Much damage done was done many years ago before anyone knew it was wrong. Many improvements have been made. More efficient irrigation systems, NRCS-engineered projects, fencing riparian and waterways are some of the main improvements. Ranchers and farmers have to make a living off the land so we have learned to take care of it. Most of those ranches have been here for over 100 years so I can't understand how people think we have ruined everything. We are fixing things along the way but people want everything fixed overnight. There is no reference in the study to those of us that are making an effort or have made an effort to fix problems in the watershed.

Response #2

The goal in any TMDL related watershed assessment is to evaluate potential significant sources of pollutants, and if there are practices or measures that can be instituted to reduce those pollutants we evaluate how much a pollutant may be reduced, where it is applicable to do so. In a watershed dominated by agriculture, much of the conversation may therefore be focused on agricultural activities. In the Boulder watershed, the dominant land use in the watershed is agriculture.

While there undoubtedly have been improvements in land management in the watershed in recent years, there are many areas where potential still exists for improvements that could ultimately reduce sediment and nutrient loading, and water temperatures. This does not imply that ranchers have ruined everything. Ranching and agriculture are a very significant part of Montana heritage and culture. The

DEQ appreciates this fact and is sensitive to the concerns of land managers throughout Montana. This document does not force land managers to change their practices, nor set any timelines for improvement in the watershed; it simply identifies where potential sources may exist, and potential reductions in loading from those sources. It is afterwards up to the land managers to identify where, how, and if measures can be enacted on their land to reduce pollutant loading. The document has been updated with a paragraph in **Section 9.1** to acknowledge that there are individuals in the watershed who are making an effort to fix problems and improve conditions in the watershed.

Comment #3
We have had problems with elk and moose damage on our grazing permits. I have seen standards met or exceeded before the cattle have even entered those permits.

Response #3
There are certainly natural factors that influence sediment, nutrients, and temperature conditions in every watershed in Montana. There may be discrete locations where natural sources elevate pollutant concentrations above target levels. However, the analysis for TMDLs strives to evaluate under "naturally occurring conditions", which is described in further detail in **Section 3.2** and **Appendix C**.

If elk or moose populations are believed to be of numbers that are unnaturally high, and thereby having significant impact on beneficial uses in the watershed, we suggest contacting your local Montana Fish, Wildlife, and Parks representative for more information.

Comment #4
In 2.2.6 it says there are no concentrated feeding operations in the watershed yet in Appendix A figure A-18, it shows one livestock confinement area. Elsewhere in the study it mentions three livestock feeding areas. It appears that there is a lot of guessing about numbers of feeding operations in this draft. It doesn't seem that the standard for determining the designation of a feeding operation has been uniformly applied. We have been working with NRCS on our own place even though we are not considered a CAFO.

Response #4
At the time **Section 2.2.6** was written, there were "no concentrated feeding operations reported in the watershed through the Montana Pollutant Discharge Elimination System (MPDES) program." That statement refers to Confined Animal Feeding Operations (CAFOs) which meet a defined regulatory criterion and are required to have an MPDES permit. That statement was followed by, "Three facilities that may be livestock feeding areas with potential for discharges to surface waters have been identified from aerial imagery." This refers to aerial photo interpretation that was conducted by the TMDL program to identify potential locations where livestock appear to be focused for extended periods of time, within close proximity to a state waterbody. Although such locations may not meet CAFO definition requirements and thus not require an MPDES permit, they still can represent areas where significant sediment or other pollutant loading can originate in the absence of BMPs. The inconsistency between the text (three livestock feeding areas) and the figure (one livestock feeding area) was investigated and found that the text was incorrect. It has been edited to state "One facility that may be livestock feeding areas…"We have also edited **Section 2.2.6** to clarify the distinction between a permitted CAFO and the identification of potential livestock feeding areas through aerial interpretation.

We also acknowledge and appreciate your efforts in working with the NRCS to improve your property and livestock management. You illustrate precisely what it is we are calling for via the TMDL; voluntary investigation of potential betterment of land and land management, and working collaboratively with local agencies to improve conditions in the watershed.

Comment #5
Sand used for traction is mentioned as a sediment contributor but I would rather have sand than all the chemical de-icer that is used. Sand is used minimally in recent years.

Response #5
As part of the source assessment, we are required to identify significant potential sources of sediment, nutrients, and temperature and evaluate the degree of contribution from these sources, as well as the potential for reduction. Because a major highway corridor parallels two of the streams of interest in this study, road sanding was investigated. However, the discussion in **Section 5.5.2.1** however does point out that sand use has been reduced in recent years, and that MDT should continue maintaining Montana's roadways such that they ensure safe driving conditions while accounting for effects on water quality to the extent practical.

Comment #6
For these reasons I do not believe this draft should be accepted as written. There seems to be too much assuming.

Comment #7
In studies of the scale and scope of one such as the Boulder-Elkhorn TMDL, there are always some assumptions that must be included. These assumptions are clearly identified and described throughout the document, and are necessary and reasonable given the task. Assumptions and considerations are specifically called out at the end of each source assessment discussion (e.g. **Sections 5.5.1.4**, **5.5.2.4**, and **5.5.3.4**).

In addition, TMDL documents incorporate adaptive management which allows for flexibility and review over time. As further information is discovered, and science and evaluation methods improve, this knowledge can be included to refine or revise the TMDL document and its analyses. Discussions about adaptive management and how it can be incorporated in the TMDL is included in **Sections 5.8**, **6.8**, **7.6**, and **10.2**.

Comment #8
As a supervisor with the Jefferson Valley Conservation District, I would like to see a list and location of impairments so when we are doing 310 inspections we can incorporate them into our plans.

Response #8
The Montana DEQ's Clean Water Act Information Site (CWAIC) provides information on pollutant listings and associated sources and causes for many of the state's waterbodies. That site can be accessed via http://cwaic.mt.gov/. CWAIC provides access to the general descriptions of causes and sources associated with pollutants in a particular waterbody. In addition, CWAIC provides access to the information used for the assessment determination.

Generally, apart from permitted point source dischargers, discrete locations of pollutant source are not identified within TMDL documents. This is for a number of reasons. First of all, the scale of the watersheds we develop TMDLs and the resources we have available for TMDL development, typically do not facilitate an exhaustive survey and analysis of each stream or lake system. Also, even if the resources were available, accessibility to all land is often not achievable and it is not our goal to identify specific landowner management practices within a TMDL document. Therefore, our analysis is based on representative samples and remote analysis techniques that incorporate the extrapolation of results to the watershed as a whole. This provides a reasonable approach to estimate the potential sources and loads, but does not always define the specific points where a pollutant load is coming from, and how much at that location.

As noted earlier, the TMDL serves as the foundation of a plan to achieve water quality standards in a watershed. It is up to the local stakeholders to further define where issues may exist, and the priority strategy for addressing those issues. **Sections 9** and **10** provide information to help investigate next steps, including references to other agencies and assistance opportunities that may be useful to local watershed groups interested in addressing water quality issues in their area. DEQ's own Water Protection Section is available to assist with initial planning and implementation stages, and personnel from state agencies such as the Department of Natural Resources and Conservation, and Fish, Wildlife, and Parks who are involved with 310 permitting may be able to further assist you with information or resources for inspection and planning of 310 permit administration.

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APPENDIX A – TABLE OF IMPAIRED WATERBODIES AND WATERSHED DESCRIPTION MAPS

LIST OF TABLES

LIST OF MAPS

Table A-1. Status of Waterbody Impairments in the Boulder-Elkhorn TPA based on the 2012 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category [1]	Impairment Cause Status [2]
BASIN CREEK, headwaters to mouth (Boulder River)	MT41E002_030	Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Addressed by Sediment TMDL in this document
		Arsenic	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Mercury	Metal	Addressed in separate TMDL Document
		Sedimentation / Siltation	Sediment	Sediment TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document
BIG LIMBER GULCH, headwaters to mouth (Cataract Creek-Boulder River)	MT41E002_140	Lead	Metal	Addressed in separate TMDL Document
		Mercury	Metal	Addressed in separate TMDL Document
BISON CREEK, headwaters to mouth (Boulder River)	MT41E002_070	Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Addressed by Sediment TMDL in this document
		Copper	Metal	Addressed in separate TMDL Document
		Iron	Metal	Addressed in separate TMDL Document
		Nitrates	Nutrient	Not impaired based on updated assessment
BOULDER RIVER, headwaters to Basin Creek	MT41E001_010	Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Iron	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Zinc	Metal	Addressed in separate TMDL Document
BOULDER RIVER, Basin Creek to Town of Boulder	MT41E001_021	Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Cadmium	Metals	Addressed in separate TMDL Document
		Copper	Metals	Addressed in separate TMDL Document
		Iron	Metals	Addressed in separate TMDL Document
		Lead	Metals	Addressed in separate TMDL Document
		Silver	Metals	Addressed in separate TMDL Document
		Zinc	Metals	Addressed in separate TMDL Document

Table A-1. Status of Waterbody Impairments in the Boulder-Elkhorn TPA based on the 2012 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category [1]	Impairment Cause Status [2]
BOULDER RIVER, Town of Boulder to Cottonwood Creek	MT41E001_022	Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Addressed by Sediment TMDL in this document
		Copper	Metals	Addressed in separate TMDL Document
		Iron	Metals	Addressed in separate TMDL Document
		Lead	Metals	Addressed in separate TMDL Document
		Low Flow Alterations	Not a Pollutant	Addressed by Temperature TMDL in this document
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Silver	Metals	Addressed in separate TMDL Document
		Temperature, water	Temperature	Temperature TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document
BOULDER RIVER, Cottonwood Creek to the mouth (Jefferson Slough), T1N R3W S2	MT41E001_030	Alteration in stream-side or littoral vegetative covers	Not a Pollutant	Addressed by Sediment TMDL in this document
		Arsenic	Metal	Addressed in separate TMDL Document
		Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Low Flow Alterations	Not a Pollutant	Addressed by Temperature TMDL in this document
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Temperature, water	Temperature	Temperature TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document
CATARACT CREEK, headwaters to mouth (Boulder River)	MT41E002_020	Arsenic	Metal	Addressed in separate TMDL Document
		Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Mercury	Metal	Addressed in separate TMDL Document
		Nitrogen, Nitrate	Nutrient	Not impaired based on updated assessment
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document

Table A-1. Status of Waterbody Impairments in the Boulder-Elkhorn TPA based on the 2012 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category [1]	Impairment Cause Status [2]
ELKHORN CREEK, headwaters to Wood Gulch	MT41E002_061	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Arsenic	Metal	Addressed in separate TMDL Document
		Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Low Flow Alterations	Not a Pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document
ELKHORN CREEK, Wood Gulch to the mouth (Unnamed Canal/Ditch), T5N R3W S21	MT41E002_062	Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Low Flow Alterations	Not a Pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Zinc	Metal	Addressed in separate TMDL Document
HIGH ORE CREEK, headwaters to mouth (Boulder River)	MT41E002_040	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Arsenic	Metal	Addressed in separate TMDL Document
		Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Mercury	Metal	Addressed in separate TMDL Document
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Temperature, water	Temperature	Temperature TMDL contained in this document
		Total Suspended Solids (TSS)	Sediment	Addressed by Sediment TMDL in this document
		Zinc	Metal	Addressed in separate TMDL Document
LITTLE BOULDER RIVER, headwaters to mouth (Boulder River)	MT41E002_080	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Copper	Metal	Addressed in separate TMDL Document
		Physical substrate habitat alterations	Not a Pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Zinc	Metal	Addressed in separate TMDL Document

Table A-1. Status of Waterbody Impairments in the Boulder-Elkhorn TPA based on the 2012 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category [1]	Impairment Cause Status [2]
LOWLAND CREEK, headwaters to mouth (Boulder River)	MT41E002_050	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Aluminum	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Physical substrate habitat alterations	Not a Pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Silver	Metal	Addressed in separate TMDL Document
MCCARTY CREEK, headwaters to mouth (Boulder River	MT41E002_110	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Fish-Passage Barrier	Not a pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Low flow alterations	Not a pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Phosphorus (Total)	Nutrient	TP TMDL contained in this document
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
MUSKRAT CREEK, headwaters to mouth (Boulder River)	MT41E002_100	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
NORTH FORK LITTLE BOULDER RIVER, headwaters to mouth (Little Boulder River)	MT41E002_090	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Nitrogen (Total)	Nutrients	Not impaired based on updated assessment
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
NURSERY CREEK, headwaters (east branch) to mouth (Muskrat Creek)	MT41E002_130	Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrient	NO_2+NO_3 TMDL contained in this document
		Nitrogen (Total)	Nutrient	TN TMDL contained in this document
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document

Table A-1. Status of Waterbody Impairments in the Boulder-Elkhorn TPA based on the 2012 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category [1]	Impairment Cause Status [2]
UNCLE SAM GULCH, headwaters to mouth (Cataract Creek)	MT41E002_010	Alteration in stream-side or littoral vegetative covers	Not a pollutant	Addressed by Sediment TMDL in this document
		Arsenic	Metal	Addressed in separate TMDL Document
		Cadmium	Metal	Addressed in separate TMDL Document
		Copper	Metal	Addressed in separate TMDL Document
		Lead	Metal	Addressed in separate TMDL Document
		Nitrogen, Nitrate	Nutrient	NO_2+NO_3 TMDL contained in this document
		Other flow regime alterations	Not a pollutant	Addressed within document **(Sections 8 & 9)**; not linked to a TMDL
		Sedimentation/Siltation	Sediment	Sediment TMDL contained in this document
		Turbidity	Sediment	Addressed by sediment TMDL in this document
		Zinc	Metal	Addressed in separate TMDL Document

[1.] Metals impairments are addressed in the "Boulder-Elkhorn Metals TMDLs and Framework Water Quality Improvement Plan" published December 2012. The document can be found on DEQ's website at: http://deq.mt.gov/wqinfo/TMDL/finalReports.mcpx.
[2.] TN = Total Nitrogen, TP = Total Phosphorus, NO_2+NO_3 = Nitrite + Nitrate

Figure A-1. Location of the Boulder-Elkhorn TMDL Planning Area

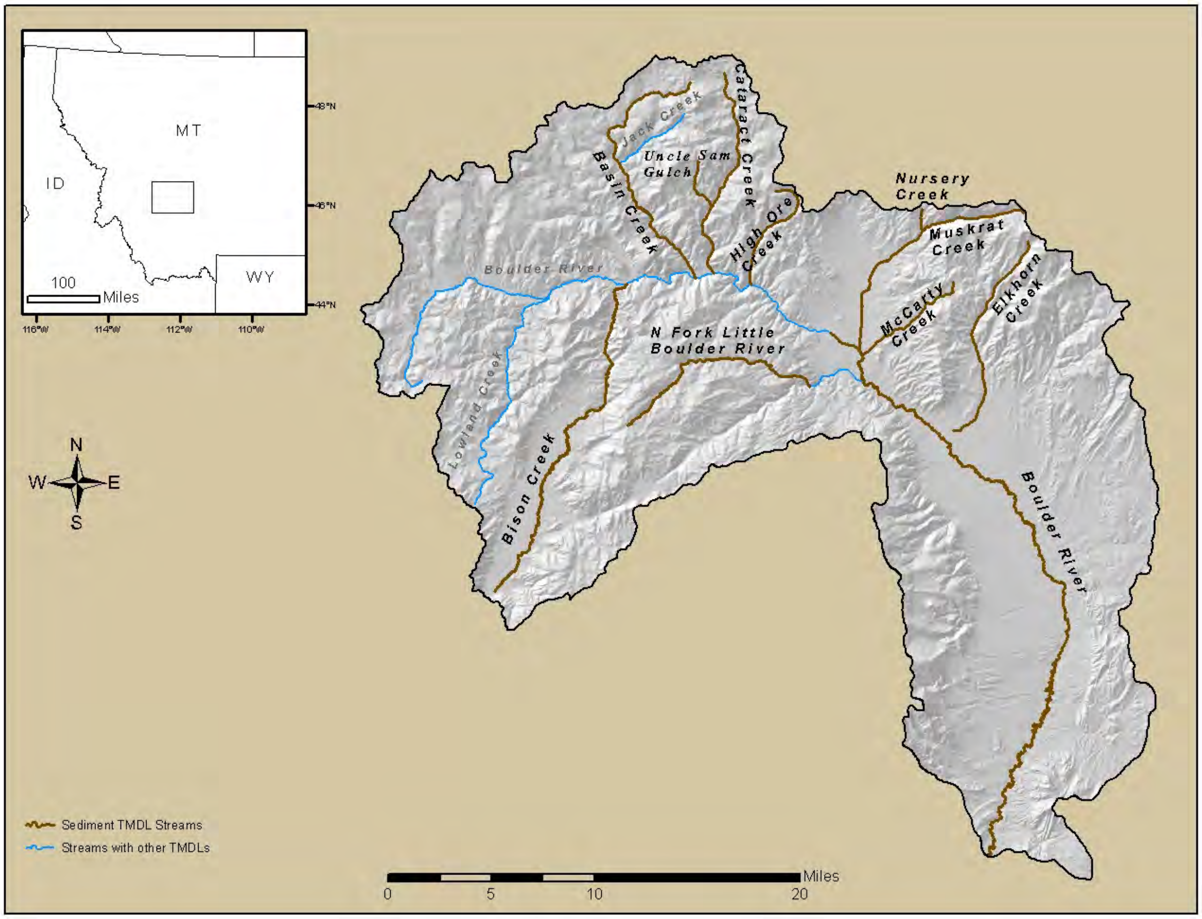

Figure A-2. Sediment TMDL Streams

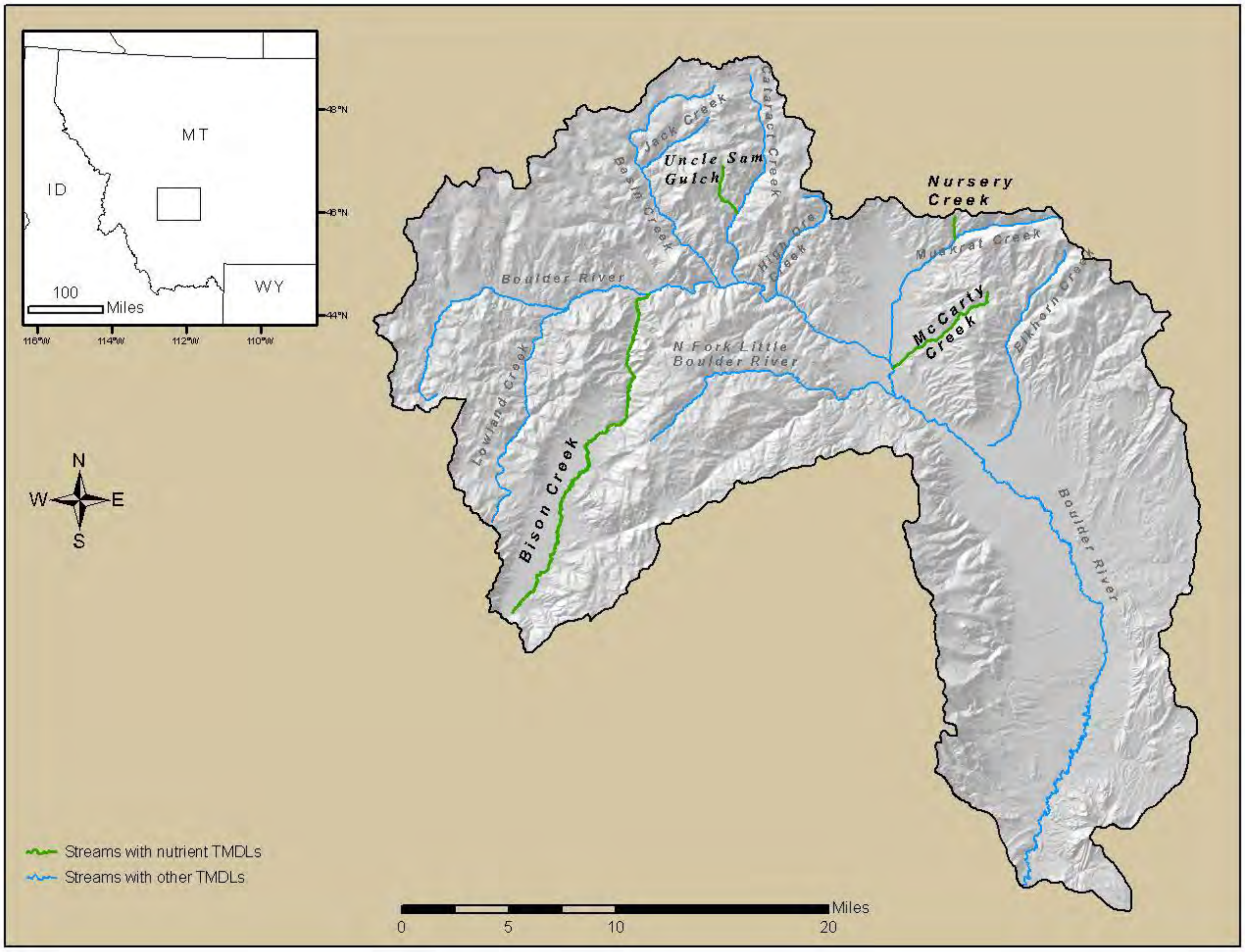

Figure A-3. Nutrient TMDL Streams

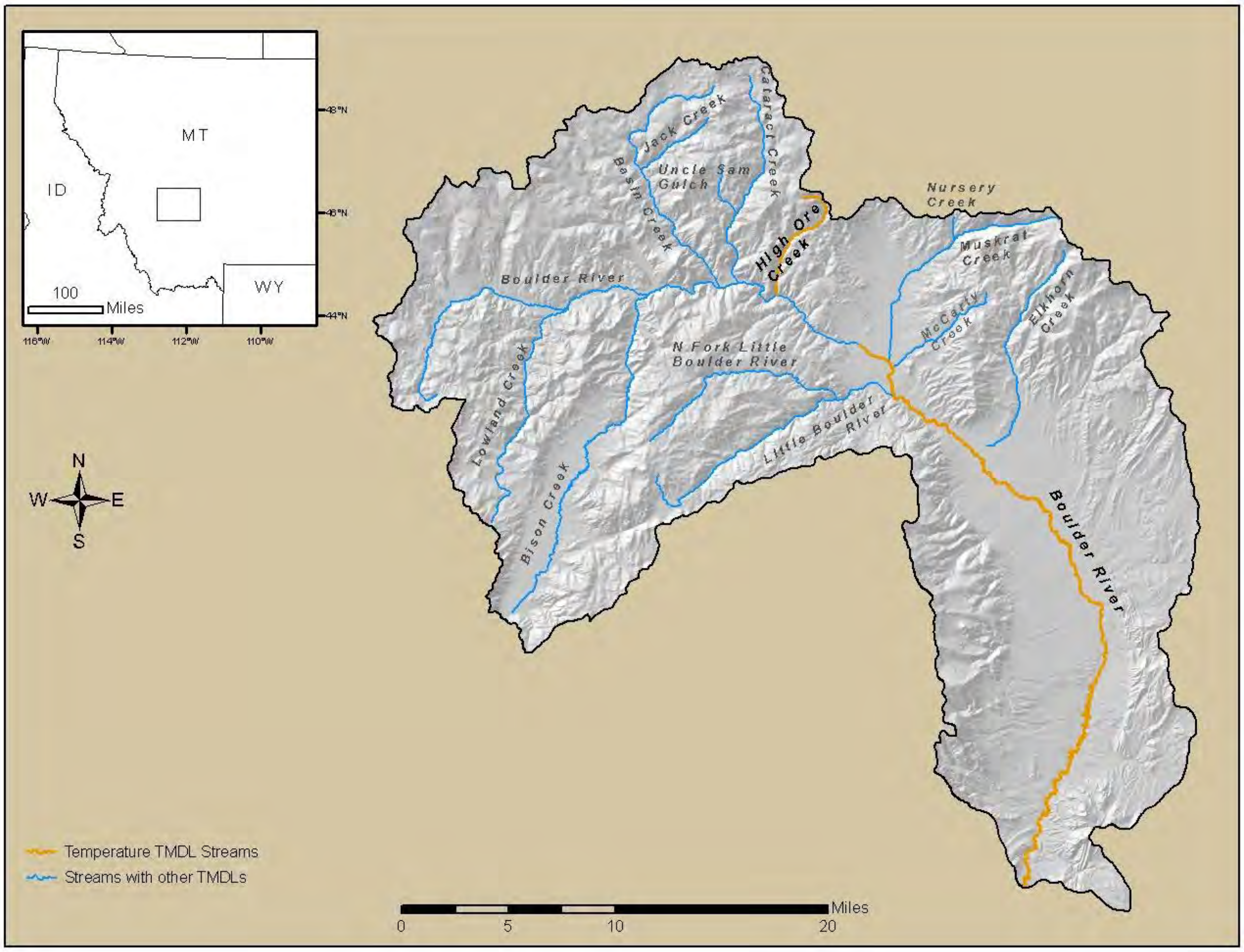

Figure A-4. Temperature TMDL Streams

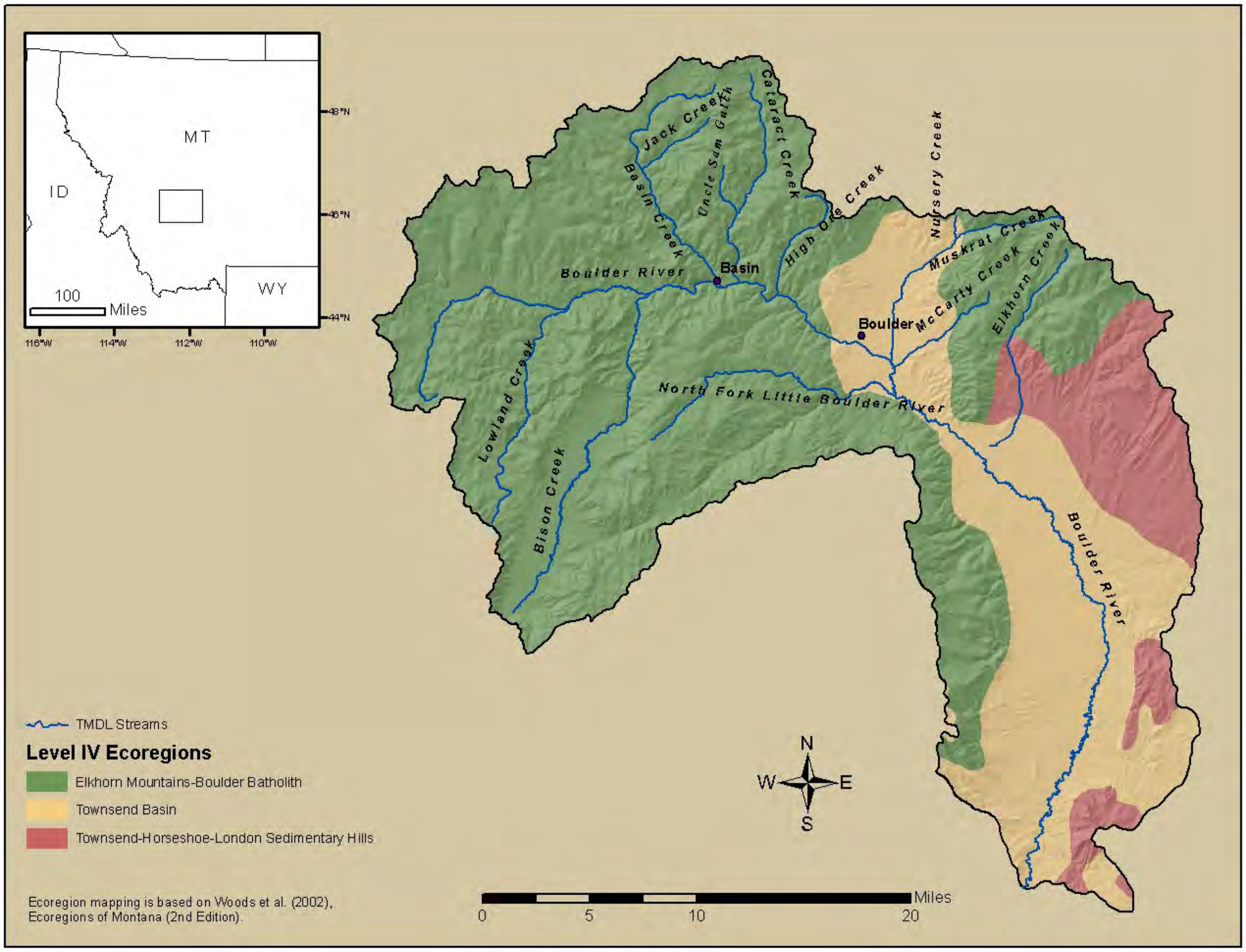

Figure A-5. Ecoregions

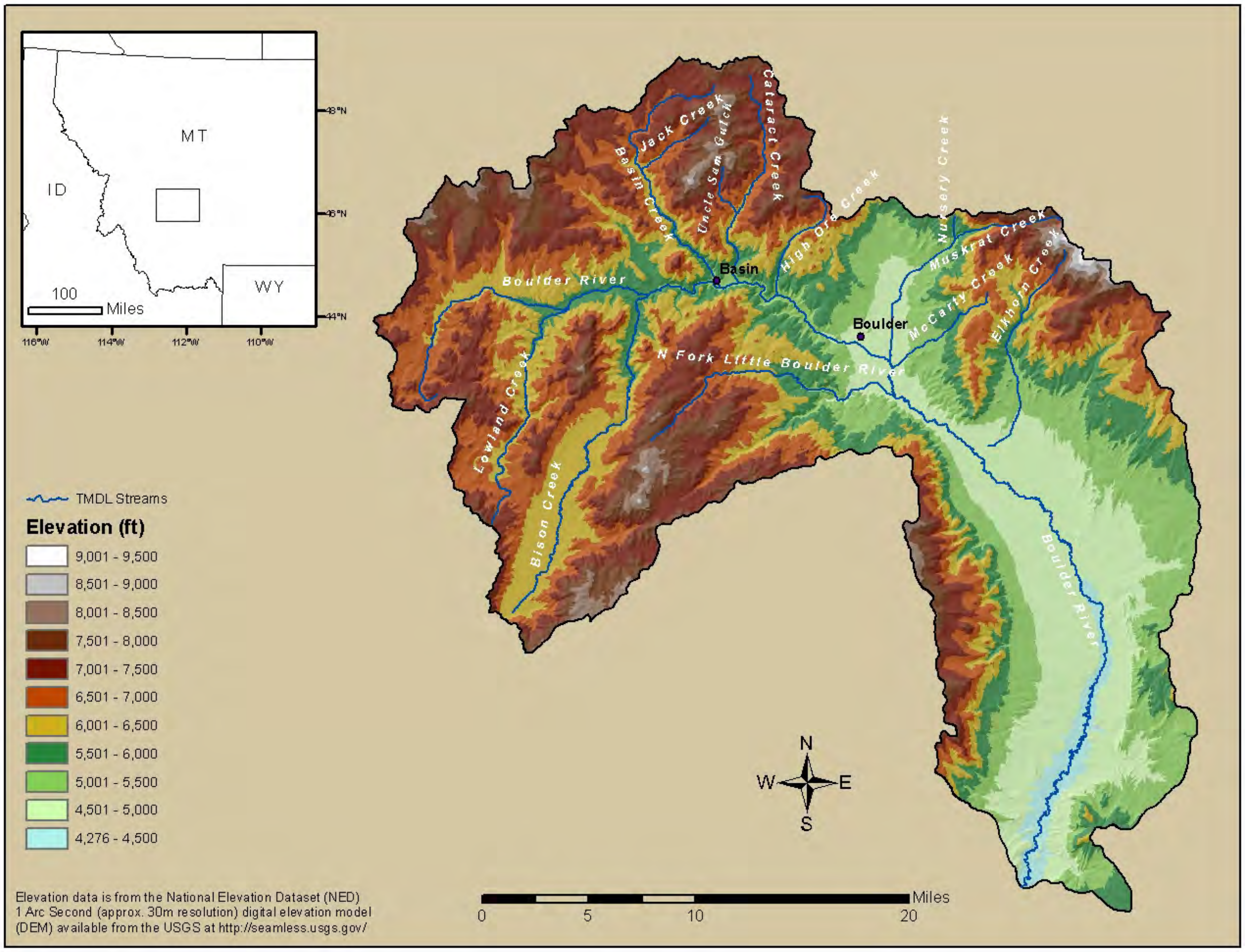

Figure A-6. Topography

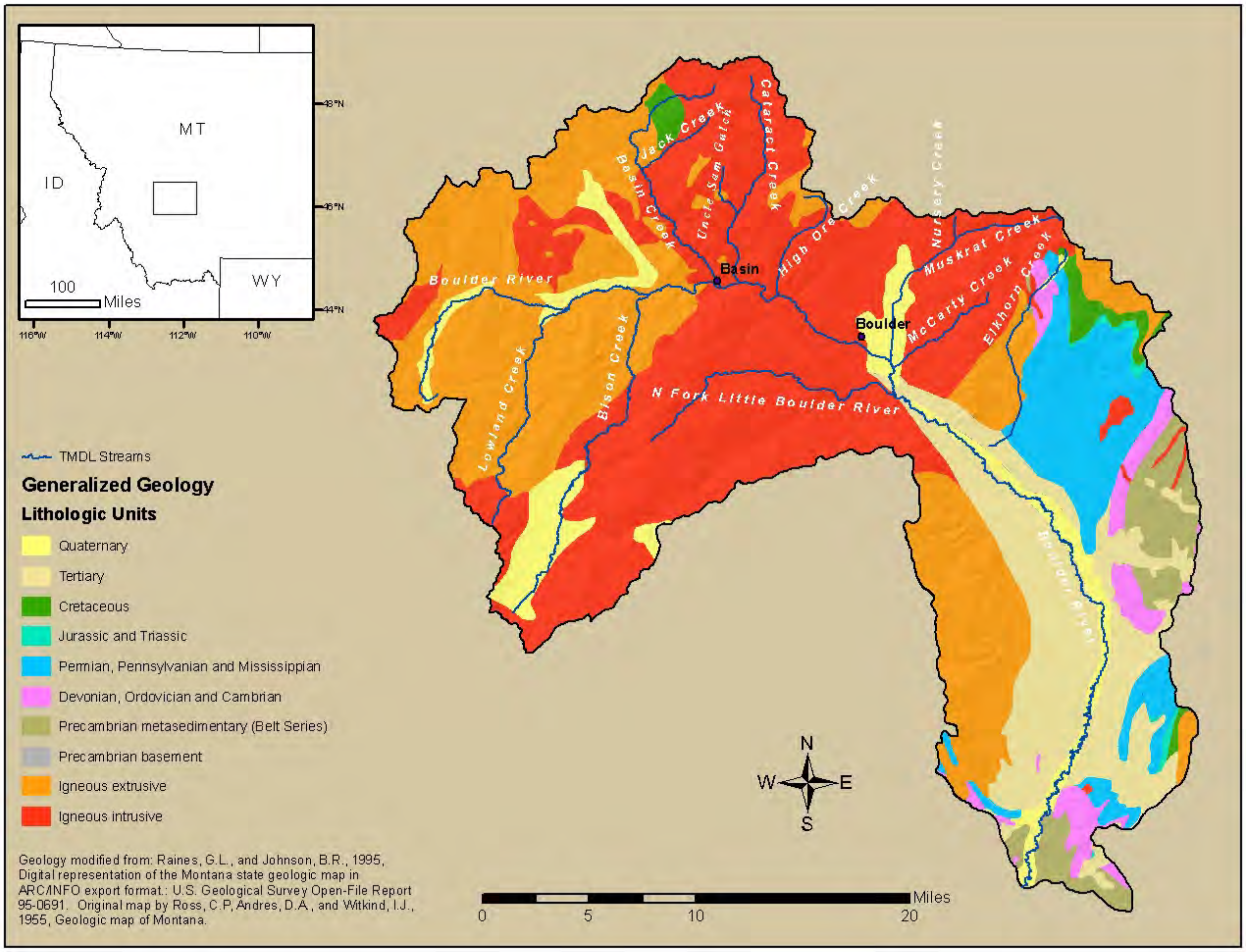

Figure A-7. Geology

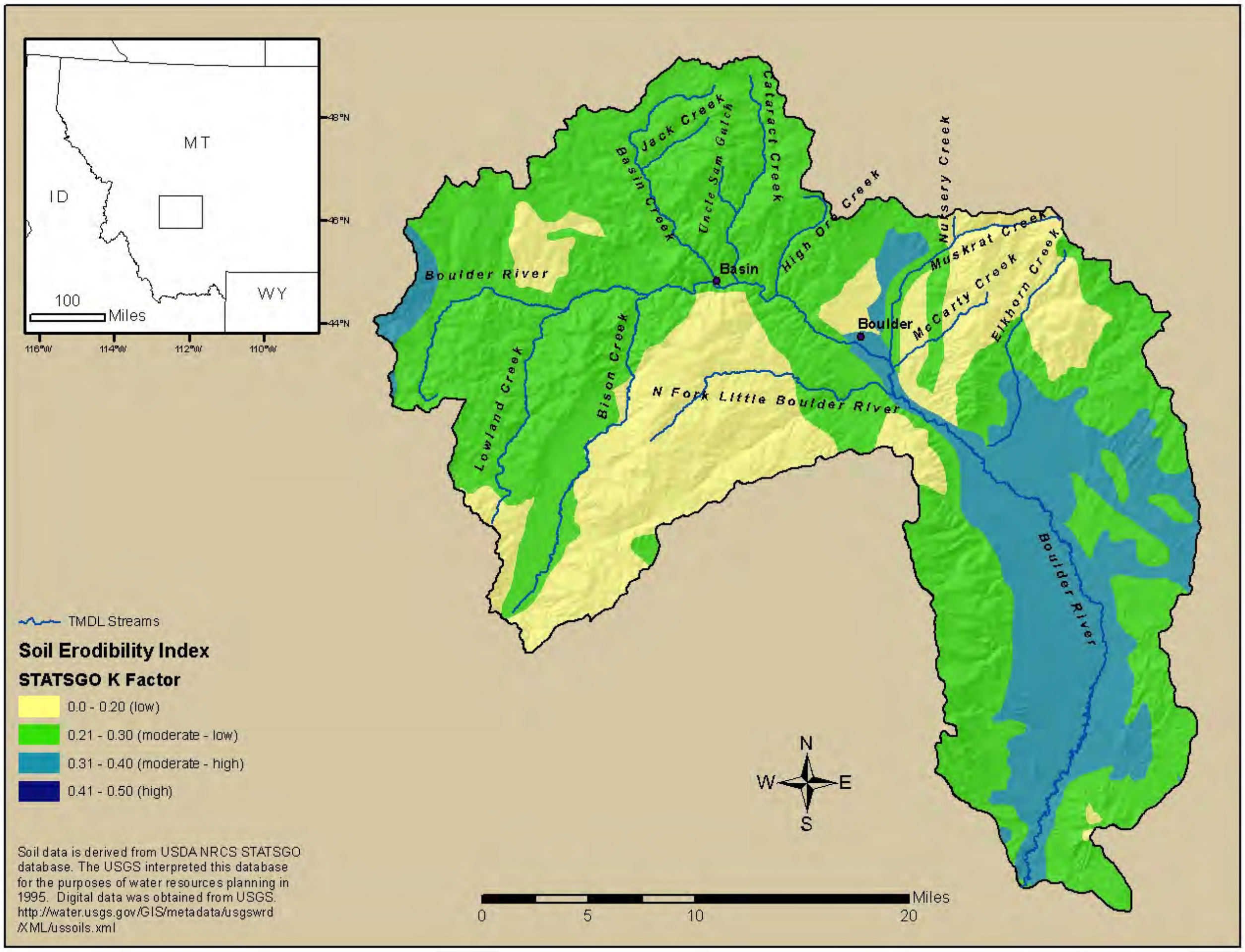

Figure A-8. Soil Erodibility

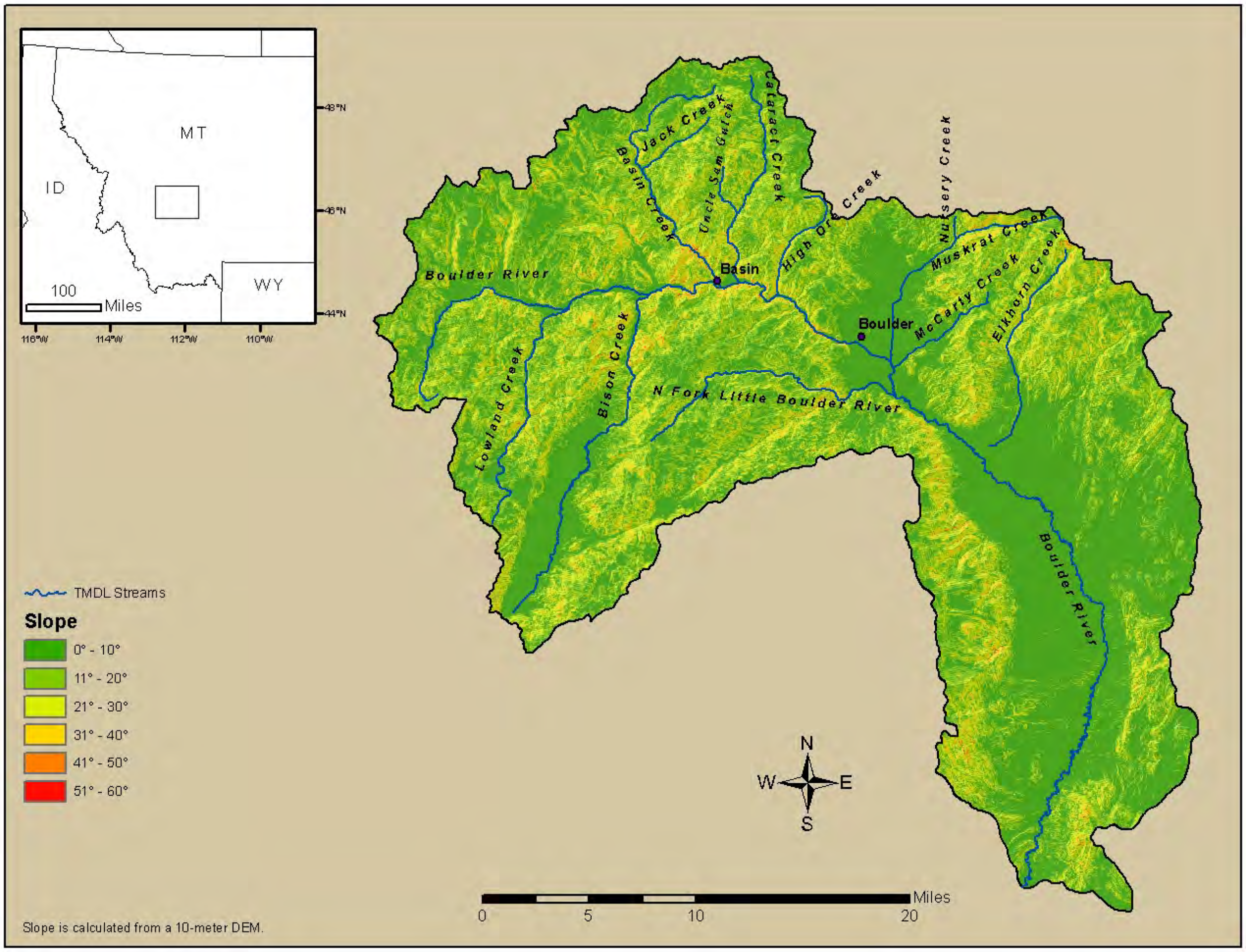

Figure A-9. Land Surface Slope

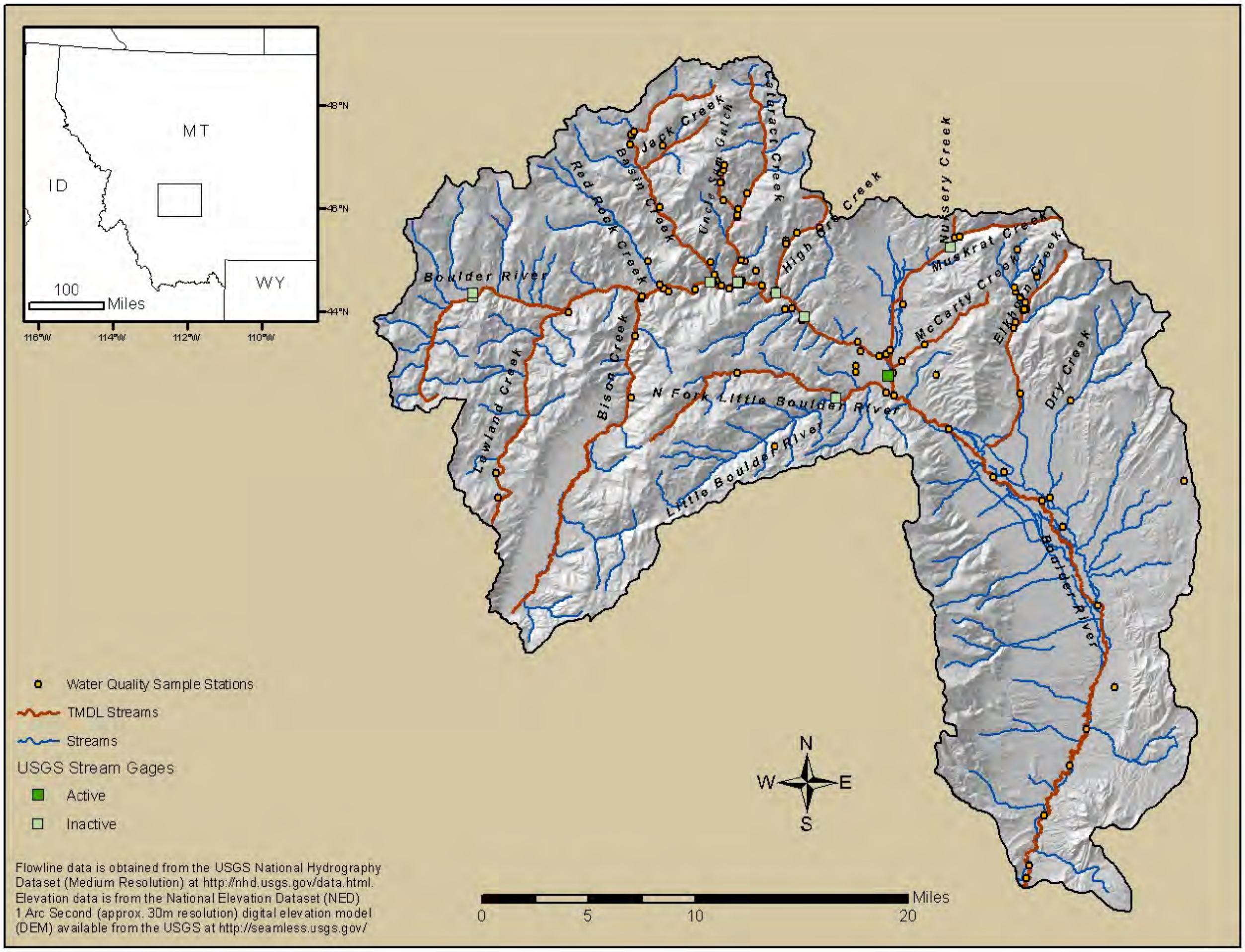

Figure A-10. Hydrography

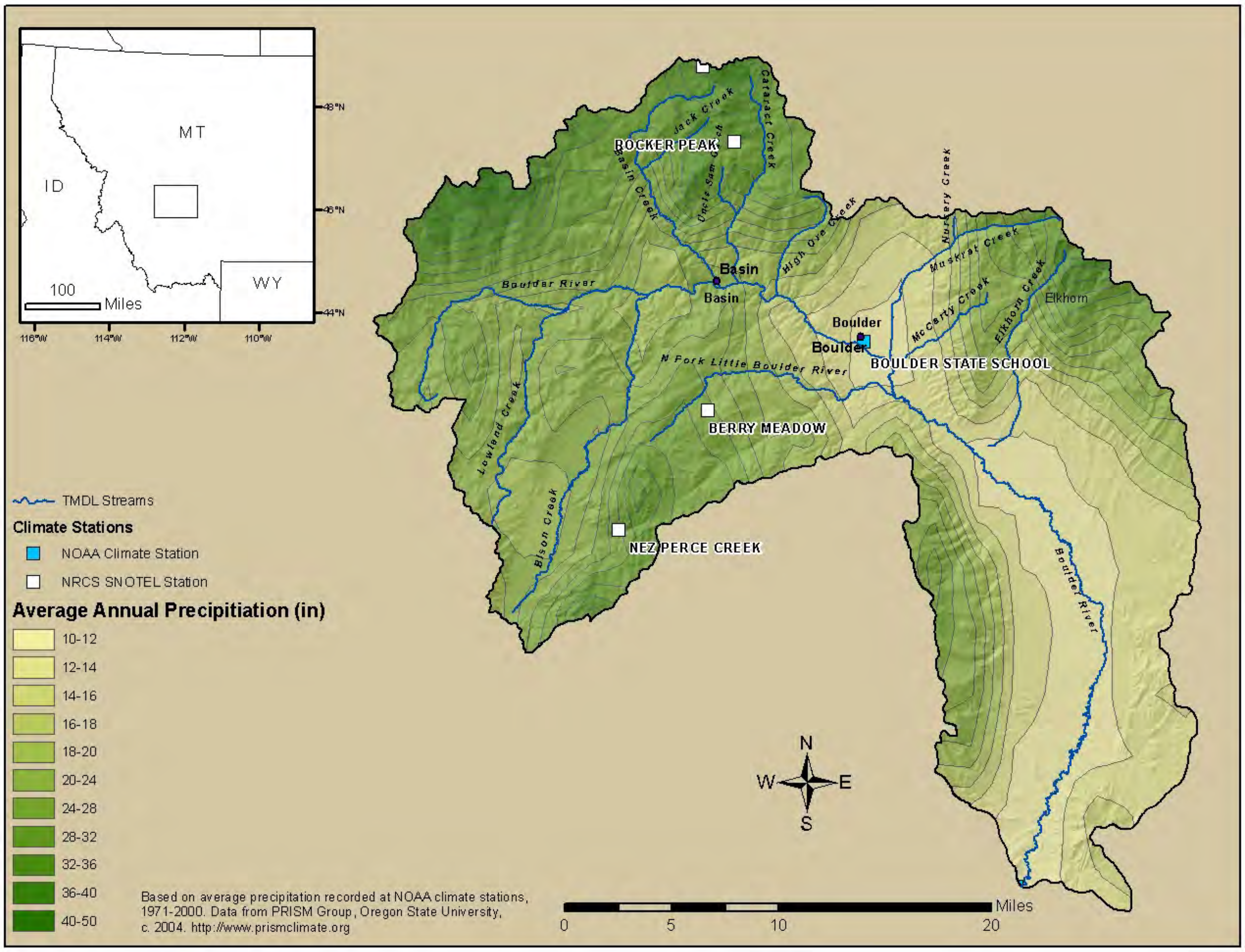

Figure A-11. Average Annual Precipitation

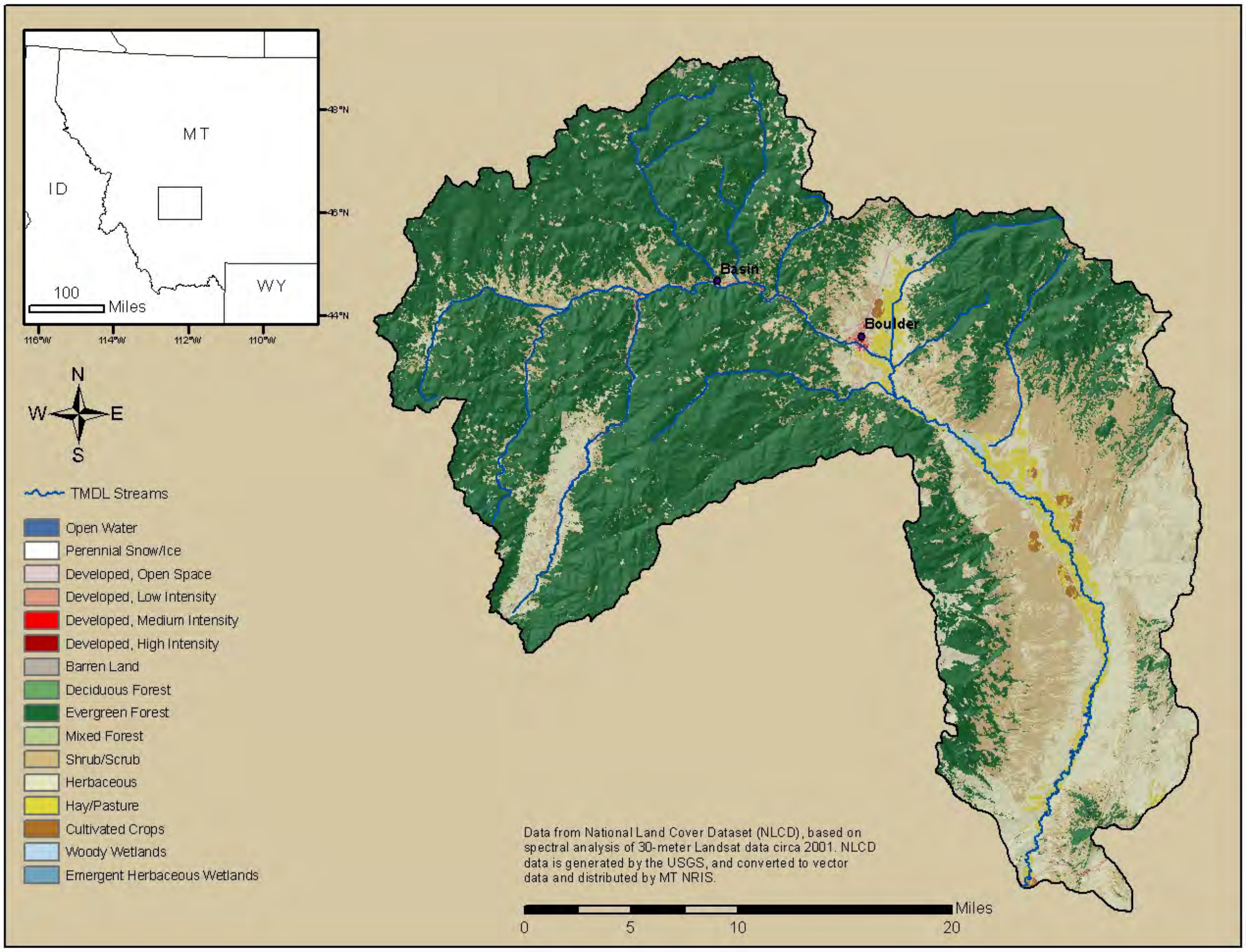

Figure A-12. Land Cover

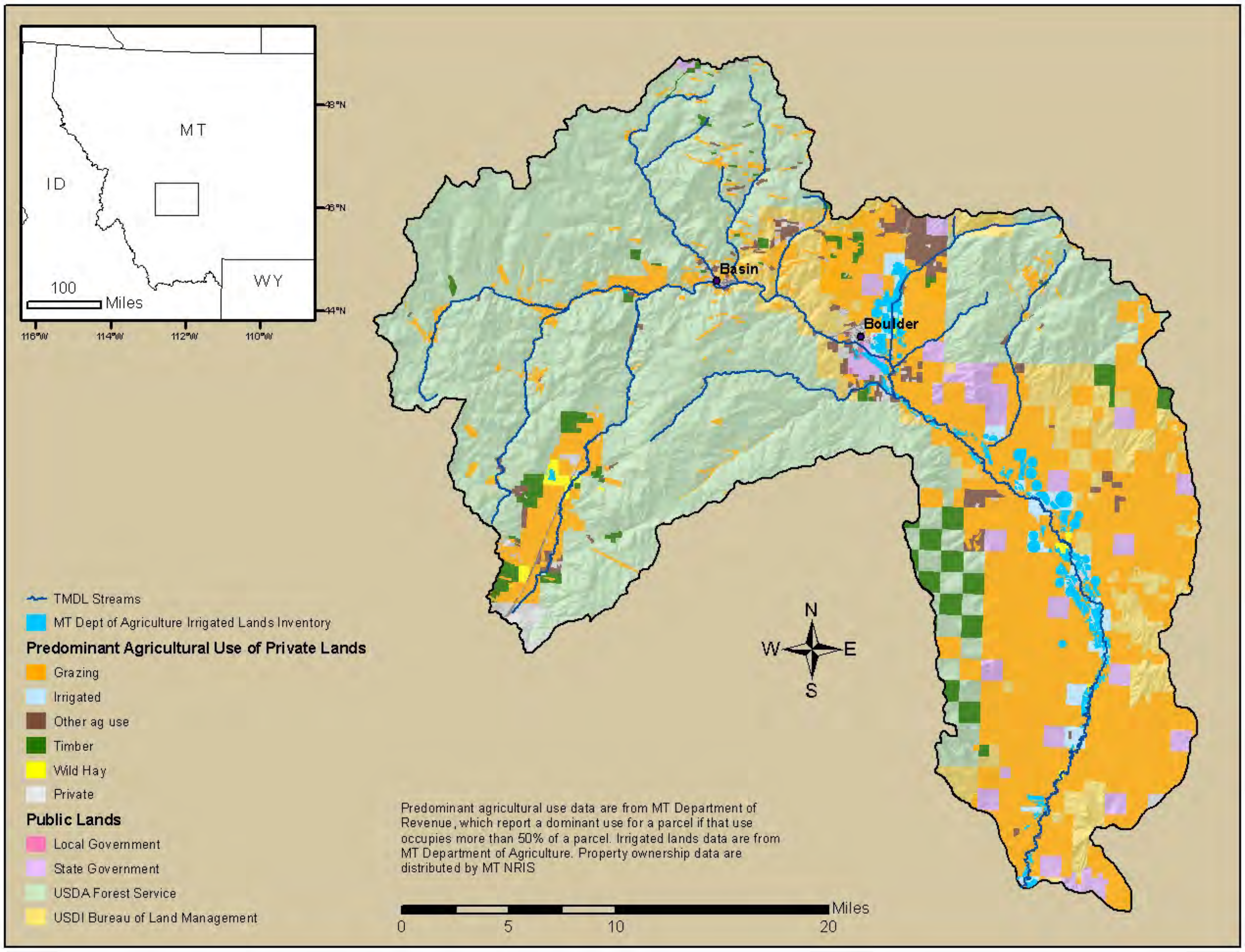

Figure A-13. Agricultural Use of Private Lands

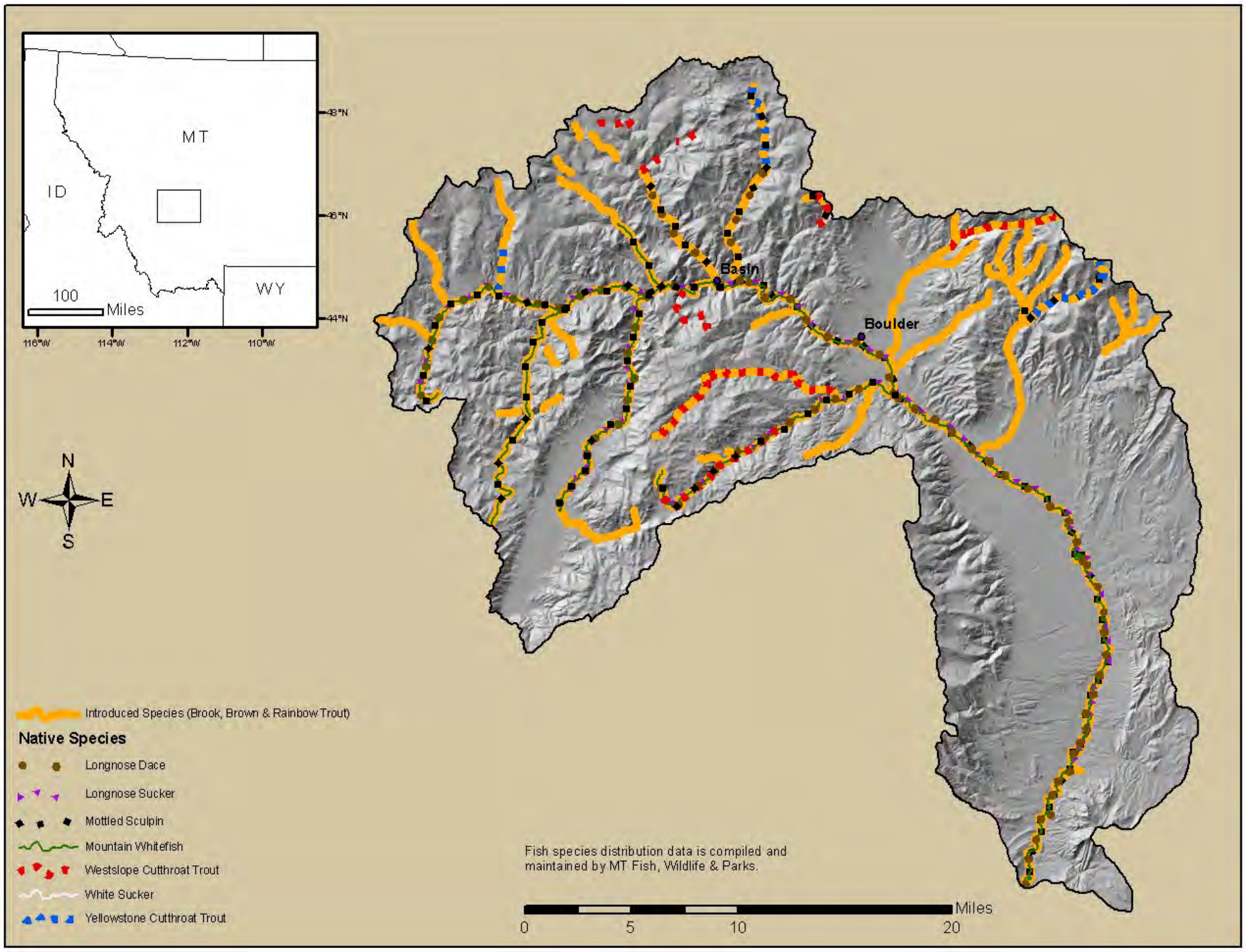

Figure A-14. Fish Species

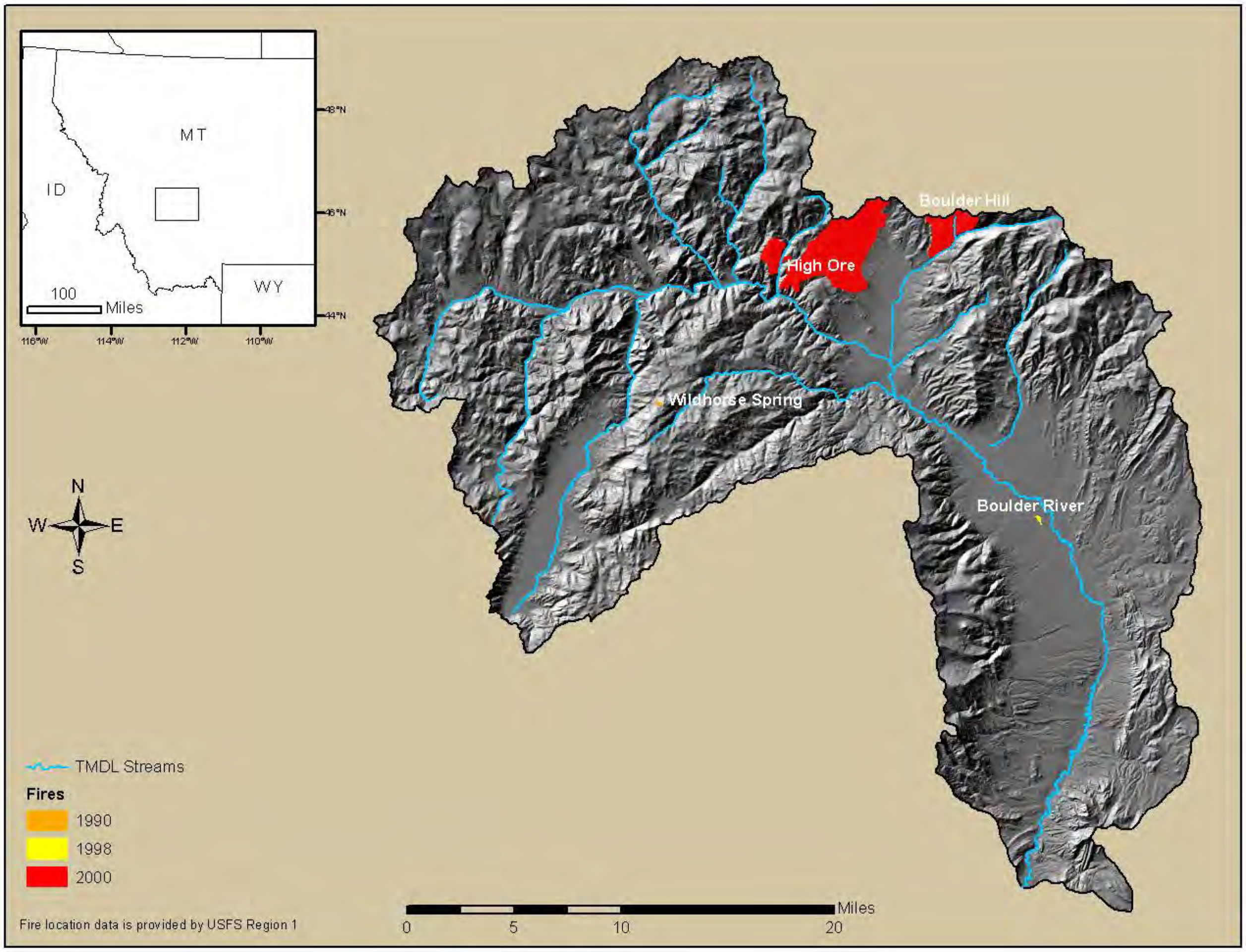

Figure A-15. Fire History

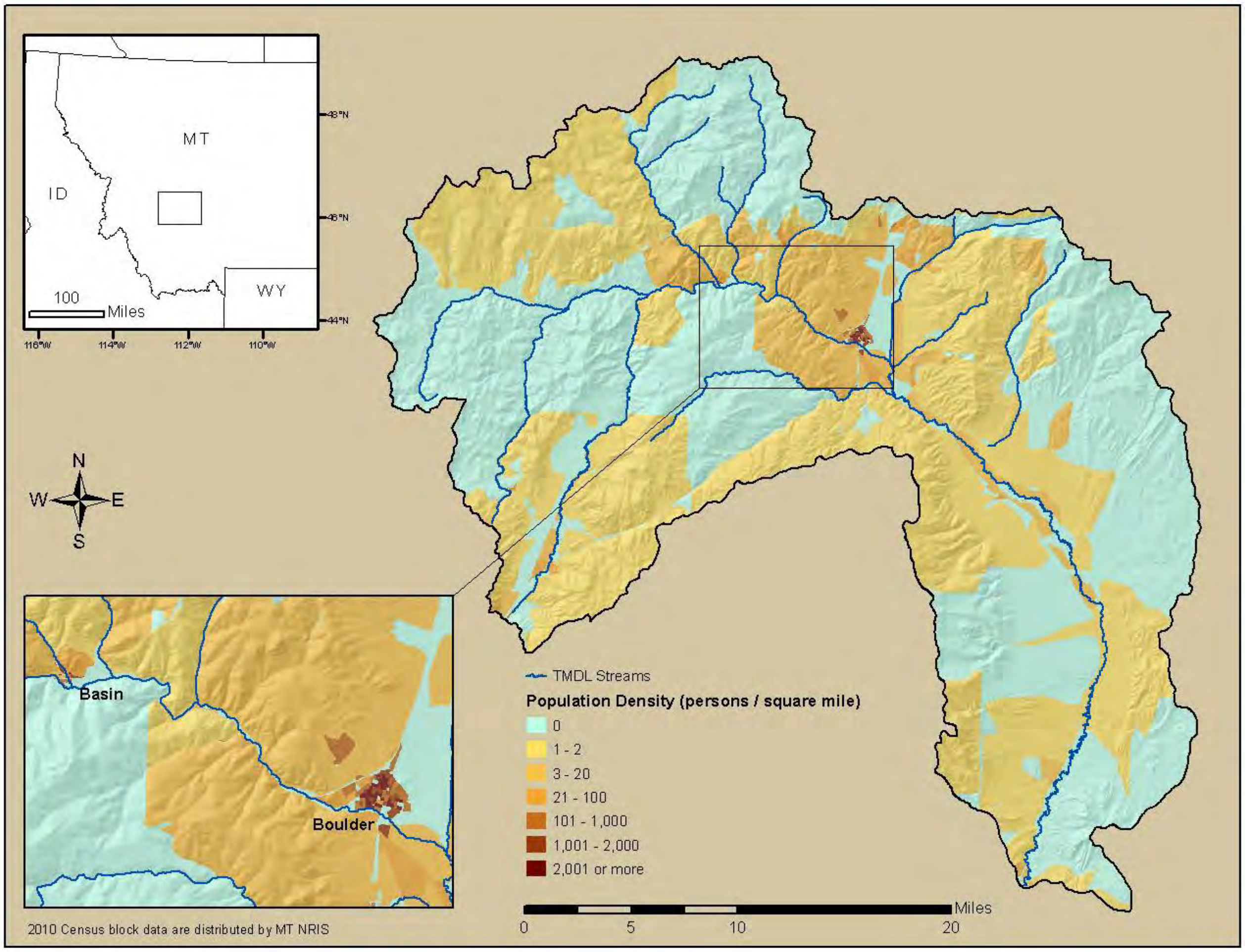

Figure A-16. Population Density

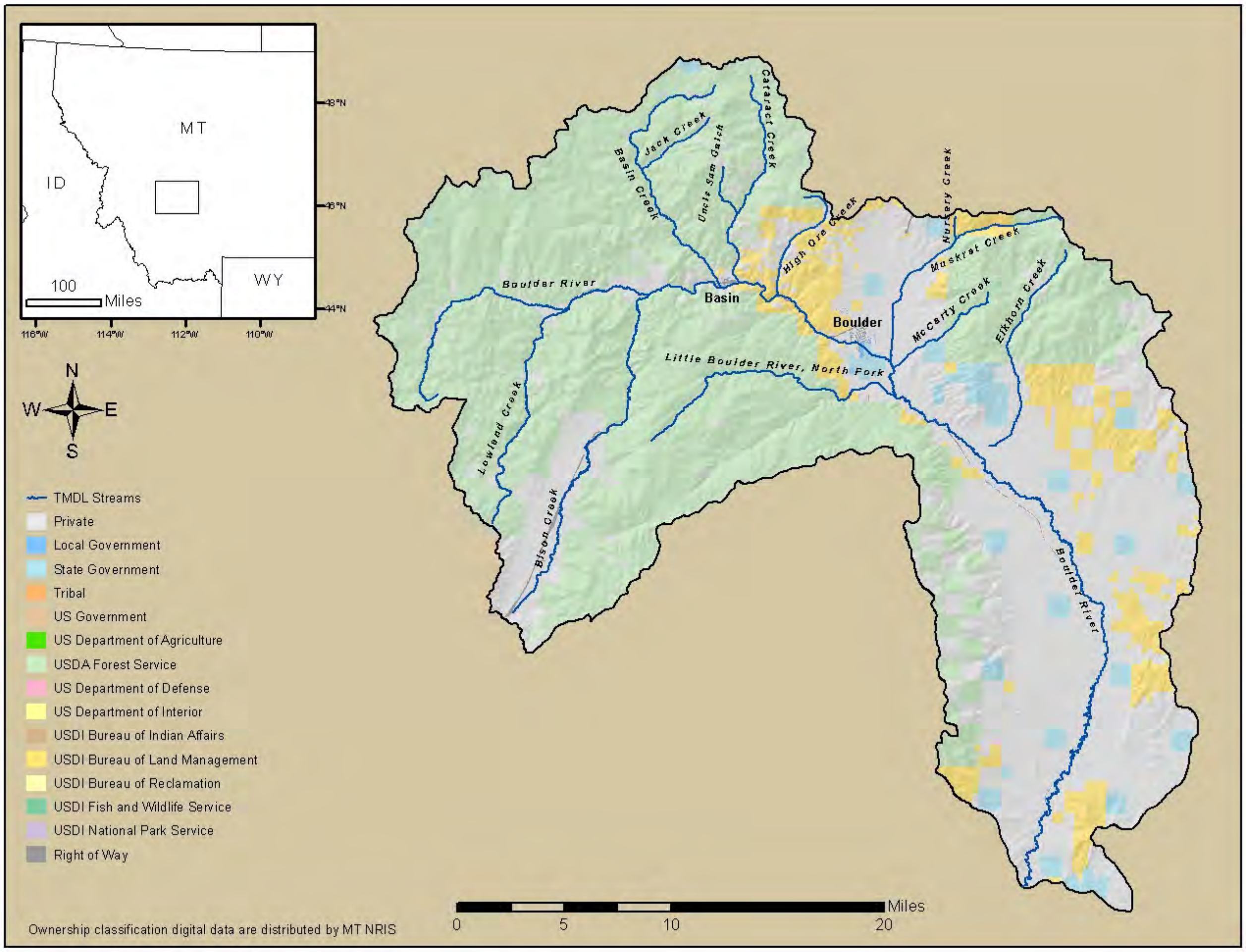

Figure A-17. Land Ownership

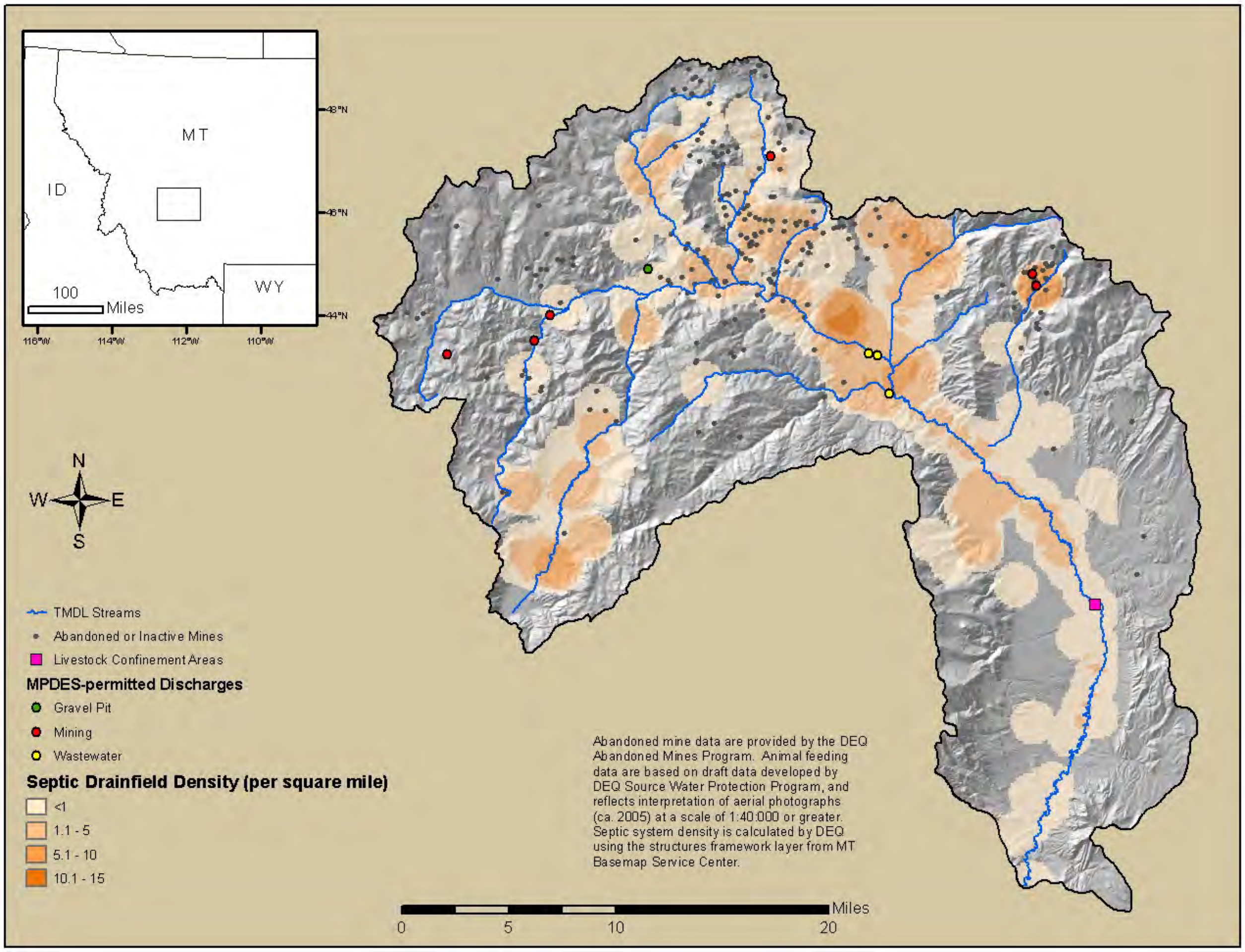

Figure A-18. Permitted Wastewater Discharges

APPENDIX B – BOULDER RIVER WATERSHED DESCRIPTION

B1.0 INTRODUCTION

This appendix describes the physical, ecological, and cultural characteristics of the Boulder River watershed and the Boulder-Elkhorn TMDL Planning Area (TPA). The TPA boundary and the watershed boundary are the same.

B2.0 PHYSICAL CHARACTERISTICS

The following information describes the physical characteristics of the Boulder River watershed.

B2.1 LOCATION

The Boulder River watershed is located in Jefferson County. The total extent is 487,142 acres, or approximately 760 square miles. The watershed is located in the Missouri Headwaters Basin (Accounting Unit 100200) of southwestern Montana, as shown on **Figure A-1**. The watershed is coincident with the 1002006 fourth-code watershed.

The Boulder River watershed is located in the Middle Rockies Level III Ecoregion. Three Level IV Ecoregions are mapped within the watershed (Woods *et al*., 2002), as shown on **Figure A-5** in **Appendix A**. These include: Elkhorn Mountains-Boulder Batholith (17ai), Townsend Basin (17w), and Townsend-Horseshoe-London Sedimentary Hills (17y). The watershed is bounded by the continental divide to the west, Boulder Hill to the north, the Elkhorn Mountains to the northeast, and Bull Mountain to the southwest.

B2.2 TOPOGRAPHY

Elevations in the watershed range from approximately 1,304 to 2,868 meters (4,275 - 9,415 feet) above mean sea level (**Appendix A**, **Figure A-6**). The lowest point is the confluence of the Boulder River and the Jefferson Slough; the highest point is Crow Peak, at the northeast corner of the watershed. Much of the watershed is rugged and mountainous, with three distinct valleys: Elk Park, a long, narrow valley drained by Bison Creek; the Boulder Valley near the Town of Boulder, a high basin hemmed in by mountains; and the Boulder River valley below Elkhorn Creek, a broad river valley opening to the Jefferson River Valley. The uplands are characterized by steep-sided valleys with gently sloping ridgelines and peaks. Rugged alpine topography is limited to the very highest elevations.

B2.3 GEOLOGY

Figure A-7 in **Appendix A** provides an overview of the geology, based on a geologic map of Montana (Ross, *et al*., 1955). These data provide the basis for the figure, however, discussion of the geology is based on a more recent map (Vuke et al., 2007), for which geographic information systems (GIS) data are not released.

B2.3.1 Bedrock

The bedrock of the watershed includes Precambrian (Belt Series), Paleozoic and Mesozoic sedimentary rocks, granitoid rocks of the Boulder batholith, and Cretaceous to Tertiary volcanic rocks. The sedimentary rocks are mainly present north of the Boulder River and east of Elkhorn Creek, and at the mouth of the Boulder River. These rocks are deformed into a series of folds related to the Helena Structural Salient. Intrusive and volcanic rocks are widely distributed through the Boulder, Elkhorn and Bull mountains.

B2.3.2 Basin Sediments

Tertiary and Quaternary sedimentary deposits are concentrated in the valleys. The Tertiary sediments are commonly fine-grained with isolated bodies of coarser material. Tertiary sediments commonly occur in benches or dry terraces. Quaternary sediments include fluvial, colluvial, glacial and proglacial deposits.

B2.4 Soils

The USGS Water Resources Division (Schwarz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the USDA Natural Resources Conservation Service (NRCS) STATSGO soil database. The STATSGO data are intended for small-scale (watershed or larger) mapping, and is too general to be used at scales larger than 1:250,000. Therefore, it is important to realize that each soil unit in the STATSGO data may include up to 21 soil components. Soil analysis at a larger scale should use NRCS SSURGO data. The soil attributes considered in this characterization are erodibility and slope.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier and Smith, 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped on **Figure A-8** in **Appendix A**, with soil units assigned to the following ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. No values greater than 0.34 are mapped in the watershed.

The majority of the watershed (57%) is mapped with moderate-low susceptibility soils. Roughly similar percentages are mapped with moderate-high susceptibility (19.5%) and low susceptibility (23.5%) soils.

Comparison of **Figures A-7** and **A-8** in **Appendix A** demonstrates that soil erodibility is related to geology. Soils with low susceptibility to erosion generally correspond to the areas underlain by the granitoid rocks of the Boulder Batholith, and the moderate-low susceptibility soils correspond to areas underlain by volcanic rocks. Moderate-high susceptibility soils are mapped in the valleys and in areas underlain by sedimentary rocks.

Due to the relatively large areas of the soil units, the slopes as mapped with the STATSGO data are generalized. **Figure A-8**, which is based on STATSGO data, maps the majority of the watershed with slopes of between 31° and 40°. However, **Figure A-9** (**Appendix A**), which shows slope interpreted from a 30-meter digital elevation model, illustrates that the watershed is characterized by locally very steep slopes along valley margins, with generally rounded mountaintops.

B2.5 SURFACE WATER

The Boulder River flows a distance of approximately 80 miles. Hydrography of the watershed is illustrated on **Figure A-10** in **Appendix A**. The National Hydrography Dataset medium resolution data (United States Department of Interior, Geological Survey, 1999) includes 374 miles of named streams, with a total of 1,042 miles of streams mapped in the watershed. This data is compiled at 1:100,000.

B2.5.1 Stream Gaging Stations

The United States Geological Survey (USGS) maintains two gaging stations within the watershed, as detailed below in **Table B-1**. The gauging stations are shown on **Figure A-10** in **Appendix A**.

Table B-1. Stream Gages in the Boulder River Watershed

Name	Number	Drainage Area	Agency	Period of Record
Cataract Creek near Basin, MT	06031950	30.6 miles2	USGS	1973-2008*
Boulder River near Boulder, MT	06033000	381 miles2	USGS	1929-1972; 1985-2008

* Annual peak data

B2.5.2 Streamflow

Streamflow data are based on records from the USGS stream gage on the Boulder River near Boulder (**Table B-1**), and is available via the USGS NWIS website (United States Department of Interior, Geological Survey, 2008). Flows in the Boulder River vary considerably over a calendar year. A hydrograph summarizing flows at this station is provided in **Figure B-1** of this document. The hydrograph is based on monthly mean flows.

Flow is variable from year to year, but on average (over a 75-year period of record), peak flows occur in May (456 cubic feet per second, or cfs). The highest recorded flow of 7,000 cfs occurred in May 1981.

Mean low flow occurs in January (26 cfs). Late summer (August and September) mean flows are nearly as low as mean flow in winter (December – February). Mean flows in October and November have been slightly higher (35 to 36 cfs). During the period of record annual peaks have ranged from 7,000 cfs (May 22, 1981) to 267 cfs (May 3, 2000). Peak annual flows have not occurred earlier than April 23, nor later than July 7.

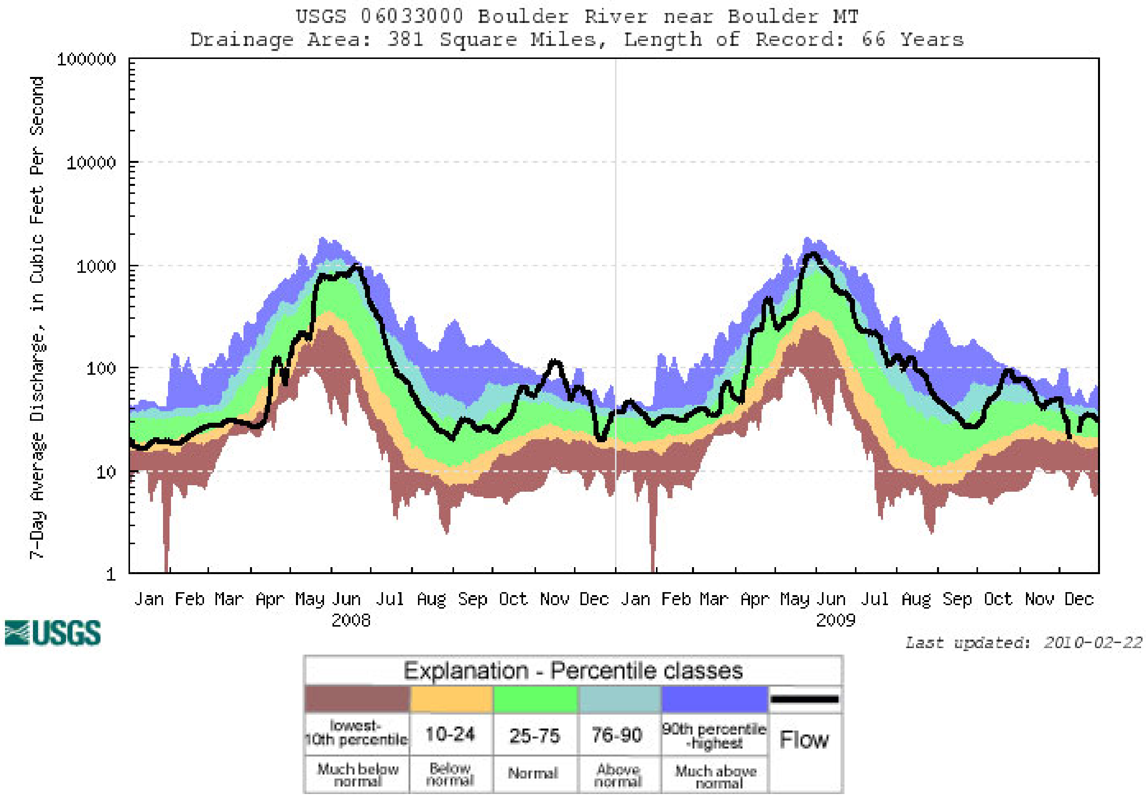

Figure B-1. Monthly Mean Flows of the Boulder River

B2.5.3 Surface Water Quality

As summarized in **Table B-2**, surface water quality data are collected from three stations in the watershed, dating to 1997. Six other stations have water quality data beginning with 1997, but discontinued in 1999, 2002 or 2004. Parameters include: pH; specific conductance; temperature; hardness as $CaCO_3$; major, minor and trace inorganics; radionuclides; and sediment.

Table B-2. Water Quality Stations in the Boulder River Watershed

Name	Number	Drainage Area	Agency	Period of Record
Boulder River above Kleinsmith Gulch	06031450	-	USGS	1997-1994
Boulder River at Basin	06031500	219 miles2	USGS	1997-1999
Basin Creek at Basin	06031600	-	USGS	1997-2008
Cataract Creek near Basin	06031950	30.6 miles2	USGS	1997-1999
Cataract Creek at Basin	06031960	-	USGS	1997-2008
Boulder River near Basin	06032000	292 miles2	USGS	1997-1999
High Ore Creek near Basin	06032300	8.86 miles2	USGS	1997-2002
Boulder River below Little Galena Gulch	06032400	318 miles2	USGS	1997-2008
Boulder River near Boulder, MT	06033000	381 miles2	USGS	1997-1999

B2.6 Groundwater

B2.6.1 Hydrogeology

No studies of the hydrogeology were identified. Kendy and Tresch (1996) described the groundwater system of the Boulder Valley in general terms, assuming that groundwater flow within the valley is typical of intermontane basins. Groundwater is presumed to flow towards the center of the basin from the head and sides, and then down valley along the central axis.

The average groundwater flow velocity in the bedrock is probably several orders of magnitude lower than in the valley fill sediments. However, zones of carbonate dissolution and faulting/fracturing may produce significant quantities of groundwater. The hydrologic role of the structural geology (faults and folds) is uncertain. No studies of the bedrock hydrogeology were identified.

Natural recharge occurs from infiltration of precipitation, stream loss, and flow out of the adjacent bedrock aquifers. Flood irrigation is an additional source of recharge to the valley aquifers, particularly on the benches that flank the modern floodplain.

B2.6.2 Groundwater Quality

The Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) program monitors and samples a statewide network of wells (Montana Bureau of Mines and Geology, 2008). As of March 2008, the GWIC database reports 590 wells within the watershed (Montana Department of Natural Resources and Conservation, 2008).

The water quality data include general physical parameters: temperature, pH and specific conductance, in addition to inorganic chemistry (common ions, metals and trace elements). MBMG does not analyze groundwater samples for organic compounds.

Kendy and Tresch (1996) report that groundwater of the northern Boulder Valley is characterized by a calcium-bicarbonate chemistry, with dissolved solids ranging from 250-500 milligrams per liter (mg/L). Dissolved solids are lower (<250 mg/L) to the south, where the basin sediments are thickest. In the southern third of the basin, groundwater is characterized by a mixed (Ca, Mg or Na) sulfate chemistry with dissolved solids ranging from 250-500 mg/L.

There are six public water supplies within the watershed, all of which use groundwater for their supply. Water quality data are available from these utilities via the SDWIS State database (Montana Department of Environmental Quality, 2008), although these data reflect the finished water provided to the public, not raw water at the source.

B2.7 Climate

Climate in the area is typical of mid-elevation intermontane valleys in western Montana. Precipitation is most abundant in May and June. Annual average precipitation ranges from 11 to 45 inches in the Boulder River watershed. The mountains receive most of the moisture, and the Boulder Valley below Elkhorn Creek receives the least. The precipitation data (**Appendix A, Figure A-11**) is mapped by Oregon State University's PRISM Group, using records from NOAA stations (PRISM Group, 2004).

See **Table B-3** for climate summaries; **Figure A-11** in **Appendix A** shows the distribution of average annual precipitation.

B2.7.1 Climate Stations

National Oceanographic and Atmospheric Administration (NOAA) currently operates one weather station in the watershed. The USDA Natural Resources Conservation Service (NRCS) operates three SNOTEL (SNOpack TELemetry) snowpack monitoring stations within the watershed. **Figure A-11** in **Appendix A** shows the locations of the NOAA and SNOTEL stations, in addition to average annual precipitation. Climate data are provided by the Western Regional Climate Center, operated by the Desert Research Institute of Reno, Nevada.

Table B-3. Monthly Climate Summary: Boulder

Boulder, Montana (241008) Period of Record : 7/1/1948 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Max. Temp (F)	33.2	38.6	44.7	54.9	64.2	72.7	82.5	82.0	71.1	59.4	42.9	34.9	56.7
Ave. Min. Temp. (F)	9.3	14.1	19.0	27.1	35.2	42.5	47.7	45.9	36.9	28.2	18.3	11.5	28.0
Ave Tot. Precip. (in.)	0.46	0.32	0.50	0.79	1.78	2.05	1.37	1.24	1.02	0.56	0.51	0.44	11.03
Ave.. Snowfall (in.)	7.3	3.6	6.3	3.8	0.4	0.1	0.0	0.0	0.1	0.4	3.9	5.3	31.2
Ave Snow Depth (in.)	3	1	1	0	0	0	0	0	0	0	1	2	1

B3.0 ECOLOGICAL PARAMETERS

B3.1 VEGETATION

The primary cover in the uplands is conifer forest. Conifers are dominated by Lodgepole pine, giving way to Douglas fir at lower elevations, with lesser amounts of White pine, Western larch and juniper. The valleys are characterized by grassland and irrigated agricultural land, with minor shrublands. Landcover is shown on **Figures A-12** and **A-13** in **Appendix A**. Data sources include the University of Montana's Satellite Imagery land Cover (SILC) project (University of Montana, 2002), and USGS National Land Cover Dataset (NLCD) mapping (Montana State Library, 1992).

B3.2 AQUATIC LIFE

Native fish species present in the watershed include: westslope cutthroat trout, mountain whitefish, mottled scuplin, longnose dace and longnose sucker. Westslope cutthroat trout are designated "Species of Concern" by Montana Department of Fish, Wildlife and Parks (FWP).

Introduced species are also present in streams, including: brook, rainbow, brown and Yellowstone cutthroat trout. Data on fish species distribution are collected, maintained and provided by FWP (Montana Department of Fish, Wildlife and Parks,2006). Fish species distribution is shown on **Figure A-14** in **Appendix A**.

B3.3 Fires

The United States Forest Service (USFS) Region 1 office and the USFS remote sensing applications center provide data on fire locations from 1940 to the present. Two fires are identified for this period, both of which burned in 2000. The High Ore fire burned 7,824 acres of the watershed north of Boulder. The Boulder Hill fire burned 1,830 acres northeast of the Town of Boulder (**Appendix A, Figure A-15**).

B4.0 Cultural Parameters

The following information describes the social profile of the Boulder River watershed.

B4.1 Population

An estimated 2,300 persons lived within the watershed in 2010 (Montana Department of Natural Resources and Conservation, 2008). Population estimates are derived from census data (United States Census Bureau, 2010), based upon the populations reported from census blocks within and intersecting the watershed boundary (**Appendix A, Figure A-16**). Basin and Boulder had reported populations of 212 and 1,183 in the 2010 census, respectively. The remainder of the population is sparsely distributed. Much of the watershed is unpopulated.

B4.2 Transportation Networks

The watershed is bisected by Interstate 15 and Montana Route 69. The network of unpaved roads on public and private lands will be further characterized as part of the source assessment. No active railways are present in the watershed. The Great Northern Railway branch to Butte formerly bisected the watershed where Interstate 15 now exists.

B4.3 Land Ownership

Land ownership data are provided by the State of Montana CAMA database via the NRIS website (Montana Department of Natural Resources and Conservation, 2008) (**Table B-4**). Slightly more than one-half of the watershed is administered by the USFS, and 8% by the U.S. Bureau of Land Management. Private lands comprise 37% of the watershed, and Montana State Trust Lands occupy 5% of the watershed. Land ownership is shown on **Figure A-17** in **Appendix A**.

Table B-4. Land Ownership

Owner	Acres	Square Miles	% of Total
Private	180,448	281.9	37%
U.S. Forest Service	249,016	389.1	51%
U.S. Bureau of Land Management	41,362	64.6	8%
State Trust Land	14,876	23.2	5%
State Department of Corrections	1,393	2.2	0.3%
Total	487,142	761.2	—

B4.4 Land Use & Cover

Land use within the watershed is dominated by forest and agriculture (**Table B-5**). Agriculture in the lowlands is primarily related to the cattle industry: irrigated hay and dry grazing. Information on land use is based on land use and land cover (LULC) mapping completed by the USGS in the 1980s. The data are at 1:250,000 scale, and are based upon manual interpretation of aerial photographs. Agricultural land use is illustrated on **Figure A-13** in **Appendix A**. Potential sources of human impacts (wastewater discharges, livestock feeding areas) are illustrated on **Figure A-18** in **Appendix A**.

Table B-5. Land Use and Cover

Land Use	Acres	Square Miles	% of Total
Evergreen Forest	256,516.6	400.8	52.66%
Grasslands/Herbaceous	154,348.5	241.2	31.68%
Shrubland	52,338.7	81.8	10.74%
Pasture/Hay	8,680.3	13.6	1.78%
Small Grains	3,843.4	6.0	0.79%
Transitional	2,999.3	4.7	0.62%
Deciduous Forest	2,223.5	3.5	0.46%
Woody Wetlands	2,177.9	3.4	0.45%
Fallow	1,096.2	1.7	0.23%
Commercial/Industrial/Transportation	981.6	1.5	0.20%
Row Crops	849.5	1.3	0.17%
Emergent Herbaceous Wetlands	474.1	0.7	0.10%
Low Intensity Residential	145.4	0.2	0.030%
Urban/Recreational Grasses	136.8	0.2	0.028%
Open Water	112.2	0.2	0.023%
High Intensity Residential	98.7	0.2	0.020%
Bare Rock/Sand/Clay	95.4	0.1	0.020%
Mixed Forest	16.0	0.0	0.003%
Perennial Ice/Snow	6.3	0.0	0.001%
Quarries/Strip Mines/Gravel Pits	0.4	0.0	0.000%

Berkas *et al*. (2005) report that roughly 3,500 acres upstream of the Boulder River near Boulder gage are irrigated with surface water diversions. Additional information on agricultural land use can be obtained from Department of Revenue data. The Department of Revenue assigns a predominant agricultural use only if more than 50% of a given parcel is so used, and then the entire acreage is ascribed to that use. A total of 6,754 acres of irrigated land is reported in the watershed. The dominant designated agricultural use is grazing, corresponding to 152,508 acres (238 square miles) or 31% of the watershed area (Montana Department of Natural Resources and Conservation, 2008).

B4.5 Mining

Mining remains an important economic activity within Jefferson County, although not in the Boulder River watershed. Mining and milling were widely performed within the watershed, as was some smelting. Waste rock and tailings are still present in many locations. Like many Montana mining districts, much of the metal production began in the 1860s with gold-bearing placers. Later, lode deposits of lead, zinc, gold and silver came to be of importance. Iron-bearing ore was mined in the Elkhorn district to provide flux to the East Helena smelter.

B4.5.1 Historic Activity

The environmental impacts of abandoned and inactive mines in the watershed have been widely studied by the MBMG and USGS (Metesh et al., 1994; Metesh et al., 1995; Metesh et al., 1998; Nimick et al., 2004), among others). The influences of historic mining are most concentrated in the Basin and Cataract Creek drainages. Numerous reclamation projects were completed in the 1990s and 2000s (Montana Department of Environmental Quality, 2009; Nimick, 2006).

DEQ Remediation Division data on abandoned mine locations are plotted on **Figure A-18**.

B4.5.2 Modern Activity

The Basin Creek Mine property, located near the divide between Basin and Tenmile Creeks, is now owned by Montana DEQ, and is operated as the Luttrell Depository. This facility provides encapsulated disposal for mine and mill waste from former mining sites in the region. Active open-pit mines (Golden Sunlight; Montana Tunnels) are located immediately outside the Boulder River watershed, but no large-scale mining operations are identified within the watershed.

B4.6 Timber Harvests

No maps of timber harvests were identified during the compilation of this watershed description. However, the 'transitional' classification in National Land Cover Dataset (NLCD) is commonly applied to harvested or burned areas. The size and distribution of areas in the watershed with this classification are consistent with timber harvests. A total of 3,000 acres are mapped 'transitional' in the 1992 NLCD data, primarily in the headwaters regions of the Boulder River. Inspection of aerial photographs reveals that additional areas appear to have been harvested since that date.

B4.7 Wastewater

The MPDES reports several regulated discharges within the watershed, both wastewater and stormwater. The towns of Boulder and Basin are sewered. Boulder's wastewater treatment facility discharges to the Boulder River, and therefore has a MPDES permit. Basin's facility (aerated lagoon with infiltration/percolation cells) discharges to groundwater rather than surface water. Wastewater treatment for other communities and rural residences is provided by on-site septic tanks and drainfields.

Septic system density is estimated from the 2000 census block data, based on the assumption of one septic tank and drainfield for each 2.5 persons (Montana Department of Natural Resources and Conservation, 2007), and that sewer systems correspond to incorporated communities. Septic system density is classified as low (less than 50 per square mile), moderate (51 to 300 per square mile) or high (greater than 300 per square mile). Nearly all of the watershed is mapped as low septic system density, with very limited areas of moderate (215 acres) and high (47 acres) density. The high and moderate density locations are found primarily around Boulder and Basin. Community sewers (727 acres) are only mapped at Boulder; the sewer system at Basin is not mapped. Septic system density is illustrated on **Figure A-18** in **Appendix A**.

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APPENDIX C - REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

C1.0 TMDL DEVELOPMENT REQUIREMENTS

Section 303(d) of the federal Clean Water Act (CWA) and the Montana Water Quality Act (WQA) (Section 75-5-703) requires development of TMDLs for impaired waterbodies that do not meet Montana WQS. Although waterbodies can become impaired from pollution (e.g. low flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, metals, pathogens, and temperature), the CWA and Montana state law (75-5-703) require TMDL development only for impaired waters with pollutant causes. Section 303(d) also requires states to submit a list of impaired waterbodies to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, EPA and DEQ referred to this list simply as the 303(d) list.

Since 2004, EPA has requested that states combine the 303(d) list with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) list also includes identification of the probable cause(s) of the water quality impairment (e.g. pollutants such as metals, nutrients, sediment, pathogens or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency. The impairment status determination methodology is identified in DEQ's Water Quality Assessment Process and Methods found in Appendix A of Montana's Water Quality Integrated Report(Montana Department of Environmental Quality, 2011)

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303(d) of the CWA require states to develop all necessary TMDLs for impaired or threatened waterbodies. There are no waterbodies within the Boulder Elkhorn TMDL Planning Area (TPA) that are considered threatened by a pollutant.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable WQS to be exceeded (violated). TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS. **Section 4.0** of the main document provides a description of the components of a TMDL.

To satisfy the federal CWA and Montana state law, TMDLs are developed for each waterbody-pollutant combination identified on Montana's 303(d) list of impaired or threatened waters, and are often presented within the context of a water quality restoration or protection plan. State law (Administrative Rules of Montana 75-5-703(8)) also directs Montana DEQ 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 development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

C2.0 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all water quality standards are met. Water quality standards form the basis for the targets described in **Sections 5.0, 6.0,** and **7.0** of the TMDL document. Pollutants addressed in this framework water quality improvement plan include sediment, temperature and nutrients. This section provides a summary of the applicable water quality standards for these pollutants.

C2.1 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 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 (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 nonpoint source activities or pollutant discharges must 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 C2-1**. All waterbodies within the Boulder Elkhorn TPA are classified as B-1 (see **Section 3.1** and **Table 3-1** in the main document for individual stream classifications).

Table C2-1. 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.
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.

C2.2 STANDARDS

In addition to the use classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric Standards

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 DEQ-7 (Montana Department of Environmental Quality, 2010). 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., lifelong) 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 DEQ. 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

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 WQS. 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 the list of pollutants addressed in the Boulder Elkhorn TPA are summarized below. In addition to the standards below, the beneficial-use support standard for B-1 streams, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include effects from dewatering/flow alterations and effects from habitat modifications.

C.2.2.1 Sediment Standards

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table C2-2**. 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 condition in which any increases in sediment above naturally occurring levels are not harmful, detrimental or injurious to beneficial uses (see definitions in **Table C2-2**).

Table C2-2. Applicable Rules for Sediment Related Pollutants

Rule	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1:
17.30.623(2)(d)	The maximum allowable increase above naturally occurring turbidity is 5 NTU for B-1 except as permitted in 75-5-318, MCA.
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.
17.30.637(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(19)	"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(25)	"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.

C.2.2.2 Temperature Standards

Montana's temperature standards were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the 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 decrease or rate at which cooling temperature changes (below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as A-1 or B-1; from Rule 17.30.622(e) and 17.30.623(e):
A 1^{o} F maximum increase above naturally occurring water temperature is allowed within the range 32^{o} F to 66^{o} F; within the naturally occurring range of 66^{o} F to 66.5^{o} F, no discharge is allowed which will cause the water temperature to exceed 67^{o} F; and where the naturally occurring water temperature is 66.5^{o} F or greater, the maximum allowable increase in water temperature is 0.5^{o} F. A 2^{o} F per-hour maximum decrease below naturally occurring water temperature is above 55^{o} F. A 2^{o} F maximum decrease below naturally occurring water temperature is allowed within the range of 55^{o} F to 32^{o} F.

C.2.2.3 Nutrient Standards

The narrative standards applicable to nutrients in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae. Montana has recently developed draft nutrient criteria for nitrate+nitrite nitrogen (NO_3+NO_2), total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* based on the Level III ecoregion in which a stream is located (Suplee, et al., 2008). For the

Middle Rockies Level III ecoregion, draft water quality criteria for NO_3+NO_2, TN, TP, and chlorophyll-*a* are presented in **Table C2-3**. These criteria are growing season, or summer, values applied from July 1st through September 30th. Additionally, numeric human health standards exist for nitrogen (**Table C2-4**), but the narrative standard is most applicable to nutrients as the concentrations in most waterbodies in Montana are well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table C2-3. Numeric Nutrient and Benthic Algae Criteria for the Middle Rockies Ecoregion.

Parameter	Criteria
Nitrate+Nitrite Nitrogen	≤ 0.100 mg/L
Total Nitrogen	≤ 0.300 mg/L
Total Phosphorus	≤ 0.030 mg/L
Benthic Algae	≤ 129 mg/m²

Table C2-4. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)[1]
Nitrate as Nitrogen (NO_3-N)	10,000
Nitrite as Nitrogen (NO_2-N)	1,000
Nitrate plus Nitrite as N	10,000

[1]Maximum Allowable Concentration.

C3.0 Reference Conditions

C3.1 Reference Conditions as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. 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 waterbodies greatest potential for water quality given historic land use activities(Montana Department of Environmental Quality, 2006).

DEQ 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 WQS 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. DEQ realizes that pre-settlement 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 Total Suspended Solids (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.).

DEQ 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 is no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

C3.2 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 (Helsel 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 non-normal distributions are far less influenced by such observations.

Figure C3-1 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 WQS or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (Buck, et al., 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is “good” confidence in the quality of the reference sites and resulting information (Suplee, 2004). 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.

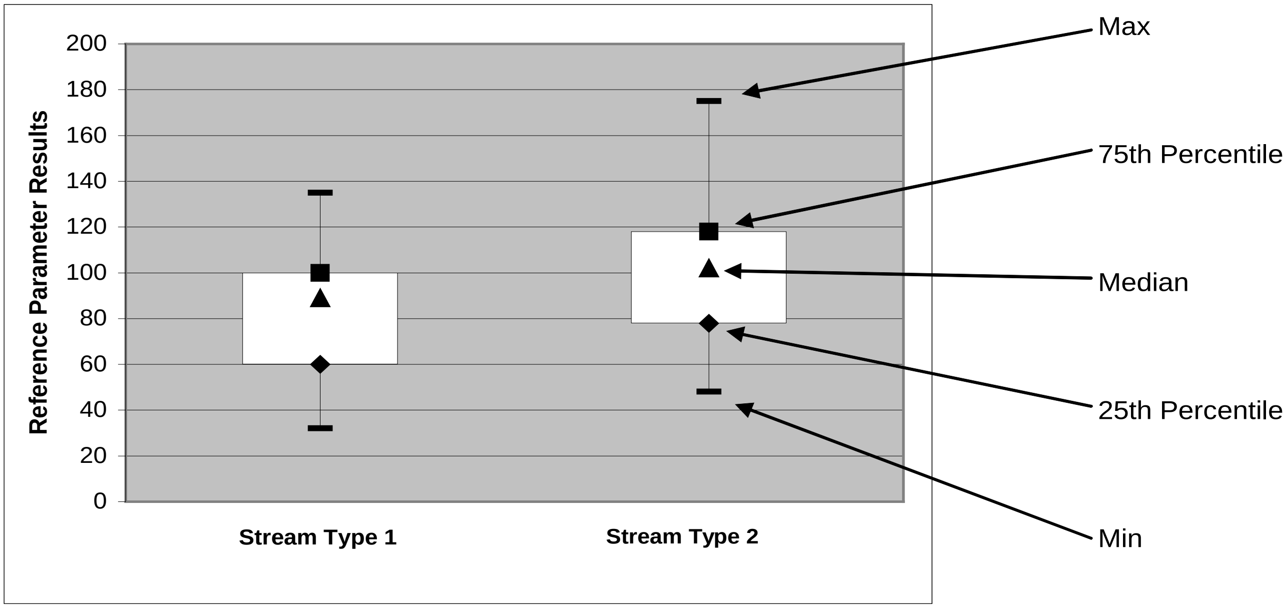

Figure C3-1. Boxplot Example for Reference Data.

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

1. It is a simple approach that is easy to apply and understand.
2. About 25 percent 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 percent of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25th to 75th 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 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 waterbodies 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 WQS in **Table C2-2**. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, coldwater fish, or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. 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 or (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 DEQ guidance and WQS (Suplee, 2004). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations.

Where the data does suggest a normal distribution, or reference data is presented in a way that precludes use of non-normal statistics, 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.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data 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.

Another approach would be to develop statistics for a given parameter from all streams within a watershed or region of interest (Buck, et al., 2000). The boxplot distribution of all the data for a given parameter can still be used to help determine potential target values knowing that most or all of the streams being evaluated are either impaired or otherwise have a reasonable probability of having significant water quality impacts. Under these conditions you would still use the median and the 25th or 75th percentiles as potential target values, but you would use the 25th and 75th percentiles in a way that is opposite from how you use the results from a regional reference distribution. This is because you are assuming that, for the parameter being evaluated, as many as 50 percent to 75 percent of the results from the whole data distribution represent questionable water quality. **Figure C3-2** is an example statistical distribution where higher values represent better water quality. In **Figure C3-2**, the median and 25th percentiles represent potential target values versus the median and 75th percentiles discussed above for regional reference distribution. Whether you use the median, the 25th percentile, or both should be based on an assessment of how impacted all the measured streams are in the watershed. Additional consideration of target achievability is important when using this approach. Also, there may be a need to also rely on secondary reference development methods to modify how you apply the target and/or to modify the final target value(s). Your certainty regarding indications of impairment or non-impairment may be lower using this approach, and you may need to rely more on adaptive management as part of TMDL implementation.

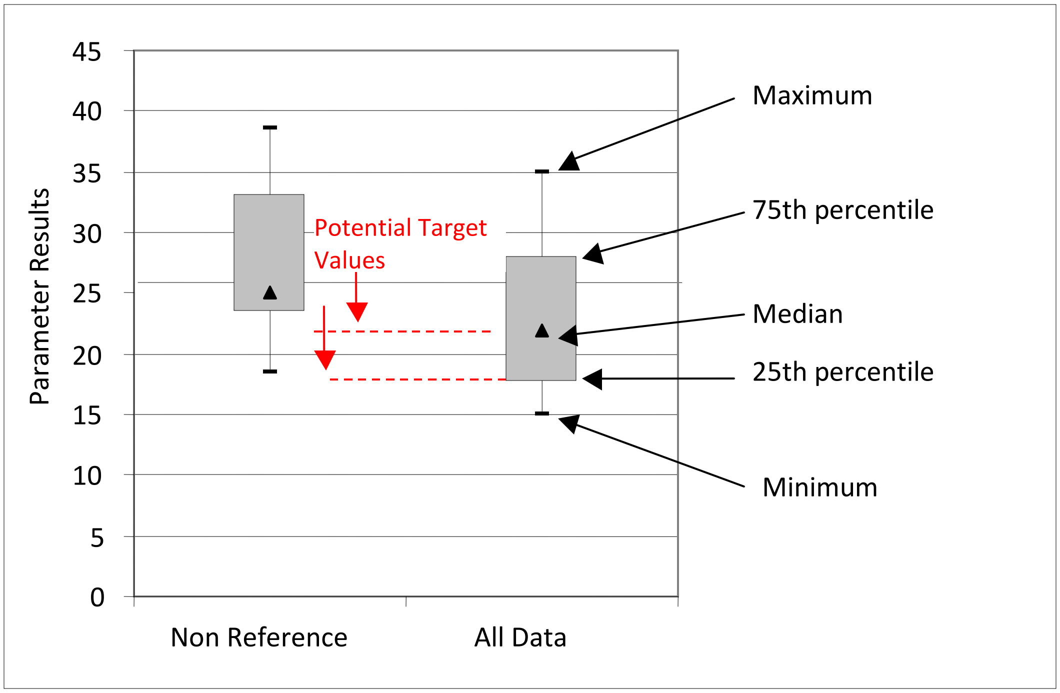

Figure C3-2. Boxplot example for the use of all data to set targets.

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APPENDIX D - REFERENCE CONDITIONS AND TARGET VALUE RATIONALE FOR SEDIMENT

D1.0 REFERENCE CONDITIONS AND DATA SOURCES

Montana Department of Environmental Quality (DEQ) applies a 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.

Waterbodies used to determine reference condition do not necessarily reflect pristine or pre-settlement conditions, or display conditions that meet all possible beneficial uses. A reference condition is intended 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. Reference conditions look to accommodate natural variations in biological communities, water chemistry, etc., due to climate, bedrock, soils, hydrology and other natural physiochemical differences. A reference condition 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. DEQ recognizes that pre-settlement water quality conditions usually are not attainable.

The following methods may be used to determine reference conditions:
Primary Approaches

- Regional Approach:
  Compare conditions in a waterbody to baseline data from reference waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Historical Approach:
  Evaluate historical data relating to condition of the waterbody in the past.
- Internal Reference Approach:
  Compare conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approaches

- Literature Approach:
  Review literature (e.g. review of studies of fish populations, etc. that were conducted on similar waterbodies.)
- Professional Judgment Approach:
  Seek expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or capability).
- Modeling Approach:
  Apply quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ prefers to use the primary approach for determining reference condition, particularly where adequate regional reference data are available. Secondary approaches are often necessary to estimate reference condition when there is no regional reference data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent. This is particularly true where the translation of a narrative standard may involve multiple target indicator parameters. Some parameters may have good regional or internal reference information; whereas regional or other primary reference information may be lacking for other parameters. Historical quantitative reference condition information is rarely available; however, historical information can supplement secondary approaches with qualitative data and best professional judgment.

Three main sources of data served as information to help identify reference conditions in the Boulder-Elkhorn TPA. Target values for the parameters of interest were based on unpublished data from the Beaverhead-Deerlodge National Forest, data from the USFS PIBO program, and from data collected during the 2010 DEQ Boulder-Elkhorn TPA sediment/habitat field study.

Beaverhead Deerlodge Regional Reference Data Regional reference data are available from the Beaverhead Deerlodge National Forest (BDNF). BDNF data were collected between 1991 and 2002 from approximately two hundred reference sites: seventy of the sites are located in the Greater Yellowstone Area and the remaining sites are in the BDNF, which is also located in southwestern Montana (Bengeyfield, 2004). Due to the size of the BDNF, a subset of sites from the dataset were selected that were located within the Boulder-Elkhorn TPA or adjacent watersheds. Applicable reference data are width/depth ratios, entrenchment ratios, and percent fine sediment <6mm from pebble counts.

United States Forest Service Pacfish/Infish Biological Opinion (PIBO) data (2010) was reviewed for the following parameters: percent fines less than 6mm in pool tails, residual pool depth, pool frequency, and large woody debris frequency. In the PIBO dataset, two sets of data were reviewed, data from managed sites, and data from reference sites. PIBO classifies their reaches as follows: “Watersheds are considered reference if there had been no livestock grazing within the past 30 years, less than 10% of the watershed had undergone timber harvest, there was no evidence of mining in proximity to riparian areas, and road density was less than 0.5 km/km2. Managed watersheds included a full complement of management activities, including timber harvest, road building and maintenance, livestock grazing, mining, and recreation” (Kershner et al., 2004). For analysis purposes, data from managed sites were selected from watersheds within the Beaverhead Deerlodge National Forest and Helena National Forest, and from similar level IV ecoregions to what is found in the Boulder Ellkhorn TPA. However, due to the small number of PIBO reference sites within the Boulder Elkhorn area, analysis of reference data includes sites from the similar, but broader encompassing Middle Rockies ecoregion, although not necessarily within or adjacent to the TPA. Data was used from 32 managed sites, and 72 reference sites.

2010 DEQ field data was used for the development of all parameter values. All streams were stratified into reaches using four main criteria: valley gradient, valley slope, stream order, and ecoregion. These reaches were further subcategorized based on adjacent land use and vegetation. 23 reaches were selected, and data from sites within each of the selected reaches was collected on streams throughout the Boulder River watershed. No reference reaches were identified from the reaches that were sampled; however, in the sampling analysis design for the 2010 field data study, sites were chosen to try to represent the variability among reach type categories and stratification parameters, and therefore include reaches that characterize a range of conditions. Sampled sites were also dependent on landowner permission and accessibility. Most of the reaches assessed in the Boulder-Elkhorn study represent conditions where past or present human activities have left signs of significant to moderate effects, however a few of the reaches do reflect healthy conditions in the study area that may be representative of all reasonable land, soil, and water conservation practices, with limited land use effects on the stream.

D2.0 Target Value Development

Target values are often presented for a range of conditions based on stream size, parent geology, or other significant factors that influence stream function and response. For instance, depending on the setting, sediment and habitat conditions in a 5th order stream may vary considerably from those in a 2nd order stream and therefore assessing the respective condition of each against the same target values would be inappropriate for some target parameters. In the Boulder-Elkhorn TPA, data was sorted and analyzed based on reach type, level of impact (reference vs. non-reference), stream gradient and stream size (bankfull width); and target values were determined based on the best approach for analysis for a given parameter.

The use of median and percentiles in statistical analysis is often employed when data, such as water quality data, tend to have a non-normal distribution. Also, limited amounts of data can sometimes result in skewed results if using normal distribution statistics. For these reasons, it is more appropriate to use non-normal or non-parametric statistics for setting reference conditions and determining target values for most parameters.

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 'water quality' criteria (U.S. Environmental Protection Agency, 1999). Therefore, the selection of the applicable statistics from a data set is consistent with ongoing development of DEQ and EPA guidance for interpreting narrative water quality standards.

If parameters are used where lower values represent better water quality conditions, then typically the 75th percentile of the reference data set is used as a potential target value. If higher values represent better water quality conditions then the 25th percentile would apply. If a dataset is known to represent a variety of conditions, and not just reference conditions, or where there is less confidence in the data to represent reference conditions, the median may be used. If a dataset is known to largely represent impacted conditions, then the opposite percentiles as mentioned above can be used, e.g. the 25th percentile of an impacted data set may be used to develop a percent fines target value (where lower values represent more desired conditions).

As described in Section D1.0, no reference sites were identified from the DEQ data set when developing target values. However most sites that were investigated represented conditions affected by human influence of varying degrees, with few sites representative of a desired to near-desired condition. Because of this, generally the quartile of the population of the DEQ data was the primary value of interest (opposite the quartile that would be reviewed under reference conditions). The USFS PIBO data contains both reference and non-reference (managed) data. The Beaverhead-Deerlodge NF data also contains reference and non-reference data sets. These data sets were reviewed and comparisons between the median of non-reference and quartiles of the reference data sets were used to help inform the target development. Medians were used from these data sets because it is assumed that managed or non-reference contains a wide range of variability that includes a relatively balanced spectrum of desired and undesired condition. The statistics from both the DEQ and PIBO or BDNF data were then compared and target values determined based on these comparisons, best professional judgment, and relation to commonly accepted literature values.

Information and rationale used to derive target values follow below. Target parameter description and rationale for inclusion is presented in **Section 5.4**.

D2.1 Width Depth Ratio

Width to depth ratios provide a metric by which we can assess the form, and therefore, relative function of a given reach. Lower values signify a narrow, deep channel, whereas larger values may indicate unnatural overwidening and shallowing of a reach. Criteria based on Rosgen stream type classification for width to depth ratios gives guidance of <12 for A, G and E stream types, and >12 for F, B and C stream types. While the upper limits are not provided for values >12, data from BDNF and DEQ can be reviewed to provide a range of targets that better represent desired conditions.

For the width/depth parameter, BDNF data was organized and reviewed according to reference sites, and managed sites. The 75th percentile of the reference sites served as the focus for evaluating a target value. The median value for managed site groupings was also reviewed, as it is assumed that the median represents desired width/depths when investigating a variety of conditions which encompass a varying level of response.

Width/depth ratios for F, B, C stream types are defined as >12, where 12 serves as the low end of the width/depth ratio range. The upper end of the range for a stream type is not defined by Rosgen classification, however it is understood that the higher the width depth ratio value, the more likely it represents conditions of disturbance to the natural form and function of the stream. Therefore, targets are developed here to provide a guideline for the upper limit of width depth ratios for the Boulder-Elkhorn watershed for B and C channels, and thereby signal when stream channel dimensions may be out of proportion.

Width/depth ratio is a dimensionless ratio that is therefore applicable regardless of stream size. However it is theorized here that larger rivers may have a somewhat higher upper range of width/depth values than smaller streams (3rd order or less). From Rosgen's Applied River Morphology textbook:

> "The distribution of energy within channels having high W/D ratios (i.e., shallow and wide channels) is such that stress is placed in the near bank region. As the W/D ratio value increases (i.e., the channel grows wider and more shallow), the hydraulic stress against the banks also increases and bank erosion is accelerated. The accelerated erosion process is generally the result of high velocity gradients and high boundary stress, as mean velocity, stream power, and shear stress decrease in the presence of an increase in width/depth ratio values. Increases in the sediment supply to the channel develop from bank erosion, which – by virtue of becoming an over widened channel – gradually loses its capability to transport sediment. Deposition occurs, further accelerating bank erosion, and the cycle continues."

Due to the years of disturbance and accelerated bank erosion in many places throughout the Boulder River watershed, it is expected that high width/depth ratios will be observed. However, it is also expected that under naturally occurring conditions, the stream size and sediment loads that exist in the

Boulder watershed may result in higher width/depth ratios than might be found in the smaller tributaries. For that reason, a width/depth ratio target for the Boulder River has been selected to account for this possibility. However, the Boulder River width/depth ratio is developed based on professional judgment and literature research as no data from streams the size of the Boulder River existed in the reference data set, other than five reaches from the Boulder River itself collected during DEQ's field effort. It is acknowledged that due to the scale of bank erosion and other sediment sources from the Boulder River watershed to the Boulder River, recovery of width/depth ratios in the Boulder River will take a significant effort and many years to accomplish.

Upon review of the width depth ratio results (**Table D-1**), a width/depth ratio of ≤13 is selected for the target value for tributary B streams, and <18 is selected for the target value for tributary C streams. For B streams, a value of 13 is roughly consistent with the 25^{th} percentile of the field data, the 75^{th} percentile of BDNF reference, and near in value to the median of the BDNF managed. The value of <18 for C stream is selected largely because the 75^{th} percentile of the BDNF reference data. Although the 25th percentile of DEQ field data and the median of BDNF managed are both near 15, knowing that C channels are typically classified as having width/depth ratios >12, and B channels are defined as <13, using the BDNF reference value provides some acceptable variability in C stream width/depth ratios while using known reference reaches to define the upper limit.

Due to the increasing size and stream power for the Boulder River, the width/depth target for the mainstem Boulder River is <30. As there were only 5 sites that were sampled on the Boulder River, all of which were 4^{th} order or larger, best professional judgment and recognition that these sites have been affected by past anthropogenic activities was factored into the determination of ≤30 as a conservative target value. Values used as width to depth targets in prior TMDLs dealing with similarly sized streams (e.g., Prospect Creek, width/depth target of <30; St. Regis, width/depth target of <30) also suggest <30 is appropriate.

Table D-1. Width to Depth Values

B Channels	**25^{th} Percentile**	**Median**	**75^{th} Percentile**
DEQ Field Data (n=45)	**12.9**	16.4	21.9
BDNF Reference (n=18)	9	10.4	**12.9**
BDNF Managed (n=156)	7.3	**10.9**	15.8
C Channels			
DEQ Field Data (n=35)	**14.5**	18.2	36.5
BDNF Reference (n=10)	10.2	13.1	**17.9**
BDNF Managed (n=53)	12.6	**15**	18.5

*Width to depth of <12 applies to low gradient E channels based on Rosgen stream classification criteria.

D2.2 ENTRENCHMENT

Criteria from Rosgen stream type classification for entrenchment gives guidance of <1.4 for A, F and G streams, 1.4-2.2 for B streams, and >2.2 for C, E streams. These literature values will serve as the target ranges for entrenchment in the Boulder-Elkhorn TPA as well. Entrenchment values >2.2 for C and E stream types are described by Rosgen as slightly entrenched to non-entrenchment as the values increase. The higher the entrenchment value the greater accessibility of streamflow to the floodplain at or greater than bankfull flow, and therefore, high entrenchment values are for C, E stream types are not considered to indicate instability. While there is no upper limit to an entrenchment value, typical entrenchment values for stable C and E streams in the Boulder-Elkhorn watershed are expected to be around 3.0 or greater, as observed in the data set (**Table D-2**).

Table D-2. Entrenchment Values

C Channels	25th Percentile	Median	75th Percentile
DEQ Field Data (n=35)	2.3	3.3	**6.3**
BDNF Reference (n=10)	**2.6**	3.2	4.9
BDNF Managed (n=53)	2.4	**3.2**	4.8
E Channels			
DEQ Field Data (n=25)	1.7	3.4	**5.1**
BDNF Reference (n=43)	**3.7**	10.9	26
BDNF Managed (n=183)	2.7	**4**	7.7

D2.3 Percent Fines Analysis

Percent fines provide a measure of substrate composition in key habitat features necessary for fish and aquatic life. Typically, riffles and pool tails are focused on due to their importance as spawning habitat and macroinvertebrate habitat.

DEQ field data and BDNF reference site data was used to develop targets for percent fines <6mm and <2mm in riffles. Percent fines data for the BDNF was only available from reference sites (not managed sites) and only for percent fines less than 6mm. In developing percent fines targets, differences in the data collection methodology between the Beaverhead Deerlodge NF and DEQ datasets necessitates some discretion when comparing results. DEQ collects percent fines data from riffles using the Wolman pebble count method. BDNF percent fine data is collected using a pebble count, but using the zigzag method which is not necessarily confined to riffles and therefore may encompass features like pool and runs that tend to have higher fine percentages.

Data from the DEQ field sites and PIBO sites was used to evaluate percent fines in pool tails. BDNF data did not include pool tail information. Pool tail values are presented as reach averages. DEQ and PIBO data is collected from pool tails using the grid toss method, and assesses those particles less than 6mm. There are some slight differences between DEQ and PIBO methods in the identification of pool tail sampling locations which should be considered: PIBO identifies pools that are wider than 50% of the wetted channel and have a maximum pool depth of 1.5 times the pool tail crest depth, and takes grid toss measurements at locations roughly equivalent to the ¼, ½, and ¾ distance points around the pool tail crest. DEQ also identifies pools that have a maximum pool depth of 1.5 times the pool tail crest depth, but does not distinguish size laterally. In addition, DEQ focuses grid toss measurements on those pool tails where it appears there is spawning potential. Spawning potential is defined as those pool tails that contain substrate size that would be moveable by fish typically found in the stream of interest. DEQ also focuses their grid toss measurements in those locations around the pool tail crest where spawning potential appears to exist. Generally, these differences in methodology may not reflect much difference in results, however it is noted that the PIBO methods are more rigid and easily repeatable, although do not necessarily have a direct relationship to spawning habitat quality; whereas DEQ methods, while more subjective and requiring best professional judgment in the field, are presumed to be a better reflection of the direct linkage between pool tail substrate and spawning potential.

It should also be noted that the percent fines targets described below are appropriate for those stream habitats and stream types that best show the effects of sediment accumulation in spawning areas.

These targets may not apply to Rosgen E channels, which typically exhibit much higher natural values of percent surface fines. Percent fines in E channel reaches should be evaluated on a case by case basis. Percent fines evaluations should occur in riffle and pool tails in Rosgen B and C Reach types as these often most clearly illustrate effects from percent fine accumulation.

D2.3.1 Percent Fines in Riffles (Wolman Method) - <6mm

Percent fines data are reviewed here in relation to the slope of the reach they are taken from. It is expected that in general, higher gradient reaches (slopes greater than 2 percent) act as transport reaches, and the velocity and turbulence within these reaches do not allow for as much sediment accumulation, in comparison to low gradient reaches, which are usually depositional reaches more likely to reflect signs of excess sediment.

In addition, sites from the BDNF reference data set, with bankfull widths less than 5 feet were excluded from the data pool. It is assumed that very small streams such as these have little capacity to move sediment, and in some cases, due to the small size and energy of the streams, the stream bottom material itself is naturally comprised of small particles. Inclusion of these results may skew the data to indicate potential target values which would not be appropriate for those streams.

Upon review of the available data, a value of <16.0 % is chosen for the target of percent fines <6mm. This is based on a review of the median and 75th percentile of the Beaverhead Deerlodge reference values. In this review, the 75th percentile of the BDNF reference data set is considerably higher than values typically cited as target values for percent fines, and is above literature values that look at harmful effects to aquatic life. These higher values may be somewhat a function of the data collection method differences, and therefore further justify the review of the median. These higher values may also be due to some areas of the Boulder River watershed which contain Boulder Batholith geology that is more erosive and produces coarse, small grain material (although this form of geology is not present throughout the entire watershed). The median of the data set however is within a range of typical values for percent fines <6mm, and relates with the 25th percentile from the DEQ field data.

In this case, the BDNF reference data appears to illustrate the concept of slope and transport capability, however the DEQ data does not. DEQ data shows higher fines in higher slope environments than in low slopes. However, since there are no reference sites in the DEQ data the results may be reflective of significant human effects rather than what can be expected under normal (reference) conditions. For this reason the low slope BDNF sites serve as the main reference to select a target value. It is expected that under naturally occurring conditions, transport reaches will have fewer percent fines than depositional reaches.

Table D-3. Wolman Pebble Count Percent Fines Values, <6mm (DEQ 2009 Data)

	25th percentile	Median	75th percentile
0-2% Slope			
DEQ Field Data (n=40)	**14.0**	20.8	33.6
BDNF – Reference; -<5 bkf (n=20)	9.5	**16.0**	32.0
>2% Slope			
DEQ Field Data (n=44)	**19.8**	27.0	35.0
BDNF – Reference; -<5 bkf (n=43)	5.5	**10.0**	21.5

D2.3.2 Percent Fines in Riffles (Wolman Method) - <2mm

No local reference data is available for percent fines <2mm in riffles. For this parameter, review of the 25th percentile of the total DEQ data set was found to be ~8% for both low gradient (0-2% slope) and high gradient (>2% slope) reaches. This value is below the minimum-effect sediment levels for sediment-sensitive species (13%) and aquatic macroinvertebrates (10%) as found by Bryce, Lomnicky, and Kaufmann (2010). Because there is no reference data available to compare field values with, the target for percent fines <2mm is set at <10%. This target value is based on the literature value for minimum-effect sediment levels for macroinvertebrates (10%), and also considers the fact that the 25th percentile of the DEQ data set is under this value (8%).

The target values for percent fine are not separated by gradient, but as discussed in section D2.3, it is expected that measured values in high gradient reaches would tend to be lower than values in low gradient reaches; however in this case, the DEQ data does not illustrate this idea. This may be in part due to the high gradient reaches in the DEQ dataset having a considerable amount of human influence, perhaps more so than the low gradient reaches in this study, which resulted in higher fines overall. It should be noted that high percent fines values in high gradient reaches may indicate increased sediment input and even higher percent fines values in low gradient reaches as well.

Table D-4. Wolman Pebble Count Percent Fines Values, <2mm (DEQ 2009 Data)

	25th percentile	Median	75th percentile
0-2% Slope			
DEQ Field Data (n=20)	**7.5**	11.7	30.2
>2% Slope			
DEQ Field Data (n=44)	**7.5**	14.6	27.5

D2.3.3 Percent Fines in Pool Tails (Grid Toss) - <6mm

In the case of percent fine data in pool tails, data exists for DEQ field sites, and PIBO reference and managed sites. In this case, the PIBO reference data again serves as the primary guide for determining the target value. The 75th percentile of the reaches with 0-2% slope (depositional reaches) is 13.5%. The target is therefore set at <13% percent fines less than 6mm in pool tails. DEQ field data with 0-2% slope did not exceed this target value in any quartiles.

The >2% slope data is presented here only to investigate the differences between transport and depositional reaches. Grid toss percent fines in reaches >2% slope were considerably higher in the PIBO 75th percentile and the majority of DEQ reaches, however, it is somewhat surprising that this would be the case because, as mentioned earlier, it is assumed that reaches of higher slopes have better ability to transport sediment and therefore would result in lower percent fines values. This may be explained in the DEQ data by the fact that a limited number of reaches were sampled, and most reaches were assessed where human activity had a definite impact to the overall quality of the stream, therefore the past or present activities are influencing the observed results, rather than being influenced of gradient. The quartile values from the PIBO reference data set were relatively similar between the 25th percentile and median; however differ sharply in the 75th percentile range. This may however be due to the methods in PIBO protocols, as to which pools are surveyed for percent fines, and where the grid toss occurs. As described above, DEQ data attempts to make a distinction by catering grid toss studies to areas of potential spawning habitat within pool tails. As a result, they may exclude some sites that would be otherwise counted as a part of PIBO methods. Therefore, PIBO may have a broader spectrum of fines witnessed, even in reference streams, which would be reflected in the quartile values.

Table D-5. Pool Tail Percent Fines (Grid Toss) Values, <6mm

	25th Percentile	Median	75th Percentile
0-2% Slope			
DEQ Field Data	2.5	4.0	10.5
PIBO Reference (n=48)	5.2	8.4	**13.5**
PIBO Managed; -<5 bkf (n=21)	17.6	30	68.4
>2% Slope			
DEQ Field Data	7.8	40.0	51.5
PIBO Reference (n=22)	5.4	10.0	28.8
PIBO Managed; -<5 bkf	23.1	33.3	44.8

D2.4 Residual Pool Depth

A slightly different approach was taken when developing target values for residual pool depth. In this case, bankfull width information for the study reaches was available for both DEQ and PIBO data (**Table D-6**). Because pool depths are frequently a function of stream size and volume, it was deemed appropriate to segregate sampled reaches by bankfull width, which provides an indication of general stream dimension and power that may affect pool size and quality.

For the PIBO data, three categories were broken out based on the sampled reaches; bankfull widths less than 15 feet, bankfull widths between 15 and 40 feet, and bankfull widths greater than 40 feet. DEQ data were split into those same three categories as well; however reaches greater than 40 feet in the PIBO data set were extremely limited (2) and therefore not used. There are only 5 reaches in the DEQ data over 40 feet; all of which occurred in the Boulder River and at sites with bankfull widths no less than 60 feet. Although no statistical analysis was used to develop these breakouts, generally it was considered that these segregations indicate reasonable size distinctions following the assumption that as size and power increases, so too does the average residual pool depths.

Although the parameter is the same in the DEQ and PIBO datasets, it should be noted that subtle differences exist in the methodology between the DEQ and PIBO to classify pools. Although both methods identify a pool as having a maximum depth 1.5 times the pool tail depth, PIBO further selects those pools that fall within the path of the thalweg and are 50% or greater of the wetted channel width, whereas DEQ methodology includes all pools throughout the channel. As a result of this, PIBO data is likely to reflect slightly deeper average pool depths than the DEQ data. Targets will be set to apply to DEQ methods, and review of PIBO reference data will focus on median values rather than the quartile.

In the <15 feet category, the reference sites exhibit slightly deeper overall pools than non-reference sites. No reference sites were identified within the DEQ reaches. The median value of the PIBO data set is 0.8 feet, whereas the 75th percentile from the DEQ data is 0.9 feet. The PIBO managed data is also reviewed for comparison purposes, looking at the 75th percentile, which is also 0.9 feet. As a result the target value for bankfull widths less than 15 feet is >0.8 feet.

In the 15-40 feet category, the PIBO reference sites again exhibit greater residual pool depth values. The median value of the PIBO reference data is 1.4 feet. The 75th percentile from the DEQ data is also 1.4 feet. Looking at the PIBO managed data; it shows a 75th percentile value of 1.8 feet. With consideration of the slight differences between PIBO and DEQ pool classification, the PIBO managed site appears to follow similarities with the DEQ and PIBO reference data. As a result of this review, a target value for bankfull widths between 15 and 40 feet is set at >1.4 feet.

For bankfull widths >40 feet, there was very limited information. DEQ data, which does not include reference sites, was taken from five sites in the Boulder River, and from sites with bankfull widths of 60 feet or greater. There were only two sites greater than 40 feet in the PIBO reference data; too few to infer a reference target. Therefore the DEQ data is assessed with the same assumptions as the other categories and is applied with respect to a presumed difference in reference and non-reference datasets, and ever increasing pool depths as bankfull widths increase. As such, the 75th percentile of the PIBO reference data from the 15-40 feet category is reviewed, and a target value of >1.9 is conservatively set for bankfull widths larger than 40 feet.

Because of the lack of good information for residual pool depth from streams with bankfull widths greater than 40 feet, some discretion must be used when applying these targets. For instance, a stream with a bankfull width of 45 feet may not achieve the target value of 1.9 for average residual pool depth, but that does not necessarily indicate the stream is impaired. There is expected to be a gradual increase in residual pool depths as stream size increases, therefore, a residual pool depth of 1.6 feet may be appropriate for a stream with a bankfull width slightly greater than 40. Conversely, a stream with a bankfull width closer to 80 feet may have an average residual pool depth that is well over 1.9 feet.

As is the case with all target comparisons, because of the interrelated nature between sediment loads, channel shape, and available habitat, all parameters must be reviewed in conjunction with each other before conclusions can be made. For instance, a stream may be meeting residual pool depth targets, but may have very high width to depth ratios. This may suggest that while residual pool depths appear normal, the residual pool depths for that stream could be potentially greater if channel morphology was within the expected target range. Similarly, residual pool depths may be met in a stream; however, those values are only reflected in a small number of pools, where under naturally occurring conditions, the number of pools would be expected to be much higher.

Table D-6. Residual Pool Depth Values

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	0.6	0.7	**0.9**
PIBO Reference (n=13)	0.6	**0.8**	1.0
PIBO Managed; -<5 bkf (n=24)	0.5	0.8	**0.9**
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	0.8	0.9	**1.4**
PIBO Reference (n=51)	1.2	**1.4**	1.7
PIBO Managed (n=8)	1.0	1.2	**1.7**
Bankfull Width >40 feet			
DEQ Field Data (n=5)	1.3	1.7	**2.5**

D2.5 Pool Frequency (Per Mile)

Pool frequency tends to be a function of stream size and power; although other factors also contribute to pool formation, such as geology, riparian condition (large woody debris input), and gradient. As streams increase in size, features such as riffles and pools also tend to increase in size, however those components such as boulders and large woody debris that influence pool development becomes less frequent, resulting in larger but fewer pools over a given distance.

Again, some differences in methodology between DEQ and PIBO do not allow for direct comparison of values. Both methods classify a pool as having a maximum pool depth > 1.5 times the pool tail depth. However, PIBO identifies those pools that fall within the path of the thalweg and that are 50% or greater of the wetted channel width; whereas DEQ methodology identifies *all* pools throughout the channel. As a result, PIBO methodology identifies fewer pools than noted according to DEQ methods. With this in mind, we can review the PIBO data in combination with the DEQ data to derive target values (**Table D-7**). Stream targets are again segregated using the same distinction of bankfull width as residual pool depth. Targets below apply to the DEQ methodology of identifying pools.

For streams with a bankfull width less than 15 feet, the target is set at >120 pools per mile. The 75th percentile of the DEQ data set is 132 and the median of the PIBO reference data set is 108. It is expected that the PIBO pool numbers would be somewhat higher if DEQ protocols were applied in their data collection and therefore in this case would likely be comparable to the DEQ 75th percentile of the data.

For streams with a bankfull width between 15 feet and 40 feet, the median (58) of the PIBO reference data set is considerably lower than the 75th percentile of the DEQ data (106). The median of the DEQ field data is 79, and while there are only 9 sites that make up the data set, most of these sites are influenced to varying degrees by anthropogenic activity, and therefore are more representative of effected conditions. As such it is expected that the target value should be higher than the median of this data range; therefore, best professional judgment is used here to select the target value of >90 pools per mile.

For tributary streams with a bankfull width equal to or greater than 40 feet, the target is set at >50 pools per mile. This is simply an estimate based on the targets from the other bankfull categories. No PIBO data is available in this stream size category for comparison. This target only applies to tributary streams to the Boulder River. The Boulder River target value is set at >30 pools per mile. The 75th percentile of the DEQ data set (28) provides a reference, but again the limited number of reaches (5) may mislead conclusions. All of the reaches reviewed occurred in the Boulder River and from sites with bankfull widths greater than 60 feet, which is why the target category for streams greater than 40 bankfull widths is split into tributary streams, and the Boulder River. Based on the field work conducted in the Boulder River watershed, there are very few, if any, reaches of tributaries to the Boulder River that exceed 60 feet in bankfull width.

Table D-7. Pool Frequency Values (per mile)

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	84	106	**132**
PIBO Reference (n=13)	82	**108**	181
PIBO Managed; -<5 bkf (n=24)	117	159	**210**
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	69	79	**106**
PIBO Reference (n=51)	39	**58**	76
PIBO Managed (n=8)	39	51	**93**
Bankfull Width >40 feet			
DEQ Field Data (Boulder River reaches) (n=5)	24	25	28

D2.6 Greenline – Percent Shrub

Riparian green line is not used as a direct measurement of sediment itself in the Boulder-Elkhorn TPA; however it is reviewed as supplemental information due to its relation to bank erosion and therefore an overall gage of stream health and potential sediment production. Shrub cover in particular provides stronger, more stable streamside woody vegetation, and it often provides an indicator of potential bank stability and temperature variability.

As mentioned in earlier target parameter discussions, there are a variety of conditions accounted for in the DEQ dataset, however few of them represent true desired or reference conditions. Although limited in the amount of available data, values were initially organized by their respective reach types to see if there were any obvious differences or similarities based on the physical characteristics of the stream (**Table D-8**). No true discernable variation in values could be determined based on the stream order, gradient, and confinement – but that is also expected since the riparian robustness is generally more a function of the activities on the land rather than the geologic constraints. As a result, the data shows that a target value can be set based on a review of the total dataset, rather than segregating it into specific categories. In reviewing these results, and knowing anthropogenic influence was common throughout the reaches, relying only on the median values in setting a target value may underestimate the potential quality that should be expected. Therefore, the 75th percentile here represents what may be expected. As such, the target is based on the 75th percentile, and is set at >65.

Table D-8. Greenline Percent Shrub Cover by Reach Type

Reach Type	25th	Median	75th
MR-0-2-U (3)	5	10	30
MR-0-3-U (4)	5	43.8	67.5
MR-0-4-U (5)	7.5	25	52.5
MR-2-1-C (1)	17.5	30	52.5
MR-2-1-U (1)	1.3	2.5	5.0
MR-2-2-U (2)	40.6	61.3	73.1
MR-2-3-C (2)	48.1	75.0	82.5
MR-2-3-U (1)	72.5	80.0	91.3
MR-4-2-C (1)	81.3	92.5	96.3
MR-4-2-U (3)	15.0	35.0	60.0
Total	15	40	65
Target Value			**>65**

D2.7 Greenline – Percent Bare Ground

As described for the Greenline – Percent Shrub Cover, riparian green line is not used as direct target of sediment analysis in the Boulder-Elkhorn TPA; however it is reviewed as supplemental information because of its relation to potential sediment production and overall gage of stream health. Bare ground along the riparian is the most unstable and most indicative display of streamside sediment sources. Similar to the percent shrub analysis, the statistics for percent bare ground are only used as a relative gage by which to select an appropriate value. In this case, lower percentages of percent bare ground are the expected and desired condition. Based on a review of the data and on-the-ground knowledge of the watershed (**Table D-9**), the Boulder-Elkhorn TPA would not expect to see any bare ground under most normal conditions. As such, the target for bare ground in conjunction with anthropogenic activities is 0%. However, it is acknowledged that some natural conditions such as talus slopes, recent landslide/avalanche chutes, and wildfire may result in small percentages of bare ground near the bank and therefore, this target is not absolute and will allow for some variance under specific naturally occurring conditions.

Table D-9. Greenline Percent Bare Ground by Reach Type

Reach Type	25th	Median	75th
MR-0-2-U (3)	0.0	0.0	0.0
MR-0-3-U (4)	0.0	5.0	11.3
MR-0-4-U (5)	7.5	40.0	42.5
MR-2-1-C (1)	0.0	0.0	0.0
MR-2-1-U (1)	37.5	52.5	63.8
MR-2-2-U (2)	0.0	10.0	17.5
MR-2-3-C (2)	1.9	5.0	10.6
MR-2-3-U (1)	43.8	47.5	52.5
MR-4-2-C (1)	10.0	15.0	22.5
MR-4-2-U (3)	0.0	5.0	10.0
Total	0.0	7.5	25.0
Target Value			**>0**

D2.8 LARGE WOODY DEBRIS

Large woody debris is not a direct measure of sediment. However, the quantification of instream large wood is reviewed as supplemental information because of its relation to riparian condition and the associated sediment production that can occur in degraded riparian environments. Large woody debris also has affect on pool formation and habitat creation for both fish and macroinvertebrates and has been shown to be an indicator of overall stream health.

A mature and healthy streamside vegetative community plays a significant role in the numbers of large woody debris found in a stream. This is apparent in comparing reference with managed PIBO data (**Table D-10**). As a result, we can presume that land management and impacts to the riparian community have a significant effect to the amount of large wood in the stream, and thereby the habitat complexity and overall health of the stream.

In addition to the quality of the riparian condition, large woody debris numbers also relate to stream size and power. Therefore, smaller streams with good riparian health would be more likely to hold pieces of large wood that fall into the stream. As the stream sizes increase, the wider and deeper channels and associated flows mobilize more wood resulting in fewer identified pieces per reach.

No large woody debris targets were selected for the Boulder Elkhorn TPA, but a review of large woody debris data illustrates the range in numbers of wood found from the various sites used in the watershed analysis. Interestingly, for streams with bankfull width <15, the DEQ field data provided the highest values and widest range between 25th and 75th percentiles (169-655 pieces per mile). This may be, in part, due to a few sites of particularly small size in heavily wooded environments. In contrast, the reference sites from PIBO had values ranging from 179-354 pieces per mile. For streams with bankfull widths 15-40 feet, the ranges in large wood for the various data types seem to follow a more intuitive pattern, where DEQ field sites range from 79-380 pieces per mile, PIBO managed sites range from 143-266 pieces per mile, and PIBO reference sites range from 239-645 pieces per mile. Although only a small number of sites can be reviewed for bankfull widths >40 feet, it does follow the thought that larger rivers have the capacity to move wood, and thereby fewer pieces are found within the channel.

Table D-10. Large Wood Values (per mile)

	25th Percentile	Median	75th Percentile
Bankfull Width <15 feet			
DEQ Field Data (n=9)	169	507	655
PIBO Reference (n=13)	179	315	354
PIBO Managed; -<5 bkf (n=22)	70	141	219
Bankfull Width 15-40 feet			
DEQ Field Data (n=9)	79	158	380
PIBO Reference (n=51)	239	350	645
PIBO Managed (n=8)	143	220	266
Bankfull Width >40 feet			
DEQ Field Data (Boulder River reaches) (n=5)	17	71	87

D3.0 References

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APPENDIX E –NUTRIENT WATER QUALITY DATA

Organization	Waterbody Segment	Station ID	Date	Flow (cfs)	Total Nitrogen (mg/L)	NO_3+NO_2 (mg/L)	Total Phosphorous (mg/L)	Chlorophyll-*a* (mg/m2)	AFDW (g/m2)
MDEQ_WQ_WQX	Bison Creek 3/4 mile upstream from mouth (Bison Creek)	M07BISNC01	7/19/2010 14:39	1.86	0.39	ND	0.029	-	-
MTWTRSHD_WQX	Bison Creek upstream of 4th of July	M07TMDL_BE-16	8/18/2009 13:30	1.87	0.18	ND	0.012	-	-
MDEQ_WQ_WQX	Bison Creek near headwaters	M07BISNC09	7/19/2010 13:26	E 0	2.7	ND	0.237	-	-
MDEQ_WQ_WQX	Bison Creek near headwaters	M07BISNC09	8/19/2010 16:58	E 0	1.75	ND	0.171	-	-
MDEQ_WQ_WQX	Bison Creek near headwaters	M07BISNC09	9/30/2010 13:43	EE 0	1.47	0.01	0.138	-	-
MTWTRSHD_WQX	Bison Creek at Sawmill Gulch Road below subdivision	M07TMDL_BE-18	8/18/2009 12:00	3.67	0.31	ND	0.04	-	-
MTWTRSHD_WQX	Bison Creek at Sawmill Gulch Road below subdivision	M07TMDL_BE-18	9/1/2009 13:00	-	-	-	-	101.0	-
MDEQ_WQ_WQX	Bison Creek just downstream Sawmill Gulch Road crossing	M07BISNC08	7/19/2010 12:24	5.7	0.48	ND	0.042	-	-
MDEQ_WQ_WQX	Bison Creek just downstream Sawmill Gulch Road crossing	M07BISNC08	8/19/2010 14:45	1.38	0.43	ND	0.042	-	-
MDEQ_WQ_WQX	Bison Creek just downstream Sawmill Gulch Road crossing	M07BISNC08	9/30/2010 12:23	1.81	0.33	ND	0.038	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Nez Perce Creek	M07BISNC07	7/19/2010 11:05	-	0.41	ND	0.025	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Nez Perce Creek	M07BISNC07	8/19/2010 10:45	8.27	0.35	ND	0.031	4.4	22.87
MDEQ_WQ_WQX	Bison Creek downstream of Nez Perce Creek	M07BISNC07	9/30/2010 10:38	6.38	0.14	ND	0.02	5.95	14.95
MTWTRSHD_WQX	Bison Creek at bridge off Elkhorn Road, N end of Elk Park reach	M07TMDL_BE-17	8/18/2009 10:45	12.91	0.21	ND	0.022	-	-
MTWTRSHD_WQX	Bison Creek at bridge off Elkhorn Road, N end of Elk Park reach	M07TMDL_BE-17	9/1/2009 16:40	-	-	-	-	6.8	-
MDEQ_WQ_WQX	Bison Creek upstream of Ice Pond	M07BISNC06	7/19/2010 10:23	2.42	0.42	ND	0.024	-	-
MDEQ_WQ_WQX	Bison Creek upstream of Ice Pond	M07BISNC06	8/18/2010 15:07	1.24	0.36	ND	0.034	10.4	-
MDEQ_WQ_WQX	Bison Creek upstream of Ice Pond	M07BISNC06	9/29/2010 15:02	0.52	0.2	ND	0.03	-	-
MDEQ_WQ_WQX	Bison Creek below USFS boundary	M07BISNC05	7/18/2010 15:54	21.66	0.43	ND	0.027	-	-
MDEQ_WQ_WQX	Bison Creek below USFS boundary	M07BISNC05	8/18/2010 11:25	12.32	0.36	ND	0.031	11.15	19.78
MDEQ_WQ_WQX	Bison Creek below USFS boundary	M07BISNC05	9/29/2010 12:25	10.25	0.22	ND	0.023	13.53	41.1
MDEQ_WQ_WQX	Bison Creek downstream of Busch Gulch	M07BISNC04	9/29/2010 10:25	12.0	0.19	ND	0.023	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Busch Gulch	M07BISNC04	7/18/2010 15:05	20.8	0.37	ND	0.025	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Busch Gulch	M07BISNC04	8/17/2010 14:45	14.98	0.35	ND	0.029	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Bear Gulch	M07BISNC03	7/18/2010 13:34	33	0.36	ND	0.028	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Bear Gulch	M07BISNC03	8/17/2010 13:06	18.9	0.32	0.01	0.03	-	-
MDEQ_WQ_WQX	Bison Creek downstream of Bear Gulch	M07BISNC03	9/28/2010 11:55	15.49	0.17	ND	0.023	-	-
MTWTRSHD_WQX	Bison Creek at mouth	M07TMDL_BE-15	8/18/2009 9:00	28.62	0.21	ND	0.026	-	-
MTWTRSHD_WQX	Bison Creek at mouth	M07TMDL_BE-15	9/1/2009 9:15	-	-	-	-	7.25	-
MDEQ_WQ_WQX	Bison Creek about 1/2 mile upstream from mouth	M07BISNC02	8/17/2010 9:48	19.58	0.3	ND	0.03	9.4	16.87
MDEQ_WQ_WQX	Bison Creek about 1/2 mile upstream from mouth	M07BISNC02	9/25/2010 10:12	13.33	0.2	ND	0.025	17.65	13.61
MDEQ_WQ_WQX	Uncle Sam Gulch near headwaters, at mine	M07UCLSG01	7/12/2010 16:07	0.03	0.09	ND	0.007	-	-
MDEQ_WQ_WQX	Uncle Sam Gulch near headwaters, at mine	M07UCLSG01	8/16/2010 11:39	0.03	0.18	0.04	0.01	10.9	-
MDEQ_WQ_WQX	Uncle Sam Gulch at mouth (Cataract Creek)	M07UCLSG03	7/12/2010 10:31	2.93	0.16	ND	0.008	1.34	4.74
MDEQ_WQ_WQX	Uncle Sam Gulch at mouth (Cataract Creek)	M07UCLSG03	8/9/2010 10:23	1.72	0.09	ND	0.01	-	-
MDEQ_WQ_WQX	Uncle Sam Gulch at mouth (Cataract Creek)	M07UCLSG03	8/12/2011 14:49	-	ND	0.034	0.004	5.78	7.49

Organization	Waterbody Segment	Station ID	Date	Flow (cfs)	Total Nitrogen (mg/L)	NO_3+NO_2 (mg/L)	Total Phosphorous (mg/L)	Chlorophyll-*a* (mg/m2)	AFDW (g/m2)
MDEQ_WQ_WQX	Uncle Sam Gulch at mouth (Cataract Creek)	M07UCLSG03	9/26/2010 10:35	1.28	0.05	ND	0.007	-	-
MDEQ_WQ_WQX	Uncle Sam Gulch at mouth (Cataract Creek)	M07UCLSG03	9/12/2011 12:58	-	ND	0.027	0.004	2.43	9.97
MDEQ_WQ_WQX	Uncle Sam Gulch 1 mile upstream from mouth	M07UCLSG04	7/12/2010 14:21	2.5	0.15	ND	0.009	-	-
MDEQ_WQ_WQX	Uncle Sam Gulch 1 mile upstream from mouth	M07UCLSG04	8/9/2010 11:35	1.28	0.11	ND	0.01	3.76	122.30
MDEQ_WQ_WQX	Uncle Sam Gulch 1 mile upstream from mouth	M07UCLSG04	9/26/2010 12:04	1.3	0.05	ND	0.01	-	-
MTWTRSHD_WQX	Uncle Sam Gulch below St. Lawrence/Crystal complex	M07TMDL_BE-75	8/21/2009 10:50	0.1	0.05	0.06	0.007	-	-
MTWTRSHD_WQX	Uncle Sam Gulch above St. Lawrence/Crystal complex	M07TMDL_BE-74	8/21/2009 9:30	0.065	0.12	ND	0.011	-	-
MTWTRSHD_WQX	Nursery Creek headwaters	M07TMDL_BE-70	8/19/2009 14:50	0.127	0.24	0.24	0.017	-	-
MDEQ_WQ_WQX	Nursery Creek	M07NRSRC02	7/6/2010 15:07	0.14	0.38	0.31	0.016	-	-
MDEQ_WQ_WQX	Nursery Creek	M07NRSRC02	8/7/2010 10:10	0.23	0.35	0.31	0.013	13.14	2.42
MDEQ_WQ_WQX	Nursery Creek	M07NRSRC02	9/10/2010 9:26	0.18	0.32	0.3	0.009	-	-
MDEQ_WQ_WQX	Nursery Creek	M07NRSRC02	8/12/2011 11:16	-	0.25	0.4	0.028	-	-
MDEQ_WQ_WQX	Nursery Creek	M07NRSRC02	9/12/2011 10:31	-	0.286	0.326	0.02	-	-
MDEQ_WQ_WQX	Nursery Creek near the mouth upstream of USFS road	M07NRSRC01	7/6/2010 10:29	0.8	0.41	0.2	0.037	5.55	4
MDEQ_WQ_WQX	Nursery Creek near the mouth upstream of USFS road	M07NRSRC01	8/6/2010 16:24	0.91	0.34	0.21	0.045	-	-
MDEQ_WQ_WQX	Nursery Creek near the mouth upstream of USFS road	M07NRSRC01	9/11/2010 9:50	0.71	0.36	0.26	0.028	7.5	-
MDEQ_WQ_WQX	Nursery Creek near the mouth upstream of USFS road	M07NRSRC01	8/12/020 11 10:17	-	0.214	0.296	0.056	-	-
MDEQ_WQ_WQX	Nursery Creek near the mouth upstream of USFS road	M07NRSRC01	9/12/2011 9:36	-	0.235	0.448	0.035	-	-
MTWTRSHD_WQX	Nursery Creek at mouth	M07TMDL_BE-76	8/19/2009 14:05	0.301	0.35	0.28	0.031	-	-
MDEQ_WQ_WQX	McCarty Creek downstream of fork near headwaters	M07MCRTC07	7/7/10 14:02	0.08	0.24	ND	0.035	-	-
MDEQ_WQ_WQX	McCarty Creek downstream of fork near headwaters	M07MCRTC07	8/8/10 14:34	0.04	0.22	ND	0.045	3.09	40.58
MDEQ_WQ_WQX	McCarty Creek downstream of fork near headwaters	M07MCRTC07	9/10/10 12:40	0.13	0.22	0.01	0.042	-	-
MDEQ_WQ_WQX	McCarty Creek above USFS boundary	M07MCRTC06	7/7/10 12:43	0.11	0.23	0.01	0.039	-	-
MDEQ_WQ_WQX	McCarty Creek above USFS boundary	M07MCRTC06	8/8/10 12:46	0.06	0.18	0.01	0.046	-	-
MDEQ_WQ_WQX	McCarty Creek above USFS boundary	M07MCRTC06	9/10/10 11:22	0.13	0.23	0.01	0.038	-	-
MTWTRSHD_WQX	McCarty Creek above reservoir	M07TMDL_BE-67	8/24/09 10:30	0.035	0.15	0.01	0.065	-	-
MDEQ_WQ_WQX	McCarty Creek just upstream from second storage reservoir	M07MCRTC05	7/7/10 11:36	0.08	0.26	ND	0.053	-	-
MDEQ_WQ_WQX	McCarty Creek just upstream from second storage reservoir	M07MCRTC05	8/7/10 16:31	0.01	0.14	ND	0.07	-	-
MDEQ_WQ_WQX	McCarty Creek just upstream from second storage reservoir	M07MCRTC05	9/11/10 15:15	0.11	0.18	ND	0.047	-	-
MDEQ_WQ_WQX	McCarty Creek between two storage reservoirs	M07MCRTC04	7/7/10 10:41	0.23	0.18	0.04	0.077	-	-
MDEQ_WQ_WQX	McCarty Creek between two storage reservoirs	M07MCRTC04	8/8/10 9:54	0.09	0.38	0.19	0.092	5.36	3.76
MDEQ_WQ_WQX	McCarty Creek between two storage reservoirs	M07MCRTC04	9/11/10 14:38	0.05	0.49	0.22	0.082	-	-
MTWTRSHD_WQX	McCarty Creek above diversion/lower dam	M07TMDL_BE-66	8/24/09 12:30	0.0256	0.65	0.4	0.114	-	-
MDEQ_WQ_WQX	McCarty Creek about 1/2 mile upstream Upper Valley Road crossing	M07MCRTC03	7/7/10 10:08	0.04	0.17	ND	0.097	-	-
MDEQ_WQ_WQX	McCarty Creek about 1/2 mile upstream Upper Valley Road crossing	M07MCRTC03	8/7/10 13:40	0.02	0.15	ND	0.131	4.8	-
MDEQ_WQ_WQX	McCarty Creek about 1/2 mile upstream Upper Valley Road crossing	M07MCRTC03	9/9/10 15:16	0.000	0.14	ND	0.309	-	-

APPENDIX F – DAILY LOADS

F1.0 OVERVIEW

In this appendix the TMDL is expressed using daily loads to satisfy an additional EPA required TMDL element. Daily loads should not be considered absolute limits for a given day and may be refined in the future as part of the adaptive management process. The TMDLs may not be feasible at all locations within the watershed but if the allocations are followed, pollutant loads are expected to be reduced to a degree that the targets are met and beneficial uses are no longer impaired. It is not expected that daily loads will drive implementation activities.

In this appendix, daily loads are presented for sediment and temperature. Given the nature of nutrient analysis, targets, and loading, daily loads for nutrients are inherently described via the TMDLs in **Section 7.0** of the main document.

F2.0 SEDIMENT DAILY LOAD

The preferred approach for calculating daily sediment loads is to use a nearby water quality gage with a long-term dataset for flow and suspended sediment. Within the Boulder River watershed, there are only two long-term gage stations: Boulder River near Boulder (06033000) and Cataract Creek near Basin (06031950). Neither of these gage stations have a record of suspended sediment data.

Although no suspended sediment data is associated with these gages, the average daily hydrograph can be used to infer an estimated daily sediment load. A daily sediment load was determined using the means of daily mean values for discharge in cfs per day from a USGS gage station on the Boulder River. The USGS station Boulder River near Boulder (06033000) was selected to represent the daily variability in flows in the Boulder River watershed. It is assumed in this representation that the sediment loads will generally follow the hydrograph, as increased flows often reflect increased runoff that carries sediment from upland erosion and is more likely to influence bank erosion. Therefore, the percentage of the mean of daily mean value for discharge, in relation to the sum of the mean of daily mean discharge values can be derived and applied to the sediment loads for a watershed of interest.

The mean of daily mean values for discharge, in cfs, was calculated based on approximately 70 years of record (October 1, 1928 – September 30, 2012) from the Boulder River USGS station (**Table F-1**). **Figure F-1** visually represents the average daily percentage of the total yearly discharge for each day of the calendar year.

To conserve resources, this appendix only provides the base data from the USGS stream gage, and the daily percentages of the total annual load. For specific streams, all daily TMDLs may be derived by using the daily percentages in **Table F-2** and the TMDLs expressed as an average annual load, which are discussed in **Section 5.6** of the main document. For example, the total allowable annual sediment load for Basin Creek was estimated to be 523 tons. To determine the TMDL for Basin Creek on January 1, this value is multiplied by 0.062% which provides a daily load of 0.3 tons.

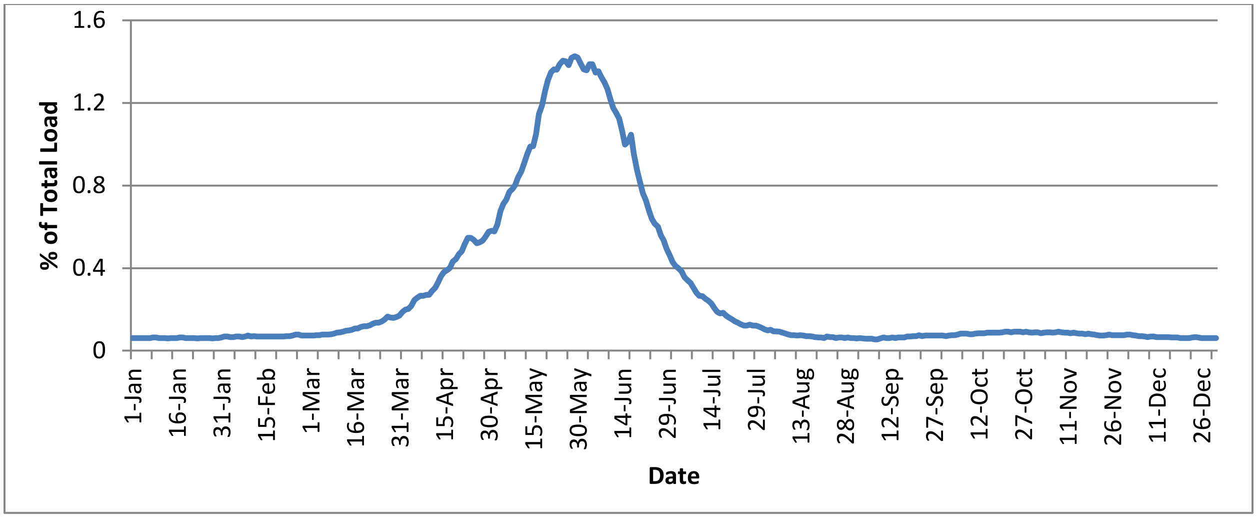

Figure F-1. Average daily percentage of the total mean yearly discharge

Figure F-1 illustrates the shape of the average hydrograph for the Boulder River, driven by climate and precipitation, and typical of many western Montana streams. In general, it appears that flows (and thereby increased sediment loads) increase in the spring as winter snowpack in the high elevations melts and drains to the waterways below. Peak flows typically occur in the month of May, followed by a declining hydrograph into August where flows near baseflow levels. The small rise in flow in late September through October likely represents the end of irrigation season and a slight increase in flow levels due to the discontinuation of water withdrawals and/or recharge from groundwater inputs.

The approach outlined above provides a simple approximation for a reasonable portioning of the total annual load among days throughout the year. It is acknowledged that a direct linear relationship between sediment load and the hydrograph may not exist. Sediment loading is frequently episodic and dependent on many differing physical, climatological, and anthropogenic factors. However, the approach for daily loads in this context does provide us with insight into those times of the year where sediment loading is most likely to occur, and thereby gives us a guide for assessment and management of sediment loading in the watershed.

F3.0 Temperature Daily Load

Because of the dynamic temperature conditions throughout the course of a day, the temperature TMDL is the thermal load, at an instantaneous moment, associated with the stream temperature when in compliance with Montana's water quality standards. The temperature standard for the Boulder River and High Ore Creek is defined as follows: For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature is 1^{o} F, if the naturally occurring temperature is less than 66^{o} F. Within the naturally occurring temperature range of 66^{o} F to 66.5^{o} F, the allowable increase cannot exceed 67^{o} F. If the naturally occurring temperature is greater than 66.5^{o} F, the maximum allowable increase is 0.5^{o} F.

The daily load for temperature is therefore the thermal load to the stream over 24 hours that is associated with all reasonable land, soil, and water conservation practices. A total maximum daily heat load can be calculated using average daily temperature values representative of conditions where the temperature standard is met and applying them to Equation F-1 below. However, the resultant daily load is not particularly useful from a management perspective. Fish are most distressed by warm water temperatures that typically peak during summer afternoons. Providing thermal loads based upon an average daily temperature does not necessarily identify the thermal loads that would be most detrimental to fish during the hottest periods of the day, but it does provide a value for the total thermal load allowed over the course of 24 hours as required by EPA. Daily thermal loads will be met through achievement of targets and allocations for the Boulder River and High Ore Creek temperature TMDLs.

Equation F-1

Total Maximum Daily Load (TMDL) = $(\Delta-32)*Q*(1.36*10^6)$

Where:

TMDL = allowed thermal load per day in kilocalories, above waters melting point
Δ = allowed average daily temperature (F)
Q = instantaneous discharge (cfs)
$1.36*10^6$ = conversion factor

Table F-1. Mean of daily mean values for each day for 69 - 71 years of record in, cfs (Calculation Period 1928-10-01 -> 2012-09-30)

Day of month	Mean of daily mean values for each day of record in cfs											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	27	30	32	82	253	594	187	45	26	31	39	34
2	27	30	32	87	252	592	179	43	27	32	37	34
3	27	29	33	88	266	605	174	44	26	33	38	33
4	27	29	33	94	295	605	167	41	25	33	39	32
5	27	30	34	107	310	587	155	41	25	34	39	31
6	27	30	34	112	319	590	149	40	25	36	38	31
7	27	29	34	116	336	578	143	38	24	36	39	30
8	28	30	35	116	341	566	133	36	24	36	40	29
9	28	32	36	118	350	553	123	34	26	35	39	30
10	27	30	38	118	366	532	116	33	28	35	38	30
11	27	31	39	126	378	513	115	33	27	36	38	29
12	27	30	40	133	396	501	110	32	27	37	37	29
13	26	30	42	144	414	490	106	33	28	37	38	29
14	27	30	43	157	431	464	100	32	27	37	37	29
15	27	30	44	166	432	435	90	31	28	38	36	29
16	27	30	47	170	457	442	82	31	28	38	36	28
17	28	30	47	175	499	456	79	30	28	38	35	28
18	28	30	50	188	518	414	80	29	30	38	36	28
19	27	30	52	194	547	380	74	28	30	38	35	27
20	27	30	52	204	571	356	70	28	31	39	34	27
21	27	30	54	210	588	332	66	27	31	40	33	27
22	27	31	57	225	594	318	62	30	33	40	32	27
23	26	31	59	238	593	296	59	29	31	39	32	28
24	27	32	59	238	605	278	56	29	32	40	33	29
25	27	34	62	234	612	268	53	27	32	40	34	28
26	27	34	66	227	611	262	53	28	32	40	33	27
27	27	32	72	229	603	244	55	28	32	39	33	27
28	26	32	70	232	618	233	53	27	32	40	33	27
29	27	32	69	240	622	215	53	28	32	39	33	27
30	27		71	251	619	201	51	27	32	38	33	27
31	28		74		607		48	27		39		27

Table F-2. Percentage of mean of daily mean values per day based on the sum of all mean of daily mean values

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.062	0.069	0.073	0.188	0.580	1.363	0.429	0.103	0.060	0.071	0.089	0.078
2	0.062	0.069	0.073	0.200	0.578	1.358	0.411	0.099	0.062	0.073	0.085	0.078
3	0.062	0.067	0.076	0.202	0.610	1.388	0.399	0.101	0.060	0.076	0.087	0.076
4	0.062	0.067	0.076	0.216	0.677	1.388	0.383	0.094	0.057	0.076	0.089	0.073
5	0.062	0.069	0.078	0.245	0.711	1.347	0.356	0.094	0.057	0.078	0.089	0.071
6	0.062	0.069	0.078	0.257	0.732	1.353	0.342	0.092	0.057	0.083	0.087	0.071
7	0.062	0.067	0.078	0.266	0.771	1.326	0.328	0.087	0.055	0.083	0.089	0.069
8	0.064	0.069	0.080	0.266	0.782	1.298	0.305	0.083	0.055	0.083	0.092	0.067
9	0.064	0.073	0.083	0.271	0.803	1.269	0.282	0.078	0.060	0.080	0.089	0.069
10	0.062	0.069	0.087	0.271	0.840	1.220	0.266	0.076	0.064	0.080	0.087	0.069
11	0.062	0.071	0.089	0.289	0.867	1.177	0.264	0.076	0.062	0.083	0.087	0.067
12	0.062	0.069	0.092	0.305	0.908	1.149	0.252	0.073	0.062	0.085	0.085	0.067
13	0.060	0.069	0.096	0.330	0.950	1.124	0.243	0.076	0.064	0.085	0.087	0.067
14	0.062	0.069	0.099	0.360	0.989	1.064	0.229	0.073	0.062	0.085	0.085	0.067
15	0.062	0.069	0.101	0.381	0.991	0.998	0.206	0.071	0.064	0.087	0.083	0.067
16	0.062	0.069	0.108	0.390	1.048	1.014	0.188	0.071	0.064	0.087	0.083	0.064
17	0.064	0.069	0.108	0.401	1.145	1.046	0.181	0.069	0.064	0.087	0.080	0.064
18	0.064	0.069	0.115	0.431	1.188	0.950	0.184	0.067	0.069	0.087	0.083	0.064
19	0.062	0.069	0.119	0.445	1.255	0.872	0.170	0.064	0.069	0.087	0.080	0.062
20	0.062	0.069	0.119	0.468	1.310	0.817	0.161	0.064	0.071	0.089	0.078	0.062
21	0.062	0.069	0.124	0.482	1.349	0.762	0.151	0.062	0.071	0.092	0.076	0.062
22	0.062	0.071	0.131	0.516	1.363	0.729	0.142	0.069	0.076	0.092	0.073	0.062
23	0.060	0.071	0.135	0.546	1.360	0.679	0.135	0.067	0.071	0.089	0.073	0.064
24	0.062	0.073	0.135	0.546	1.388	0.638	0.128	0.067	0.073	0.092	0.076	0.067
25	0.062	0.078	0.142	0.537	1.404	0.615	0.122	0.062	0.073	0.092	0.078	0.064
26	0.062	0.078	0.151	0.521	1.402	0.601	0.122	0.064	0.073	0.092	0.076	0.062
27	0.062	0.073	0.165	0.525	1.383	0.560	0.126	0.064	0.073	0.089	0.076	0.062
28	0.060	0.073	0.161	0.532	1.418	0.534	0.122	0.062	0.073	0.092	0.076	0.062
29	0.062	0.073	0.158	0.551	1.427	0.493	0.122	0.064	0.073	0.089	0.076	0.062
30	0.062	0.000	0.163	0.576	1.420	0.461	0.117	0.062	0.073	0.087	0.076	0.062
31	0.064	0.000	0.170	0.000	1.392	0.000	0.110	0.062	0.000	0.089	0.000	0.062

ATTACHMENT 1 – ANALYSIS OF BASE PARAMETER DATA AND EROSION INVENTORY DATA FOR SEDIMENT TMDL DEVELOPMENT WITHIN THE BOULDER-ELKHORN TPA

ANALYSIS OF BASE PARAMETER DATA AND EROSION INVENTORY DATA FOR SEDIMENT TMDL DEVELOPMENT WITHIN THE BOULDER-ELKHORN TPA

Prepared for:

Montana Department of Environmental Quality
Water Quality Planning Bureau
P.O. Box 200901
Helena, MT 59620-0901

Prepared by:

Water & Environmental Technologies, PC
480 East Park Street, #200
Butte, MT 59701

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1.0 INTRODUCTION

The Boulder-Elkhorn TPA encompasses an area of approximately 760 square miles in Jefferson County of southwestern Montana (**Attachment A - Figure 1**). The TPA is bounded by the continental divide to the west, Boulder Hill to the north, the Elkhorn Mountains to the northeast, and the Bull Mountains to the southwest. Elevations in the Boulder TPA range from approximately 1,304 to 2,868 meters (4,275 - 9,415 feet) above mean sea level. The lowest point is the confluence of the Boulder and Jefferson Rivers. The highest point is Crow Peak, at the northeast corner of the TPA in the Elkhorn Mountains. Much of the TPA is rugged and mountainous, with three distinct valleys: Elk Park, a long, narrow valley drained by Bison Creek; the Boulder Valley near Boulder, a high basin hemmed in by mountains; and the Boulder River valley below Elkhorn Creek, a broad river valley opening to the Jefferson River Valley. The uplands are characterized by steep-sided valleys with gently sloping ridgelines and peaks. The Boulder River itself flows a distance of approximately 70 miles, and the TPA (which includes the entire Boulder River watershed) contains 374 miles of named streams. An estimated 2,245 persons live within the TPA. Basin and Boulder had reported populations of 255 and 1,300 in the 2000 census, respectively. The remainder of the population is sparsely distributed throughout rural areas, and much of the TPA is unpopulated.

Mining, timber and agriculture were historically major economic components of the Boulder-Elkhorn TPA. Current land use within the TPA is dominated by forest and agriculture. Agriculture in the lowlands is primarily related to the cattle industry, including irrigated hay pasture and dryland grazing. Mining remains a major economic activity within Jefferson County, but active mining sites are predominantly located outside the TPA. Slightly more than one-third (37%) of the TPA is privately owned, and approximately half (51%) is administered by the US Forest Service. The remainder of the TPA is administered by the US Bureau of Land Management (8%) or Montana State Trust land (3%). Private land is generally concentrated in the valley bottoms and foothills and public land in the uplands, although patented mining claims are scattered throughout the mountains.

Under Montana law, an impaired water body is defined as a water body for which sufficient and credible data indicates non-compliance with applicable water quality standards (MCA 75-5-103). Section 303 of the Federal Clean Water Act requires states to submit a list of impaired water bodies or stream segments to the U.S. Environmental Protection Agency (EPA) every two years. This list of impaired waters, known as the 303(d) list, is included within the DEQ's biannual "Integrated Report". The Montana Water Quality Act further directs states to develop TMDLs for all water bodies appearing on the 303(d) list as impaired or threatened by "pollutants" (MCA 75-5-703).

In 2010, Montana Department of Environmental Quality (DEQ) initiated an effort to collect data to support the development of sediment TMDLs for streams within the Boulder-Elkhorn TPA. The data collection effort involved assessing sediment and habitat conditions within the Boulder-Elkhorn watershed, including stream stratification, sampling design, ground surveys, and sediment and habitat analyses. The data collection effort is intended to assist DEQ in evaluating the condition of tributary streams in the TPA and developing TMDLs where necessary.

A total of thirteen streams in the Boulder-Elkhorn TPA were included in the sediment and habitat investigation, including Basin Creek, Bison Creek, Cataract Creek, Elkhorn Creek, High Ore Creek, Little Boulder River, Lowland Creek, McCarty Creek, Muskrat Creek, North Fork of the Little Boulder River, Nursery Creek, Uncle Sam Creek, and the mainstem of the Boulder River. All of these streams were listed on the 2008 303(d) list for sediment except, Bison Creek, Little Boulder River, Lowland Creek, and Muskrat Creek (which are listed for habitat alterations).

A stream stratification process was previously completed on stream segments in the Boulder-Elkhorn TPA and is intended to develop similar water body characterizations that can be applied across watersheds, accounting for localized ecological and hydrologic variations. The stratification enables comparison between observed and expected values for various sediment and habitat parameters, and helps quantify the effects of anthropogenic influences. Stratification for streams in the Boulder-Elkhorn TPA began by dividing the water bodies into reaches and sub-reaches based on aerial photo interpretation of stream characteristics, landscape conditions, and land-use factors.

Following the initial primary reach stratification, representative reaches were chosen by DEQ for data collection. A two-day sampling reach reconnaissance was conducted on July 19 and 20, 2010, and field personnel completed full site surveys from August 31 to September 10, 2010. Field personnel visited the selected reaches and recorded bank erosion sites, vegetation, and channel characteristic data. Data were later compiled and analyzed resulting in full descriptions of sediment and habitat conditions for all of the surveyed reaches and the ability to extrapolate to non-surveyed reaches.

2.0 AERIAL ASSESSMENT REACH STRATIFICATION

2.1 Methods

An aerial assessment of streams in the Boulder-Elkhorn TPA was conducted by Montana DEQ using geographic information systems (GIS) software and 2009 color aerial imagery. Relevant geographic data layers were acquired from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA) and the Montana State National Resource Information System (NRIS) database. Layers include the following data sets.

- Ecoregion (USEPA)
- Scanned and Rectified Topographic Maps, 1:24,000 and 1:100,000 (USGS)
- National Hydrography Dataset Lakes and Streams (USGS)
- 2009 National Aerial Image Program (NAIP – NRIS)

GIS data layers were used to stratify streams into primary reaches based on stream characteristics, landscape and land-use factors. The stream reach stratification methodology applied in this study is described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations* (DEQ 2008). The reach stratification methodology involves delineating a water body stream segment into stream reaches and sub-reaches. This process was completed for the following stream segments in the Boulder-Elkhorn TPA: Basin Creek, Bison Creek, Cataract Creek, Elkhorn Creek, High Ore Creek, Little Boulder River, Lowland Creek, McCarty Creek, Muskrat Creek, North Fork of the Little Boulder River, Nursery Creek, Uncle Sam Creek, and the mainstem of the Boulder River.

2.2 Stream Reaches

Water body segments are delineated by a water use class designated by the State of Montana, e.g. A-1, B-3, C-3 (Administrative Rules of Montana Title 17 Chapter 30, Sub-Chapter 6). Although a water body segment is the smallest unit for which an impairment determination is made, the stratification approach described in this document initially stratifies individual water body segments into discrete assessment reaches that are delineated by landscape controls including Ecoregion, Strahler stream order, valley gradient, and valley confinement. The reason for this stratification is that the inherent differences in landscape controls between stream reaches often prevents a direct comparison from being made between the physical attributes of one stream reach to another. By initially stratifying water body segments into stream reaches having similar landscape controls, it is feasible to make comparisons between similar reaches in regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification (e.g. grazed vs. non-grazed sub-reaches), sediment and habitat parameters for impaired stream reaches can be more readily compared to reference reaches that meet the same geomorphic stratification criteria.

The aerial photograph reach stratification methodology involves dividing a stream segment into distinct reaches based on four primary watershed characteristics: Ecoregion, valley gradient, Strahler stream order, and valley confinement. Once stream reaches have been classified by the four watershed characteristics, reaches are further divided based on the surrounding vegetation and land-use characteristics as observed in the color aerial imagery using GIS. The result is a series of stream reaches and sub-reaches delineated by landscape and land-use factors. Stream reaches with similar landscape factors can then be compared based on the character of surrounding land-use practices.

For ease of labeling, each listed stream in the assessment was assigned an abbreviation based on the stream name. These labels were use in the individual stream reach classification. **Table 2-1** shows the abbreviations developed for each water body.

Table 2-1. Water body naming key.

Water Body	Label Abbreviation
Basin Creek	BASI
Bison Creek	BISO
Boulder River	BLDR
Cataract Creek	CATA
Elkhorn Creek	ELKH
High Ore Creek	HIOR
Little Boulder River	LBLR
Lowland Creek	LOWL
McCarty Creek	MCCA
Muskrat Creek	MUSK
North Fork Little Boulder River	NFLB
Nursery Creek	NURS
Uncle Sam Gulch	USGU

2.3 Reach Types

Individual stream reaches were delineated by reach type based on four watershed characteristics. For the purposes of this report, a “reach type” is defined as a unique combination of Ecoregion, valley gradient, Strahler stream order, and valley confinement, and is designated using the following naming convention based on the reach type identifiers provided in **Table 2-2**:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

The Boulder-Elkhorn TPA exists solely within the Middle Rockies Level III Ecoregion (Ecoregion 17), which includes three Level IV Ecoregions within the Boulder-Elkhorn TPA, including the Elkhorn Mountains-Boulder Batholith (17ai), the Townsend-Horseshoe-London Sedimentary Hills (17y), and the Townsend Basin (17w). Present reach type combinations for the Boulder-Elkhorn TPA are provided in **Table 2-3**, including the number of sites monitored of each reach type. Overall, 23 monitoring sites were selected for field evaluation.

Table 2-2. Reach type identifiers.

Watershed Characteristic	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-2%	0
	2-4%	2
	4-10%	4
	> 10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
Confinement	confined	C
	unconfined	U

Table 2-3. Stratified reach types within the Boulder-Elkhorn TPA.

Level III Ecoregion	Valley Gradient	Strahler Stream Order	Confine -ment	Reach Type	Total Number of Reaches	Number of Monitoring Sites
Middle Rockies	<2%	1	U	MR-0-1-U	9	
		2	C	MR-0-2-C	3	
			U	MR-0-2-U	42	3
		3	C	MR-0-3-C	2	
			U	MR-0-3-U	57	4
		4	U	MR-0-4-U	40	5
	2-4%	1	C	MR-2-1-C	1	1
			U	MR-2-1-U	23	1
		2	C	MR-2-2-C	6	
			U	MR-2-2-U	46	2
		3	C	MR-2-3-C	5	2
			U	MR-2-3-U	28	1
	4-10%	1	C	MR-4-1-C	12	
			U	MR-4-1-U	50	
		2	C	MR-4-2-C	15	1
			U	MR-4-2-U	34	3
		3	C	MR-4-3-C	5	
			U	MR-4-3-U	12	
	>10%	1	C	MR-10-1-C	14	
			U	MR-10-1-U	32	
		2	C	MR-10-2-C	8	
			U	MR-10-2-U	6	
		3	C	MR-10-3-C	2	
				Totals:	**452**	**23**

Table 2-4 shows the assessed water bodies and monitored reaches included within each reach type. A map of monitoring site locations is provided as **Attachment A – Figure 2**.

Table 2-4. Monitoring sites in assessed reach types.

Reach Type	Water body	Monitoring Sites
MR-0-2-U	Basin Creek, Bison Creek, Lowland Creek	BASI 08-02, BISO 04-01, LOWL 08-01
MR-0-3-U	Basin Creek, Bison Creek, Little Boulder River, Muskrat Creek	BASI 15-02, BISO 11-01, LBLR 37-01, MUSK 22-08
MR-0-4-U	Boulder River	BLDR 12-04, BLDR 13-04, BLDR 13-10, BLDR 13-23, BLDR 13-33
MR-2-1-C	Nursery Creek	NURS 07-01
MR-2-1-U	Uncle Sam Gulch	USGU 10-01
MR-2-2-U	Cataract Creek, Muskrat Creek	CATA 18-01, MUSK 18-01
MR-2-3-C	Elkhorn Creek, Little Boulder River	ELKH 23-01, LBLR 32-01
MR-2-3-U	Elkhorn Creek	ELKH 28-01
MR-4-2-C	North Fork Little Boulder River	NFLB 42-01
MR-4-2-U	High Ore Creek, McCarty Creek	HIOR 09-01, HIOR 15-01, MCCA 22-01

3.0 SEDIMENT AND HABITAT DATASET REVIEW

3.1 Field Methodology

The following sections describe the field methodologies employed during the stream assessments. The methods follow standard DEQ protocols for sediment and habitat assessment as presented in the document *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (DEQ 2010). For most survey sites, a minimum of 5 team members were present, which were always divided into 3 teams, referred to as the “Greenline”, “Longitudinal Profile” or “Long-Pro”, and “Cross-Section” teams. The teams worked independently moving upstream through the survey site and in a pre-established order to facilitate accurate data collection and to create the least possible in-stream disturbance. All field data were collected on DEQ standard forms for sediment and habitat assessments, and are summarized and provided in tabular format in **Attachment B**.

3.1.1 Survey Site Delineation

Stream survey sites were delineated beginning at riffle crests at the downstream end of each surveyed reach. Survey sites were measured upstream at pre-determined lengths based on the bankfull width at the selected downstream riffle. Survey lengths of 500 ft were used for bankfull widths less than 10 ft; survey lengths of 1,000 ft were used for bankfull widths between 10 ft and 45 ft; and survey lengths of 1,500 or 2,000 ft were used for bankfull widths greater than 45 ft depending on stream size and the homogeneity of features within the reach. The two Boulder River sites lowest in the watershed were surveyed as 2,000’ reaches, while the three upper Boulder River sites were surveyed as 1,500’ reaches. Each survey site was divided into 5 equally sized study cells. For each site, the field team leader identified the appropriate downstream riffle crest to begin a reach. Where no riffles were present or the stream was dry, the field team leader identified the appropriate starting point. The GPS location of the downstream and upstream ends of the survey site was recorded on the **Sediment and Habitat Assessment Site Information Form**. Digital photographs were taken at both upstream and downstream ends of the survey site, looking both upstream and downstream. Photo numbers and a brief description were recorded in the **Photo Log**, which is included in **Attachment C**.

3.1.2 Field Determination of Bankfull

All members of the field crew participated in determining the bankfull elevation prior to breaking into their respective teams. Indicators that were used to estimate the bankfull channel elevation included scour lines, changes in vegetation types, tops of point bars, changes in slope, changes in particle size and distribution, stained rocks and inundation features. Multiple locations and indicators were examined, and bankfull elevation estimates and their corresponding indicators were recorded in the **Bankfull Elevation and Slope Assessment Field Form** by the field team leader. Final determination of the appropriate bankfull elevation was determined by the team leader, and informed by the team experience and notes from the field form.

3.1.3 Channel Cross-Sections

The “Cross-Section team” was composed of two members of the assessment crew, who also performed pebble counts, riffle stability index, and riffle grid tosses. Channel cross-section surveys were performed at the first riffle in each cell moving upstream using a line level and a measuring rod. Channel surveys were recorded in the **Channel Cross-section Field Form**. Cross-sections were surveyed in each cell containing a riffle. In the case that riffles were present in only 1 or 2 cells, but those cells contained multiple riffles, additional cross-sections were performed at the most downstream unmeasured riffle, such that a minimum of three cross-sections were surveyed. If only 1 or 2 riffles were present in the entire reach, all riffle cross-sections were surveyed.

To begin each survey, the Cross-Section team placed a bank pin at the pre-determined bankfull elevation (using bankfull indicators as guides) on the right and left banks. A measuring tape was strung perpendicular to the stream channel at the most well-defined portion of the riffle and tied to the bank pins. Where mid-channel bars or other features were present which prevented a clean line across the channel, the protocol provided in the field methodology document was followed (DEQ 2010b). Bankfull depth measurements were collected to the nearest tenth of a foot across the channel at regular intervals depending on channel width. The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals. From the recorded data, the following information was calculated for each cross-section:

Bankfull channel width = with of the channel measured at bankfull height.

Cross-sectional area = the sum of the calculated areas from each measured cross-section cell. This value is estimated in the field and later calculated in a spreadsheet.

Mean bankfull depth = cross-section area/bankfull channel width. This value is estimated in the field and later calculated in a spreadsheet.

Width/depth ratio = bankfull width / mean bankfull depth.

Entrenchment ratio = floodprone width / bankfull width.

The floodprone depth was determined by doubling the maximum channel depth. The floodprone width was then determined by stringing a tape from the bankfull channel margin on both right and left banks until the tape (pulled tight and flat) touched ground at the floodprone elevation. The total floodprone width was calculated by adding the bankfull channel width to the distances on each end of the channel to the floodprone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, best professional judgment was used to determine the floodprone width. GPS coordinates for each cross-section were recorded. Photos were taken upstream and downstream of the cross section from the middle of the channel. A photo was also taken across the channel, showing the tape across the stream.

3.1.4 Channel Bed Morphology

A variety of channel bed morphology features were measured and recorded by the “Long-Pro” team, which consisted of one team member experienced in identifying these features, and who could consult with the field team leader when needed. The length of the survey site occupied by pools and riffles was identified and recorded in the **Pools, Riffles and Large Woody Debris Field Form.** Beginning from the downstream end of the survey site, the upstream and downstream stations of dominant riffle and pool stream features were recorded. Features were considered dominant when occupying over 50% of the stream width for riffles and 33% for pools. Pools and riffles were measured from the downstream to upstream end of each feature. Runs and glides were not recorded in the field form. Stream features were identified using standard methods (DEQ 2010b).

3.1.4.1 Residual Pool Depth

For this assessment, a pool is defined as a depression in the streambed that is concave in profile, is bounded by a “head crest” at the upstream end and a “tail crest” at the downstream end, and has a maximum depth that is 1.5 times the pool-tail depth. Backwater pools were not measured. The station (distance in feet) of each measured pool was recorded beginning at the downstream end of the survey site. At all pools, the maximum pool depth and pool tail depth were measured, the difference of which provides the residual pool depth. In the case of dry channels, readings were taken from channel bed surface to bankfull height. No pool tail crest depth was recorded for dammed pools (see **Section 3.1.4.2**).

3.1.4.2 Pool Habitat Quality

Qualitative assessments of each pool feature were undertaken and recorded in the **Pools, Riffles and Large Woody Debris Field Form** as follows:

1. Pool types were determined to be either Scour (S) or Dammed (D).
2. Pool size was estimated relative to bankfull channel width was recorded as Small (S), Medium (M), or Large (L). Small pools were defined as <1/3 of the bankfull channel width; medium pools were >1/3 and <2/3 of the bankfull channel with; and large pools were determined to be those >2/3 of the bankfull channel width or >20 feet wide.
3. Pool formative features were recorded as lateral scour (LS), plunge (P), boulder (B), or woody debris (W).
4. The primary pool cover type was recorded using the following codes:
    - V = Overhanging Vegetation
    - D = Depth
    - U = Undercut
    - B = Boulder
    - W = Woody Debris
    - N = No apparent cover
5. When undercut banks were present, their depths were measured to the nearest tenth of a foot by inserting a measuring rod horizontally into the undercut bank.

3.1.4.3 Fine Sediment in Depositional Spawning Areas

A measurement of the percent of fine sediment in depositional spawning areas was taken using the grid toss method at the first and second scour pool of each cell. Grid toss readings were focused in those gravels that appeared to be suitable or potentially suitable for trout spawning. Measurements were taken within the "arc" just upstream of the pool tail crest, following the methodology in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (DEQ 2010b). Three measurements were taken across the channel with specific attention given to measurements in gravels determined to be of appropriate size for salmonid spawning. The presence of spawning gravels was recorded as Yes (Y), No (N) or Unknown (?) at each pool location.

3.1.4.4 Fine Sediment in Riffles

Measurements of fine sediment in riffles were recorded by the Cross-Section team using the same grid toss method as used in pools (**Section 3.1.4.3**). Grid tosses were performed approximately within the right, middle, and left third of the riffle. Grid tosses were performed in the same general location but before the pebble counts (**Section 3.1.4.6**) to avoid disturbances to fine sediments. These measurements were recorded in the **Riffle Pebble Count Field Form.**

3.1.4.5 Woody Debris Quantification

The amount of large woody debris (LWD) was recorded by the Long-Pro team along the entire assessment reach in the **Pools, Riffles and Large Woody Debris Field Form**. Large pieces of woody debris within the bankfull channel and which were relatively stable as to influence the channel form were counted as either single, aggregate or willow bunch. For this assessment, a piece of large woody debris is defined as being greater than 9 feet long or two-thirds of the wetted stream width, and at least 4 inches in diameter at the small end. An aggregate is comprised of two or more single pieces of large woody debris. Further description of these categories is provided in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (DEQ 2010b).

3.1.4.6 Riffle Pebble Count

A Wolman pebble count (Wolman 1954) was performed by the Cross-Section team at the first riffle encountered in cells 1, 3 and 5 as the team progressed upstream. These data were recorded in the **Riffle Pebble Count Field Form**. Particle sizes were measured along their intermediate length axis (*b-axis*) and results were grouped into size categories. The team progressed from bankfull edge to bankfull edge using the "heel to toe" method, measuring particle size at the tip of the boot at each step. More specific details of the pebble count methodology can be found in the field methods document (DEQ 2010b).

3.1.4.7 Riffle Stability Index

In stream reaches that had well developed point bars downstream of riffles, a riffle stability index (RSI) was performed to determine the average size of the largest recently deposited particles, and to calculate an RSI which evaluates riffle particle stability (Kappesser 2002). For stream reaches in which well developed gravel bars were present, a RSI was determined by first measuring the intermediate axis (*b-axis*) of 15 of the largest recently deposited particles on a depositional bar. This information was recorded in the **Riffle Pebble Count Field Form**. During post-field data processing, the arithmetic mean of the largest recently deposited particles is calculated. This value is then compared to the cumulative particle size distribution of an adjacent riffle, as determined by the Wolman pebble count. The RSI is reported as the cumulative percentile of the particle size classes that are smaller than the arithmetic mean of the largest recently deposited particles. The RSI value generally represents the percent of mobile particles within the riffle that is adjacent to the sampled bar.

3.1.5 Riparian Greenline Assessment

After the entire survey station length was measured by the "Greenline" team member, an assessment of riparian vegetation cover was performed. The reach was walked by the "Greenline" team member who noted the general vegetation community type of the groundcover, understory and overstory on both banks. Vegetation types were recorded in the **Riparian Greenline Field Form** at intervals of 10', 15' or 20' depending on the length of the reach.

The *ground cover* vegetation (<1.5 feet tall) was described using the following categories:

- **W** = Wetland vegetation, such as sedges and rushes
- **G** = Grasses or forbs, rose, snowberry (vegetation lacking binding root structure)
- **B** = Bare/disturbed ground
- **R** = Rock, when a large cobble or bolder is encountered
- **RR** = Riprap

The *understory* (1.5 to 15 feet tall) and *overstory* (>15 feet tall) vegetation was described using the following categories:

- **C** = Coniferous
- **D** = Deciduous, riparian shrubs and trees with sufficient rooting mass and depth to provide protection to the streambanks
- **M** = mixed coniferous and deciduous

At 50-foot intervals, riparian buffer width was estimated for both banks by evaluating the belt of riparian vegetation buffering the stream from adjacent land uses. Upon conclusion of the Greenline measurements, the total numbers of each type of vegetation were tallied.

3.1.6 Streambank Erosion Assessment

An assessment of all actively/visually eroding and slowly eroding/undercut/vegetated streambanks was conducted along each survey site. This assessment consisted of the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) estimation which are used to quantify sediment loads from bank erosion. All streambank measurements were recorded in the **Streambank Erosion Field Form** and **Additional Streambank Erosion Measurements Form.** Further information related to the streambank erosion assessment methodology and results is included in **Sections 4.2** and **4.3**.

3.1.7 Water Surface Slope

Where possible, water surface slope measurements were estimated and recorded in the **Elevation & Water Surface Slope Field Form**. Two crew members, usually part of the Cross-Section team, stood distant from each other within direct line-of-sight at the water's surface between two similar stream features, and estimated slope with a clinometer.

3.1.8 Field Notes

At the completion of data collection at each survey site, field notes were collected by the field team leader with inputs from the entire field team. The following four categories contributed to field notes, which served to provide an overall context for the condition of the stream channel relative to surrounding and historical uses:

- Description of human impacts and their severity;
- Description of stream channel conditions;
- Description of streambank erosion conditions; and
- Description of riparian vegetation conditions.

3.1.9 Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC) was achieved through strict adherence to the project's Sampling and Analysis Plan (DEQ 2010a). During each stream assessment, the field team leader and most experienced crew members led the separate teams. Equipment checks were done each morning and field maps were reviewed with drivers before approaching field sites. Field forms were distributed and double-checked before teams left the vehicles to the survey sites. At the conclusion of each stream assessment, all field forms were reviewed for completeness and accuracy. Any questions that arose from field teams were brought to the attention of the field team leader until resolved to the leader's satisfaction.

Despite the best efforts to adhere to the project's Sampling and Analysis Plan (SAP), some deviations did occur while in the field and during data processing. Additionally, parameters used for sediment loading calculations were adjusted during data processing and following review of field photos to better represent actual field conditions. These adjustments and any deviations from the SAP are described in the Quality Assurance/Quality Control Review provided in **Attachment D**.

3.2 Sampling Parameter Descriptions and Summaries by Reach Type

The following sections provide definitions of sampling parameters that were measured at each reach, and basic statistical summaries of data for each parameter organized by reach type. Parameters described in this section include bankfull channel width, width/depth ratio, entrenchment ratio, percent understory shrub cover, percent bare/disturbed ground, riffle pebble count data (% <2 mm and <6 mm, D50), riffle grid toss data (% <6 mm), riffle stability index (RSI), mean pool depth, pool frequency, pool grid toss data (% <6 mm), and large woody debris (LWD) frequency. Data for each individual measurement site were used in the statistical analysis (i.e. data from each of the individual cross sections in one assessment reach were used), and then sample reaches and water bodies were grouped into reach types as shown in **Table 2-3**.

Data provided for each parameter include statistical box plots and data tables organized by each reach type and a total that includes all monitored sites. The box plots and data tables provide the minimum and maximum observed values, and the 25th (Q1), 50th (median), and 75th (Q3) percentile values. The statistics tables also provide the number of reaches sampled and the number of data cases available for each parameter. Parameters with a limited number of cases (N<4) or with little variability may appear as a single line on the box plots.

3.2.1 Bankfull Channel Width

Bankfull is a concept used by hydrologists to define a regularly occurring, channel-forming high flow. One of the first generally accepted definitions of bankfull was provided by Dunne and Leopold (1978):

> *"The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels."*

Bankfull channel width is measured at each surveyed cross-section as the width of the channel at bankfull height. In general, bankfull channel width will increase with stream order, although over-widened streams may have an artificially high channel width.

The measured bankfull channel widths are presented in **Figure 3-1** by reach type, and summary statistics are provided in **Table 3-1**. All surveyed cross sections are included in the data generated for each reach type**.**

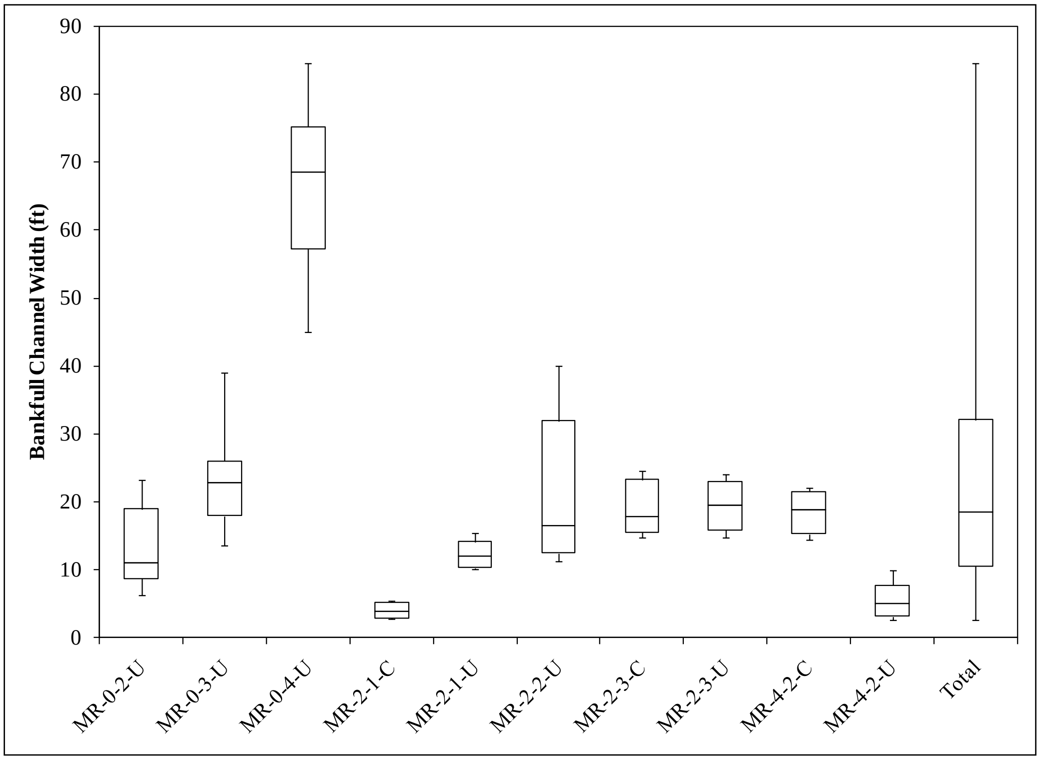

Figure 3-1. Bankfull channel width by reach type.

Table 3-1. Summary statistics of bankfull channel width by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	6.3	8.7	11.0	19.0	23.3
MR-0-3-U	4	19	13.6	18.0	22.8	26.0	39.0
MR-0-4-U	5	22	45.0	57.3	68.5	75.3	84.5
MR-2-1-C	1	5	2.8	2.9	3.8	5.3	5.5
MR-2-1-U	1	5	10.1	10.4	12.0	14.1	15.4
MR-2-2-U	2	9	11.3	12.5	16.5	32.0	40.0
MR-2-3-C	2	10	14.8	15.6	17.8	23.3	24.5
MR-2-3-U	1	4	14.8	15.9	19.5	23.0	24.0
MR-4-2-C	1	4	14.5	15.3	18.9	21.6	22.0
MR-4-2-U	3	15	2.7	3.2	5.0	7.7	10.0
Total	**23**	**108**	**2.7**	**10.5**	**18.5**	**32.1**	**84.5**

3.2.2 Width/Depth Ratio

The stream channel width/depth ratio is defined as the channel width at bankfull height divided by the mean bankfull depth (Rosgen 1996). The channel width/depth ratio is one of several standard measurements used to classify stream channels, making it a useful variable for comparing conditions on reaches within the same stream type. A comparison of observed and expected width/depth ratio is a useful indicator of channel over-widening and aggradation, which are often linked to excess streambank erosion or acute or chronic erosion from sources upstream of the study reach. Channels that are over-widened often are associated with excess sediment deposition and streambank erosion, contain shallower, warmer water, and provide fewer deepwater habitat refugia for fish.

The measured width/depth ratios are presented in **Figure 3-2** by reach type, and summary statistics are provided in **Table 3-2**. All surveyed cross sections are included in the data generated for each reach type**.**

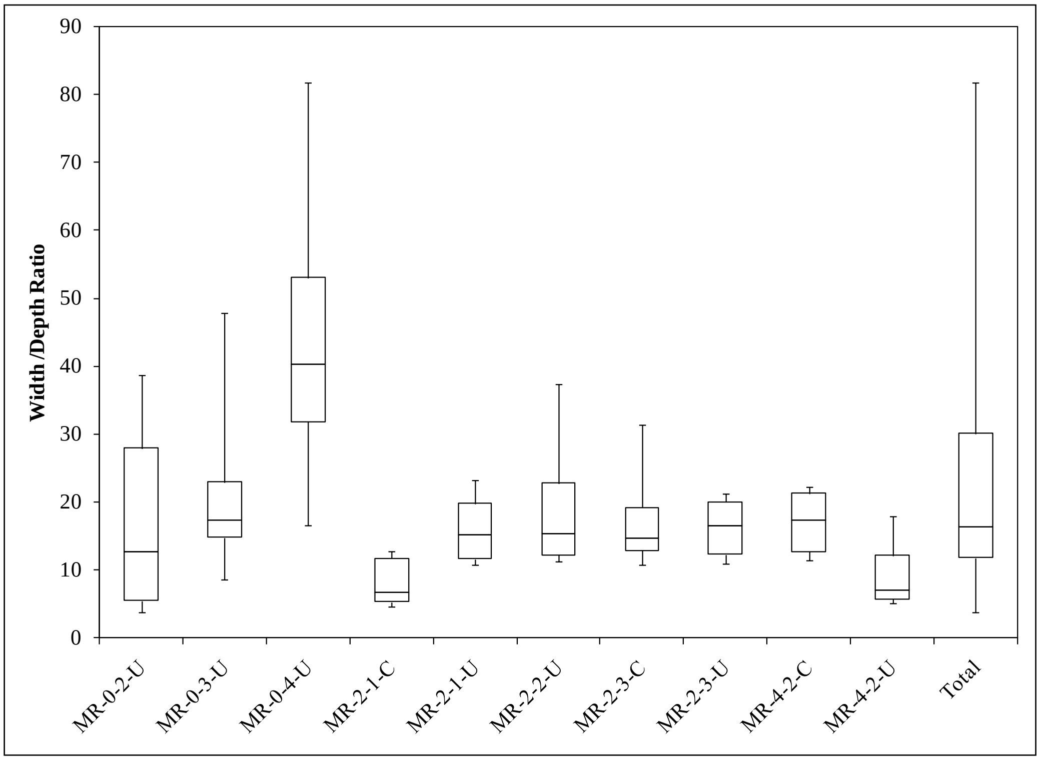

Figure 3-2. Width/depth ratio by reach type.

Table 3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	3.8	5.5	12.7	27.9	38.8
MR-0-3-U	4	19	8.6	14.8	17.3	23.0	47.8
MR-0-4-U	5	22	16.5	31.8	40.4	53.0	81.7
MR-2-1-C	1	5	4.7	5.4	6.7	11.7	12.8
MR-2-1-U	1	5	10.8	11.7	15.2	19.8	23.2
MR-2-2-U	2	9	11.3	12.2	15.3	22.8	37.4
MR-2-3-C	2	10	10.8	12.9	14.6	19.2	31.4
MR-2-3-U	1	4	10.9	12.3	16.5	20.1	21.2
MR-4-2-C	1	4	11.5	12.7	17.4	21.3	22.2
MR-4-2-U	3	15	5.1	5.7	7.0	12.1	18.0
Total	**23**	**108**	**3.8**	**11.9**	**16.4**	**30.1**	**81.7**

3.2.3 Entrenchment Ratio

Stream entrenchment ratio is equal to the floodprone width divided by the bankfull width (Rosgen 1996). Entrenchment ratio is used to help determine if a stream shows departure from its natural stream type. It is an indicator of stream incision, and therefore indicates how easily a stream can access its floodplain. Streams are often incised due to detrimental land management or may be naturally incised due to landscape characteristics. A stream that is overly entrenched generally is more prone to streambank erosion due to greater energy exerted on the banks during flood events. Greater scouring energy in incised channels results in higher sediment loads derived from eroding banks. If the stream is not actively degrading (down-cutting), the sources of human caused incision may be historical in nature and may not currently be present, although sediment loading may continue to occur. The entrenchment ratio is an important measure of channel condition as it relates to sediment loading and habitat condition, due to the long-lasting impacts of incision and the large potential for sediment loading in incised channels.

The entrenchment ratios by reach type are presented in **Figure 3-3**, and summary statistics are provided in **Table 3-3**. All surveyed cross sections are included in the statistics generated within each reach type**.**

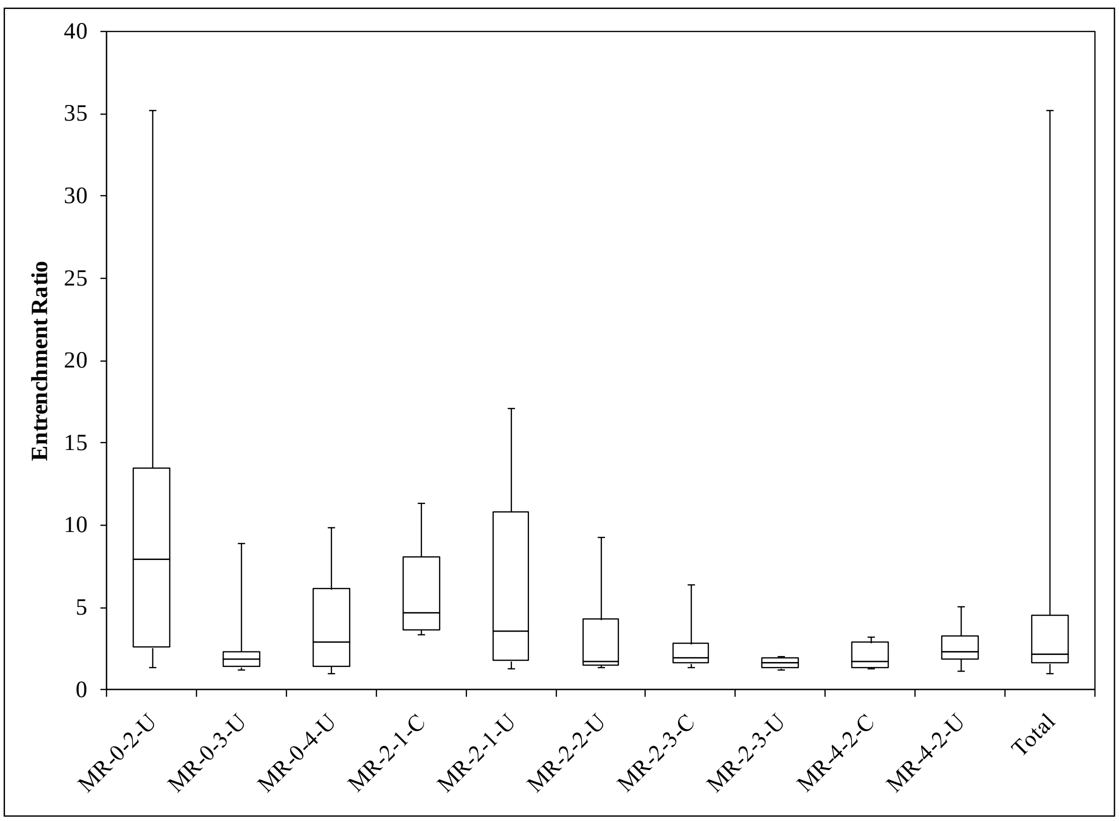

Figure 3-3. Entrenchment ratio by reach type.

Table 3-3. Summary statistics of entrenchment ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	1.4	2.6	7.9	13.5	35.2
MR-0-3-U	4	19	1.2	1.4	1.8	2.3	8.9
MR-0-4-U	5	22	1.0	1.4	2.9	6.1	9.9
MR-2-1-C	1	5	3.4	3.7	4.7	8.1	11.4
MR-2-1-U	1	5	1.4	1.8	3.6	10.8	17.1
MR-2-2-U	2	9	1.4	1.5	1.7	4.3	9.3
MR-2-3-C	2	10	1.4	1.6	1.9	2.8	6.4
MR-2-3-U	1	4	1.3	1.3	1.6	1.9	2.1
MR-4-2-C	1	4	1.3	1.4	1.7	2.9	3.2
MR-4-2-U	3	15	1.2	1.9	2.3	3.3	5.1
Total	**23**	**108**	**1.0**	**1.6**	**2.2**	**4.6**	**35.2**

3.2.4 Riffle Pebble Count: Substrate Fines (% <2 mm)

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation occur when critical habitat components such as spawning gravels (Chapman and McLeod 1987) and cobble surfaces are physically covered by fines, thereby decreasing inter-gravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates and algae (Lisle 1989, Waters 1995). Chapman and McLeod found that size of bed material is inversely related to habitat suitability for fish and macroinvertebrates and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows: 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as particle size of substrate changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters 1995).

The percent of fine sediment in a stream channel provides a measure of the siltation occurring in a river system and is an indicator of stream channel condition. Although it is difficult to correlate percent surface fines with sediment loading directly, the Clean Water Act allows “other applicable measures” for the development of TMDL water quality restoration plans. Percent surface fines have been used successfully in other TMDLs in western Montana addressing sediment related to stream bottom deposits, siltation, and aquatic life uses. Surface fine sediment measured in the Wolman pebble count is one indicator of aquatic habitat condition and can indicate excessive sediment loading. The Wolman pebble count method provides a survey of the particle distribution of the entire channel width, allowing investigators to calculate a percentage of the surface substrate (as frequency of occurrence) composed of fine sediment.

In addition to being a direct measure of impairment to the aquatic macroinvertebrate community, riffle percent surface fines can be used as an indicator of possible impairment condition to cold water fish since the elevated riffle surface fines are likely an indicator of elevated subsurface fines within spawning gravels.

The pebble count measurements for particles <2 mm by reach type are presented in **Figure 3-4**, and summary statistics are provided in **Table 3-4**.

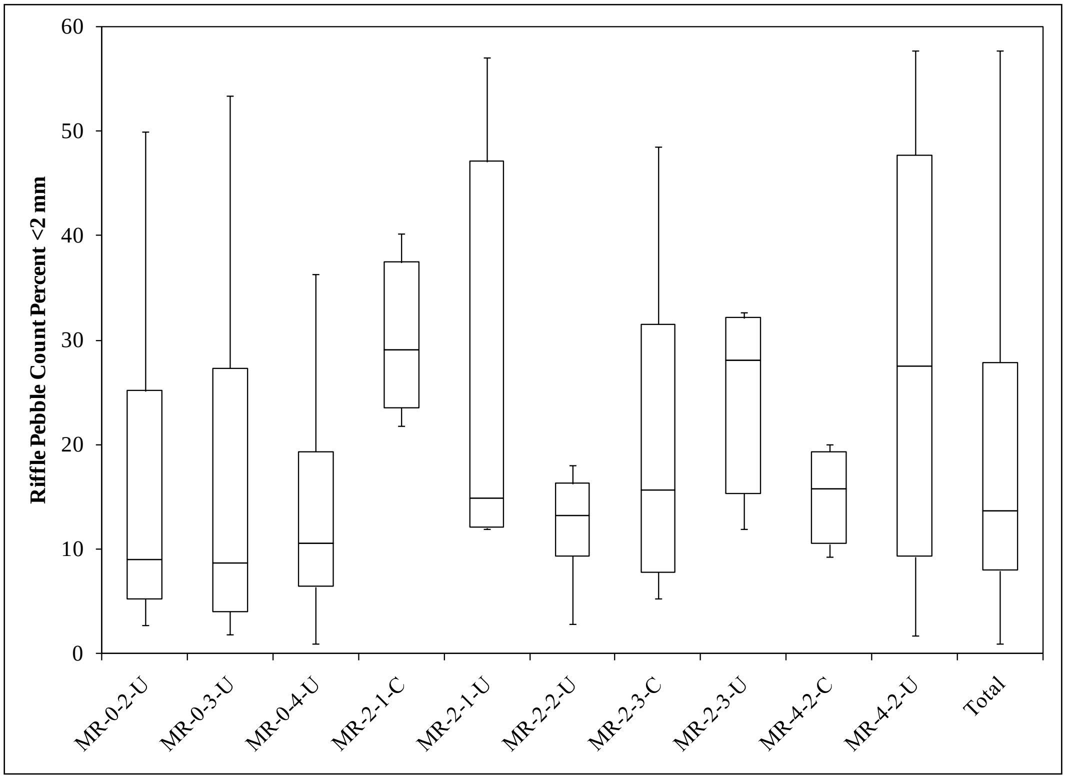

Figure 3-4. Riffle pebble count (% <2 mm) by reach type.

Table 3-4. Summary statistics of riffle pebble count (% <2 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	2.8	5.3	9.0	25.2	50.0
MR-0-3-U	4	16	1.9	4.0	8.7	27.3	53.4
MR-0-4-U	5	20	1.0	6.4	10.5	19.4	36.4
MR-2-1-C	1	4	21.8	23.6	29.1	37.5	40.2
MR-2-1-U	1	4	12.0	12.1	14.9	47.1	57.0
MR-2-2-U	2	8	2.9	9.4	13.2	16.3	18.0
MR-2-3-C	2	8	5.3	7.8	15.6	31.5	48.6
MR-2-3-U	1	4	11.9	15.4	28.1	32.1	32.7
MR-4-2-C	1	4	9.3	10.5	15.8	19.3	20.0
MR-4-2-U	3	12	1.8	9.3	27.5	47.7	57.7
Total	**23**	**92**	**1.0**	**8.0**	**13.7**	**27.9**	**57.7**

3.2.5 Riffle Pebble Count: Substrate Fines (% <6 mm)

As with surface fine sediment smaller than 2 mm diameter, an accumulation of surface fine sediment less than 6 mm diameter may also indicate excess sedimentation and has the potential to negatively impact the spawning success of cold water fish. The size distribution of substrate material in the streambed is also indicative of habitat quality for salmonid spawning and incubation. Excess surface fine substrate may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan 1991). Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material less than 6.35 mm and the emergence success of westslope cutthroat trout and bull trout.

The pebble count measurements for sediment fines (% <6 mm) by reach type are presented below in **Figure 3-5** and summary statistics are provided in **Table 3-5**.

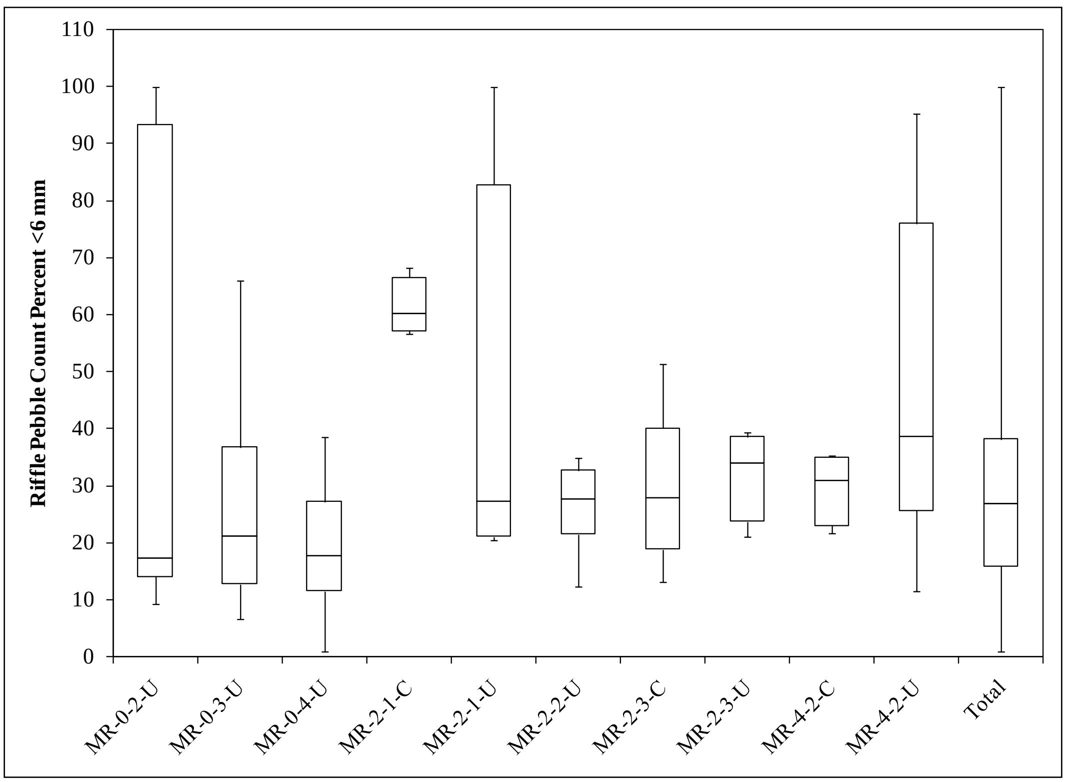

Figure 3-5. Riffle pebble count (% <6 mm) by reach type.

Table 3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	9.3	14.1	17.3	93.4	100.0
MR-0-3-U	4	16	6.7	12.8	21.2	36.8	66.0
MR-0-4-U	5	20	1.0	11.6	17.7	27.3	38.5
MR-2-1-C	1	4	56.7	57.2	60.2	66.6	68.2

Table 3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.

MR-2-1-U	1	4	20.4	21.1	27.3	82.8	100.0
MR-2-2-U	2	8	12.4	21.5	27.7	32.8	35.0
MR-2-3-C	2	8	13.3	18.9	27.9	40.1	51.4
MR-2-3-U	1	4	21.1	23.8	34.0	38.6	39.4
MR-4-2-C	1	4	21.7	23.1	31.0	35.0	35.2
MR-4-2-U	3	12	11.6	25.7	38.7	76.0	95.2
Total	**23**	**92**	**1.0**	**16.0**	**27.0**	**38.2**	**100.0**

3.2.6 Riffle Pebble Count: D50

The D50 represents the median (50th percentile) particle size of a riffle as determined by the Wolman pebble count. This value can be used to evaluate the suitability of a riffle as spawning gravel for salmonids. Kondolf and Wolman (1993) state that the appropriate size of spawning gravels varies based on stream size and fish species, since larger fish are capable of moving larger particles. In general, appropriate sized spawning gravels should be less than approximately 40 mm for salmonids.

Results of the riffle pebble count D50 are presented below by reach type in **Figure 3-6** and summary statistics are provided in **Table 3-6**.

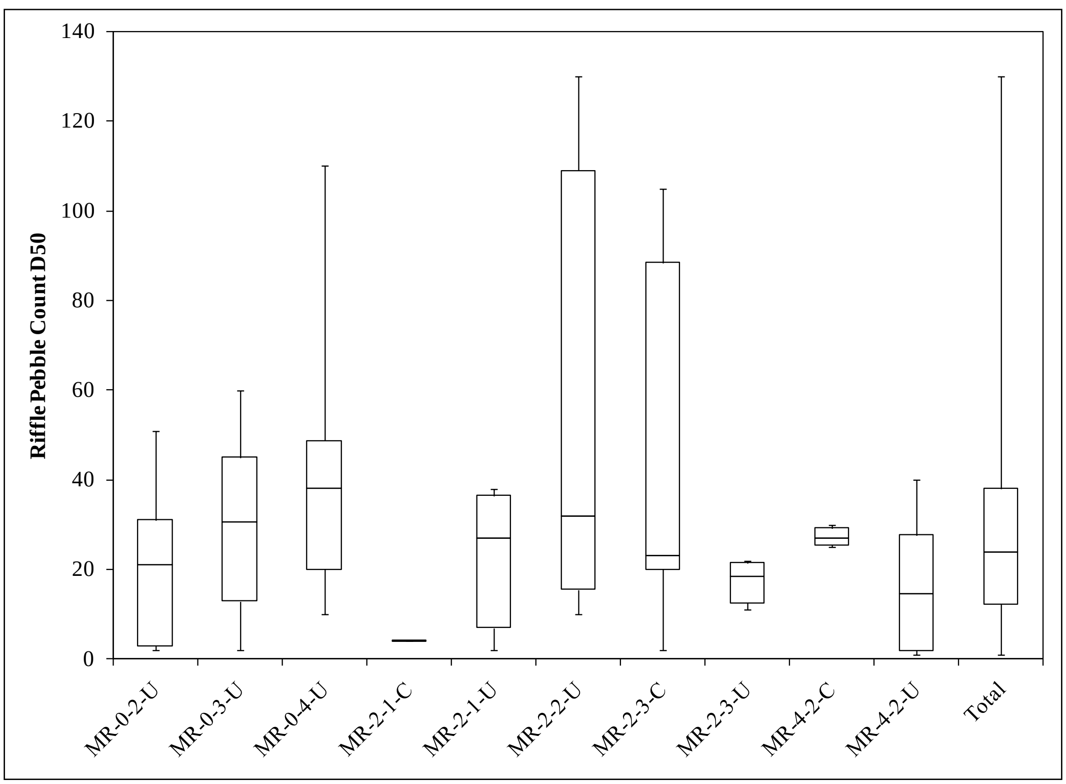

Figure 3-6. Riffle pebble count D50 (mm) by reach type.

Table 3-6. Summary statistics of riffle pebble count D50 (mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	2	3	21	31	51
MR-0-3-U	4	16	2	13	31	45	60
MR-0-4-U	5	20	10	20	38	49	110
MR-2-1-C	1	4	4	4	4	4	4
MR-2-1-U	1	4	2	7	27	37	38
MR-2-2-U	2	8	10	16	32	109	130
MR-2-3-C	2	8	2	20	23	89	105
MR-2-3-U	1	4	11	13	19	22	22
MR-4-2-C	1	4	25	26	27	29	30
MR-4-2-U	3	12	1	2	15	28	40
Total	**23**	**92**	**1**	**12**	**24**	**38**	**130**

3.2.7 Riffle Stability Index

The riffle stability index (RSI) is used to evaluate riffle particle mobility in an area receiving excessive sediment input (Kappesser 2002). The mobile fraction in a riffle is estimated by comparing the particle sizes in the riffle to the arithmetic mean of the largest mobile particles on an adjacent depositional bar. Riffle particles of the size class smaller than the largest particles on a depositional bar are interpreted as mobile, and the RSI value represents the percent of mobile particles within a riffle. Riffles that have received excessive sediment from upstream eroding banks have a higher percent of mobile particles than riffles in equilibrium. The following breaks are provided as general guidelines for interpreting RSI values:

RSI Value	**Description**
< 40	High bedrock component to riffle (very stabile system) or channel has been scoured
40 – 70	Stream is in dynamic equilibrium – good channel and watershed stability
70 – 85	Riffle is somewhat loaded with excessive sediment
> 85	Riffle is loaded with excessive sediment

Limited RSI data were collected during this field effort due to the frequency of poorly developed point bars downstream of riffles and actively eroding banks. The riffle stability index results for all reaches are provided below in **Table 3-7**.

Table 3-7. Riffle stability index results for all reaches.

Reach ID	Cell	Reach Type	Arithmetic Mean (cm)	Riffle Stability Index
BASI 15-02	1	MR-0-3-U	99	96
BLDR 13-04	3	MR-0-4-U	77	67
BLDR 13-10	2	MR-0-4-U	79	90

3.2.8 Riffle Grid Toss: Substrate Fines (% <6 mm)

The wire grid toss is a standard procedure frequently used in aquatic habitat assessment to approximate the percent fine material in a stream. The grid toss measurement does not cover the entire channel width as in the Wolman pebble count, but rather provides a more focused measurement of surface fines in a subsample of the cross-section.

The riffle grid toss results for sediment fines (% <6 mm) are presented below in **Figure 3-7** and summary statistics are provided in **Table 3-8**. One reach (HIOR 09-01, reach type MR-4-2-U) was unable to be assessed due to murky water.

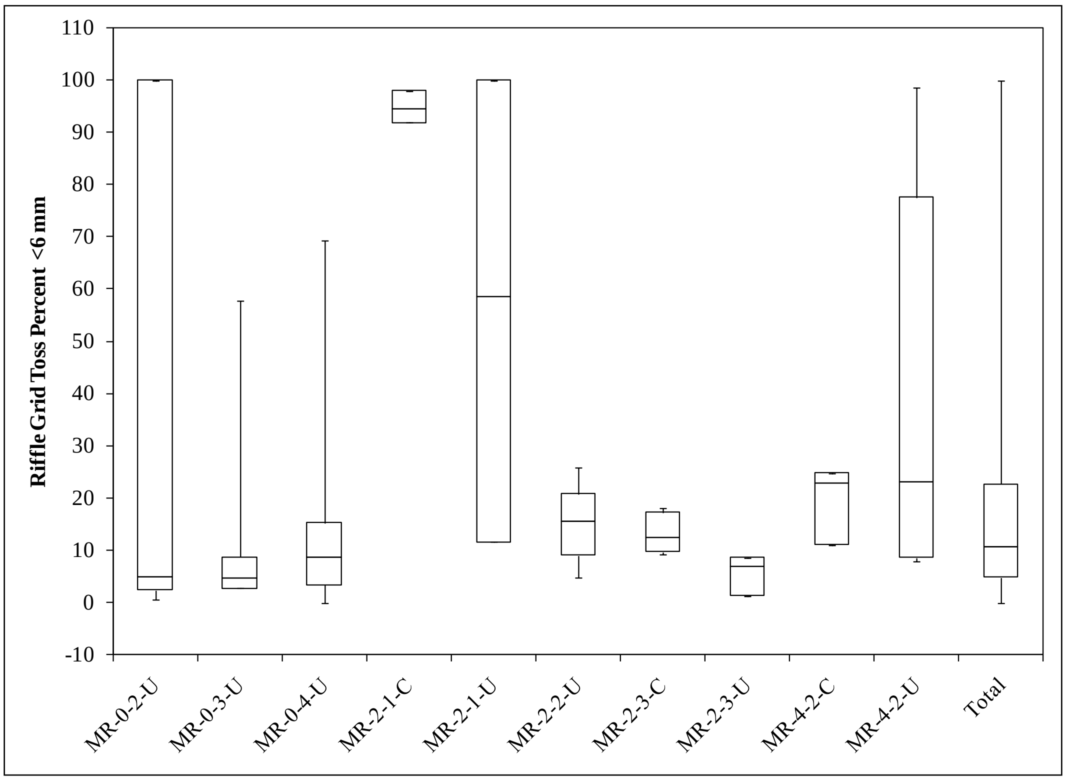

Figure 3-7. Riffle grid toss (% <6 mm) by reach type.

Table 3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	9	0.7	2.4	5.0	100.0	100.0
MR-0-3-U	4	12	2.7	2.8	4.8	8.7	57.8
MR-0-4-U	5	13	0.0	3.4	8.6	15.3	69.4
MR-2-1-C	1	3	91.8	91.8	94.6	98.0	98.0
MR-2-1-U	1	3	11.6	11.6	58.5	100.0	100.0
MR-2-2-U	2	6	4.9	9.1	15.5	20.8	25.9
MR-2-3-C	2	8	9.2	9.7	12.4	17.2	18.2
MR-2-3-U	1	3	1.4	1.4	7.0	8.6	8.6

Table 3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-4-2-C	1	3	11.1	11.1	22.8	24.8	24.8
MR-4-2-U	2	6	7.9	8.6	23.0	77.6	98.6
Total	**22**	**64**	**0.0**	**4.8**	**10.7**	**22.8**	**100.0**

3.2.9 Pool Grid Toss within Depositional Spawning Areas: Sediment Fines (% <6 mm)

Grid toss measurements in depositional spawning areas provide a measure of fine sediment accumulation in potential spawning sites. Excess surface fines may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan 1991). Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material less than 6.35mm and the emergence success of westslope cutthroat trout and bull trout.

Grid toss results for sediment fines (% <6 mm) found within depositional spawning areas are provided below in **Figure 3-8** and summary statistics are provided in **Table 3-9**. The data presented represents only pool tails that were identified as having the appropriate sized gravels to support spawning. There were four assessed reaches (BASI 15-02, BISO 04-02, BLDR 13-33, and HIOR 09-01) where spawning gravels did not exist in pool tails.

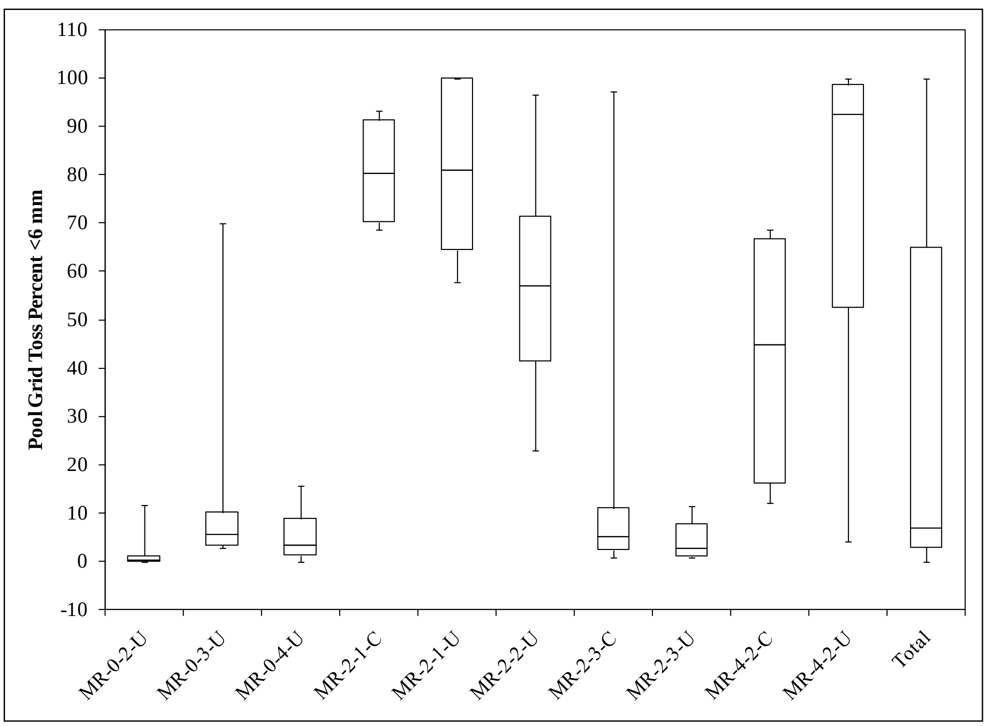

Figure 3-8. Pool grid toss (% <6 mm) by reach type.

Table 3-9. Summary statistics of pool grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	2	16	0.0	0.0	0.3	1.2	11.7
MR-0-3-U	3	19	2.7	3.4	5.5	10.2	70.1
MR-0-4-U	4	15	0.0	1.4	3.5	8.8	15.6
MR-2-1-C	1	4	68.7	70.2	80.3	91.3	93.2
MR-2-1-U	1	6	57.8	64.5	81.0	100.0	100.0
MR-2-2-U	1	7	23.1	41.5	57.0	71.4	96.6
MR-2-3-C	2	10	0.7	2.4	5.1	11.0	97.3
MR-2-3-U	1	5	0.7	1.1	2.7	7.9	11.6
MR-4-2-C	1	4	12.2	16.3	44.9	66.8	68.7
MR-4-2-U	3	13	4.2	52.6	92.5	98.6	100.0
Total	**19**	**99**	**0.0**	**3.0**	**7.0**	**65.0**	**100.0**

3.2.10 Pool Residual Depth

Residual pool depth, defined as the difference between pool maximum depth and crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods. Pool residual depth is also an indirect measurement of sediment inputs to listed streams. An increase in sediment loading would be expected to cause pools to fill, thus decreasing residual pool depth over time.

Data are presented below in **Figure 3-9** and **Table 3-10**. Note that the data presented represents the mean residual pool depth for each reach, so some reach types have only one data point. Residual pool depths were not calculated for dammed pools.

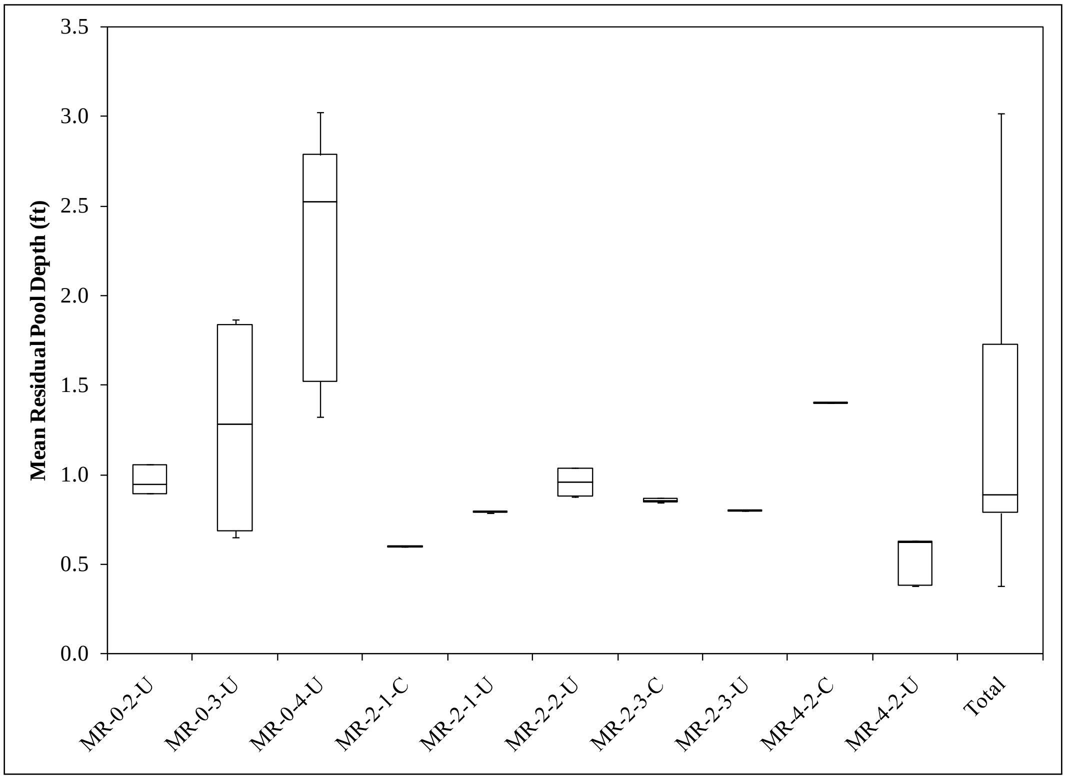

Figure 3-9. Residual pool depth (ft) by reach type.

Table 3-10. Summary statistics of residual pool depth (ft) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	0.9	0.9	0.9	1.1	1.1
MR-0-3-U	4	4	0.7	0.7	1.3	1.8	1.9
MR-0-4-U	5	5	1.3	1.5	2.5	2.8	3.0
MR-2-1-C	1	1	0.6		0.6		0.6
MR-2-1-U	1	1	0.8		0.8		0.8
MR-2-2-U	2	2	0.9		1.0		1.0
MR-2-3-C	2	2	0.8		0.9		0.9
MR-2-3-U	1	1	0.8		0.8		0.8
MR-4-2-C	1	1	1.4		1.4		1.4
MR-4-2-U	3	3	0.4	0.4	0.6	0.6	0.6
Total	**23**	**23**	**0.4**	**0.8**	**0.9**	**1.7**	**3.0**

3.2.11 Pool Frequency

Pool frequency is a measure of the availability of pools within a reach to provide rearing habitat, cover, and refugia for salmonids. Pool frequency is related to channel complexity, availability of stable obstacles, and sediment supply. Excessive erosion and sediment deposition can reduce pool frequency by filling in smaller pools. Pool frequency can also be affected adversely by riparian habitat degradation resulting in a reduced supply of large woody debris or scouring from stable root masses in streambanks.

The pool frequencies per 1,000 ft for each reach type are presented in below **Figure 3-10** and summary statistics are provided in **Table 3-11**. As with residual pool depth, some reach types are represented by only a single value.

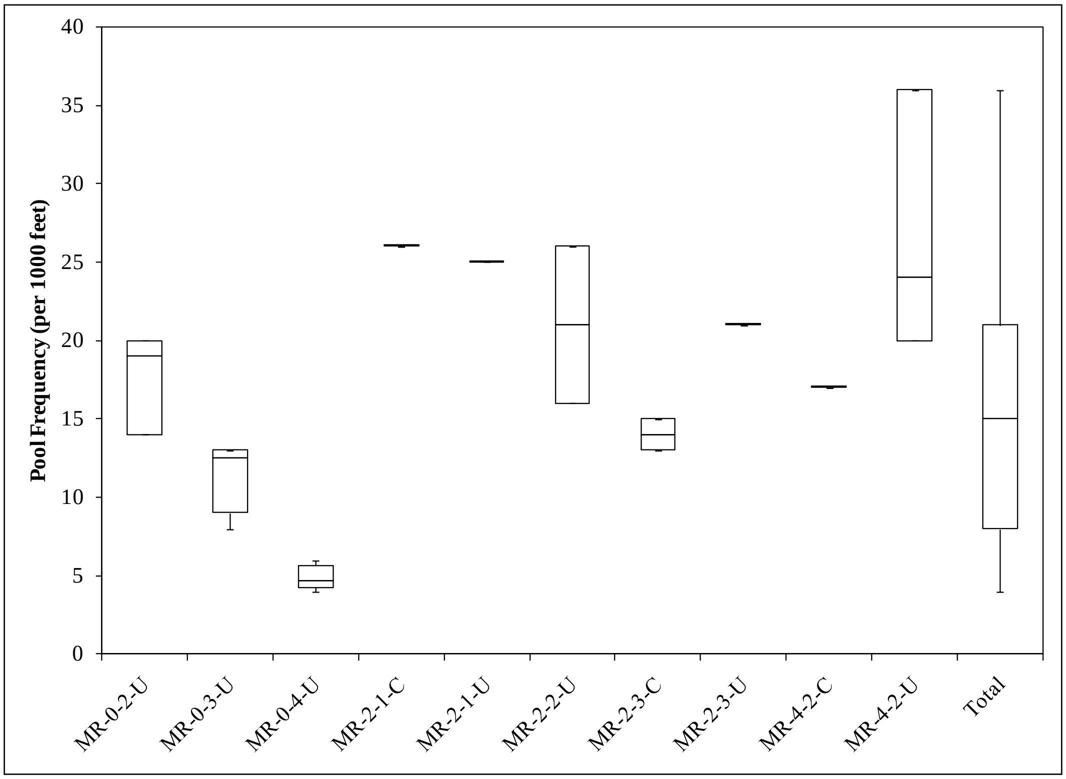

Figure 3-10. Pool frequency (per 1,000 ft) by reach type.

Table 3-11. Summary statistics of pool frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	14.0	14.0	19.0	20.0	20.0
MR-0-3-U	4	4	8.0	9.0	12.5	13.0	13.0
MR-0-4-U	5	5	4.0	4.3	4.7	5.7	6.0
MR-2-1-C	1	1	26.0		26.0		26.0
MR-2-1-U	1	1	25.0		25.0		25.0
MR-2-2-U	2	2	16.0		21.0		26.0
MR-2-3-C	2	2	13.0		14.0		15.0
MR-2-3-U	1	1	21.0		21.0		21.0
MR-4-2-C	1	1	17.0		17.0		17.0
MR-4-2-U	3	3	20.0	20.0	24.0	36.0	36.0
Total	**23**	**23**	**4.0**	**8.0**	**15.0**	**21.0**	**36.0**

3.2.12 Large Woody Debris Frequency

Large woody debris (LWD) is a critical component of salmonid habitat, providing stream complexity, pool habitat, cover, and long-term nutrient inputs. LWD also constitutes a primary influence on stream function, including sediment and organic material transport, channel form, bar formation and stabilization, and flow dynamics (Bilby and Ward 1989). LWD frequency can be measured and compared to reference reaches or literature values to determine if more or less LWD is present than would be expected under reference conditions. Too little or too much LWD may indicate riparian habitat impairment or upstream influences on habitat quality.

Target values for LWD span a broad range of values, even for streams of similar size. A guideline value of approximately 150 pieces of LWD per mile, or approximately 28 pieces of LWD per 1000 feet, represents an average of target values from other studies. Results for LWD should be interpreted with caution, as the guideline value for this parameter is tied to a high degree of variability due to land use, vegetative community and soils, among other factors.

The LWD frequencies for each reach type are provided below in **Figure 3-11** and summary statistics are provided in **Table 3-12**.

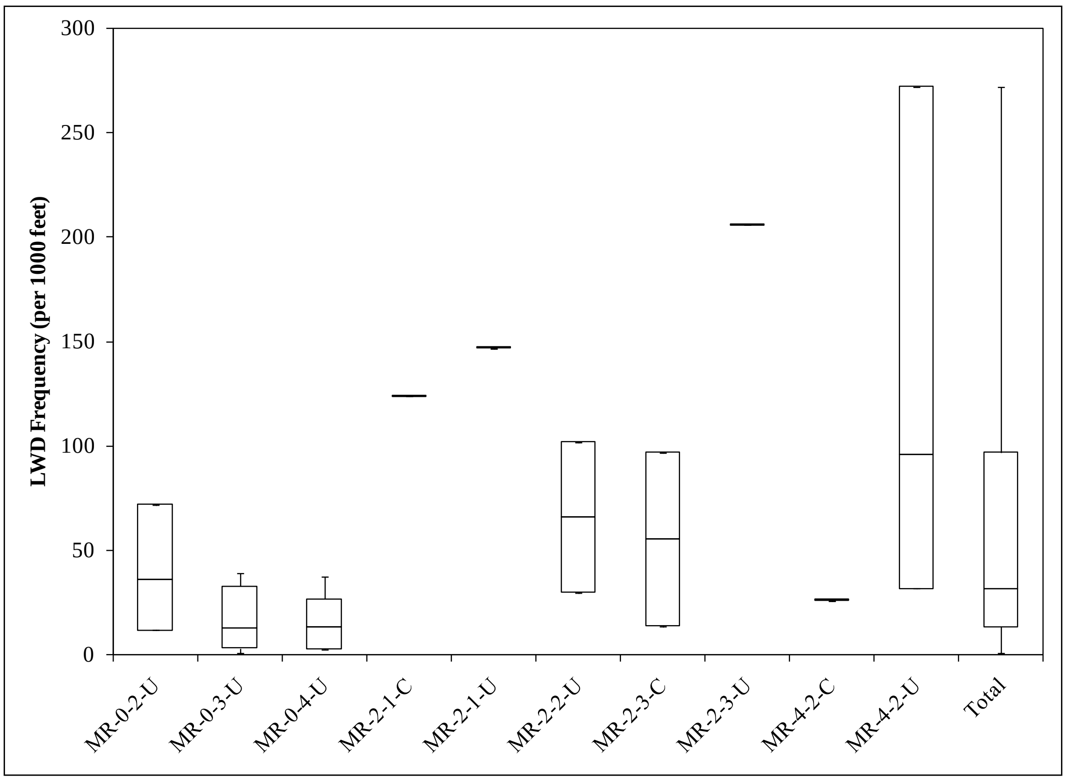

Figure 3-11. LWD frequency (per 1,000 ft) by reach type.

Table 3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	12	12	36	72	72
MR-0-3-U	4	4	1	4	13	33	39

Table 3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-4-U	5	5	3	3	14	27	37
MR-2-1-C	1	1	124		124		124
MR-2-1-U	1	1	147		147		147
MR-2-2-U	2	2	30		66		102
MR-2-3-C	2	2	14		56		97
MR-2-3-U	1	1	206		206		206
MR-4-2-C	1	1	26		26		26
MR-4-2-U	3	3	32	32	96	272	272
Total	**23**	**23**	**1**	**14**	**32**	**97**	**272**

3.2.13 Greenline Inventory: Percent Understory Shrub Cover

Riparian shrub cover is an important factor on streambank stability. Removal of riparian shrub cover can dramatically increase streambank erosion and increase channel width/depth ratios. Shrubs stabilize streambanks by holding soil and armoring lower banks with their roots, and reduce scouring energy of water by slowing flows with their branches. Good riparian shrub cover is also important for fish habitat. Riparian shrubs provide shade which reduce solar inputs and help maintain cooler water temperatures. The dense network of fibrous roots of riparian shrubs allows streambanks to remain intact while water scours the lowest portion of streambanks, creating important fish habitat in the form of overhanging banks and lateral scour pools. Overhanging branches of riparian shrubs provide important cover for aquatic species. In addition, riparian shrubs provide critical inputs of food for fish and other aquatic life. Terrestrial insects falling from riparian shrubs provide one main food source for fish. Organic inputs from shrubs, such as leaves and small twigs, provide food for aquatic macroinvertebrates, which are also an important food source for fish.

The Greenline understory shrub cover percentages by reach type are presented in **Figure 3-12**. The summary data are also presented in **Table 3-13**.

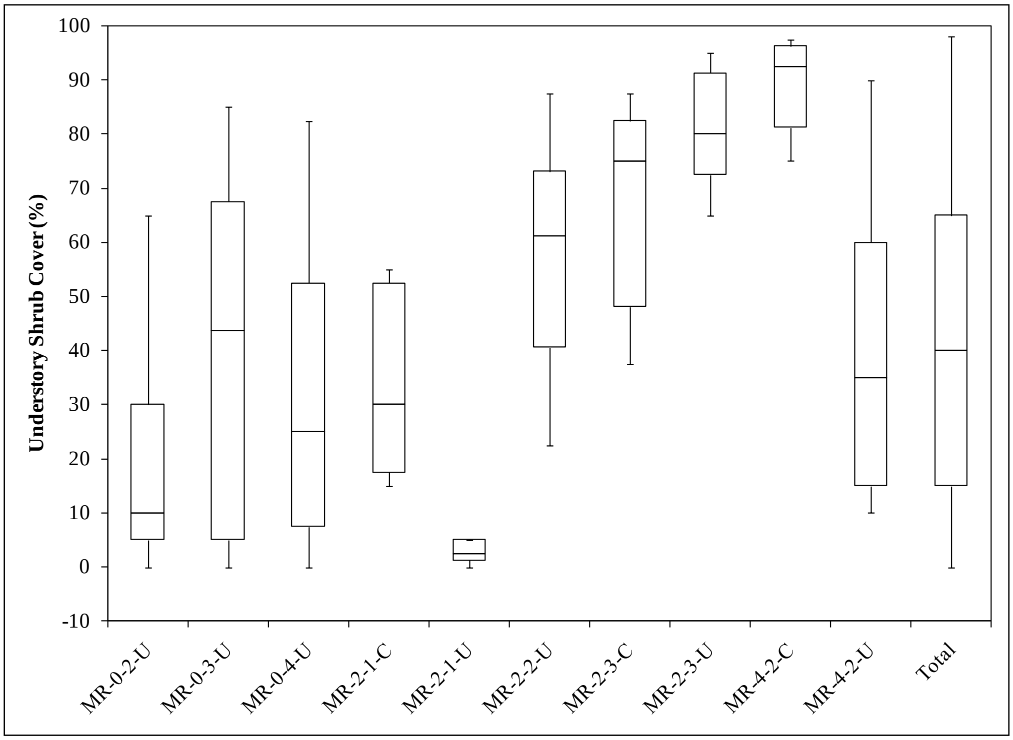

Figure 3-12. Greenline understory shrub cover (%) by reach type.

Table 3-13. Summary statistics of understory shrub cover (%) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	0.0	5.0	10.0	30.0	65.0
MR-0-3-U	4	20	0.0	5.0	43.8	67.5	85.0
MR-0-4-U	5	25	0.0	7.5	25.0	52.5	82.5
MR-2-1-C	1	5	15.0	17.5	30.0	52.5	55.0
MR-2-1-U	1	5	0.0	1.3	2.5	5.0	5.0
MR-2-2-U	2	10	22.5	40.6	61.3	73.1	87.5
MR-2-3-C	2	10	37.5	48.1	75.0	82.5	87.5
MR-2-3-U	1	5	65.0	72.5	80.0	91.3	95.0
MR-4-2-C	1	5	75.0	81.3	92.5	96.3	97.5
MR-4-2-U	3	15	10.0	15.0	35.0	60.0	90.0
Total	**23**	**115**	**0.0**	**15.0**	**40.0**	**65.0**	**98.0**

3.2.14 Greenline Inventory: Percent Bare/Disturbed Ground

Percent bare ground is an important indicator of erosion potential, as well as an indicator of land management influences on riparian habitat. Bare ground was noted in the Greenline inventory in cases where recent ground disturbance was observed, leaving bare soil exposed. Bare ground is often caused by trampling from livestock or wildlife, fallen trees, recent bank failure, new sediment deposits from overland or overbank flow, or severe disturbance in the riparian area, such as past mining, road-building, or fire. Ground cover on streambanks is important to prevent sediment recruitment to stream channels. Sediment can wash in from unprotected areas due to snowmelt, storm runoff, or flooding. Bare areas are also much more susceptible to erosion from hoof shear. Most stream reaches have a small amount of naturally-occurring bare ground. As conditions are highly variable, this measurement is most useful when compared to reference values from best available conditions within the study area or literature values.

Results of the Greenline survey for percent bare/disturbed ground are provided by reach type below in **Figure 3-13**, and tabular data are presented in **Table 3-14**.

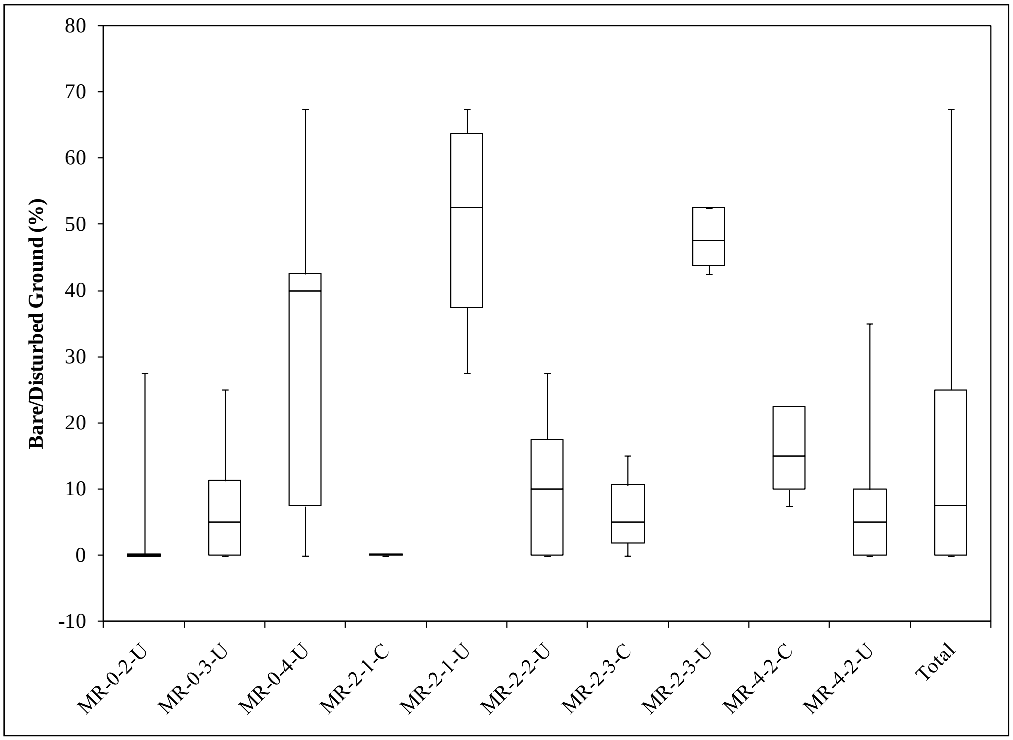

Figure 3-13. Greenline bare/disturbed ground (%) by reach type.

Table 3-14. Summary statistics of bare/disturbed ground (%) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	0.0	0.0	0.0	0.0	27.5
MR-0-3-U	4	20	0.0	0.0	5.0	11.3	25.0
MR-0-4-U	5	25	0.0	7.5	40.0	42.5	67.5
MR-2-1-C	1	5	0.0	0.0	0.0	0.0	0.0
MR-2-1-U	1	5	27.5	37.5	52.5	63.8	67.5
MR-2-2-U	2	10	0.0	0.0	10.0	17.5	27.5
MR-2-3-C	2	10	0.0	1.9	5.0	10.6	15.0
MR-2-3-U	1	5	42.5	43.8	47.5	52.5	52.5
MR-4-2-C	1	5	7.5	10.0	15.0	22.5	22.5
MR-4-2-U	3	15	0.0	0.0	5.0	10.0	35.0
Total	**23**	**115**	**0.0**	**0.0**	**7.5**	**25.0**	**67.5**

3.3 Assessment Reach Field Descriptions

The following sections provide brief descriptions of each sampled reach. Descriptions are provided for human impacts, stream channel conditions, and riparian vegetation conditions. Stream bank erosion conditions are provided with sediment loading results in **Section 4.6**. Assessment reaches are organized by water body and reach location starting at the upstream end and moving downstream.

3.3.1 Basin Creek

BASI 08-02

Description of human impacts and their severity:

This stream has been heavily affected by human activity. A road parallels the stream for much of the reach on river right. Placer tailings are also evident in places throughout the reach, particularly the berms that confine the stream at the uppermost end. Some banks in the section have little vegetation and appear to be a loosely consolidated collection of cobbles, sand, and overlying duff. The stream has found some semblance of a stable form; however, the channel is easily diverted and braided by tree fall in areas with loose cobble banks and steeper slopes.

Description of stream channel conditions:

Stream reach is a B4 type channel dominated by riffles with a stream bottom comprised of mostly small to mid-sized angular cobble, gravel and sand. Little pool formation exists in most of the reach; however, some lateral scour pools occur at bends. Where LWD does exist some stream variability also occurs, with braided channels and pool formation (cell 3). In general, stream appears significantly over-widened as a result of human alterations and impacts throughout. This reach has very little spawning gravel, with only two spawning gravel locations observed in LWD pools.

Description of streambank erosion conditions:

Despite the obvious alteration and historic disturbance to the stream, little stream bank erosion was witnessed; however, eroding banks may not exist because the stream corridor has been so over-widened that not many discernable banks exist anymore. Plus, where eroding banks do exist they are comprised of cobbles and gravel that effectively armor the bank. Only where the stream was directed into the old placer pilings did the banks become unstable. In cell 3, where the stream became braided, the large wood and natural vegetation through this section helped maintain stable banks. This was the only section that appeared to have a better vegetation community.

Description of riparian vegetation conditions:

Ground cover was predominantly sedges along stream edge with some rushes. Some grasses were also present but up-gradient of stream edge. Forbs are in abundance throughout the area. Understory consisted of lodgepole saplings, a few large willows, and a few smaller bushes along the stream edge. Overstory consisted of lodgepole/spruce mix with abundant beetle kill.

BASI 15-02

Description of human impacts and their severity:

The stream through this reach definitely appears to have had some anthropogenic impacts. Upstream of the reach the valley has been cleared for a small plane landing strip and a residence exists on river left in the lower part of the reach. Large size cobbles occupy multiple gravel bars and point bars and these features are often over a foot deep with this type of substrate. Multiple transverse bars also occur throughout the reach. The area surrounding the stream is occupied by transitional and young size class vegetation suggesting historic logging or potentially mining, as occurred upstream. The excess cobbles and expansive point bars suggest strong spring runoff capable of moving larger material. The cobbles are possibly resulting from the upstream conditions affected by historic mining, logging and road building.

Description of stream channel conditions:

This reach is predominantly a high energy B4 type channel. Multiple transverse bars and deep, large point bars indicate an aggrading system. Where transverse bars or large wood occur, deep scour pools result often exerting near bank stress leading to eroding banks. Stream width/depth ratios appear variable, with frequent overwidening and pinch points where gravel bars constrict channel into deeper run features at the beginning of bends. Substrate is dominated by coarse cobbles with little suitability for spawning. Not much fine material exists within the substrate. LWD and deep bends provide good cover. A fair amount of algae was noted throughout the reach.

Description of streambank erosion conditions:

This reach has a number of long, actively eroding banks corresponding with bends or transverse bars that direct flow into the bank. Banks have poor stabilizing vegetation, possibly as a result of historic logging and mining or more recent residential development. Bank material is typically loosely consolidated large angular cobble within sand/clay matrix. Where slowly eroding banks occurred they were often accompanied by dense, mature vegetation on the bank, including established willow and fir trees.

Description of riparian vegetation conditions:

Ground cover is predominantly rushes and sedges along stream edge. Grasses are more abundant up gradient from stream edge. Moderate forb growth exists throughout the area. Understory has good recruitment of lodgepole and spruce saplings along stream bank with multiple age classes. Willow exists throughout area, but none over 15 feet tall. Few old and mature conifers are present. The overstory is mostly lodgepole pine and spruce with moderate beetle kill. Spruce is more prevalent in riparian areas.

3.3.2 Bison Creek

BISO 04-02

Description of human impacts and their severity:

Site is actively grazed and shows signs of historic grazing. A dirt road exists approximately 150’ upstream of reach top. The interstate and a paved frontage road exist within 0.5 miles of the stream. Some logging and historic mining has occurred in the upper watershed.

Description of stream channel conditions:
The stream channel in this reach is a meandering E5 type channel that is completely filled with coarse sand. Some small gravel (11.3 -16 mm size) exists in the lower part of the reach, but mostly fines occur. Lots of undercut banks exist, and pools are mostly lateral scour pools with some willow bunches. Spawning gravels do not exist in pool tails. Much of the coarse sand is likely naturally derived from weathered granite of the Boulder batholith. The reach exists within a glacial outwash area with a large amount of sediment delivered from neighboring foothills.

Description of streambank erosion conditions:
This site has mostly natural/slowly eroding banks with low NBS in lower reach. Upper reach has more hoof shear, trampling, and actively eroding banks with some slowly eroding banks on outside bends. Reach has low root density and root depth, with good access to floodplain.

Description of riparian vegetation conditions:
Ground cover is almost all sedges with few grasses. Site has been lightly grazed. Understory is predominantly cinquefoil, willows, and a few weed species with little evidence of browse. No overstory exists throughout the reach.

BISO 11-01
Description of human impacts and their severity:
Transportation has played a significant role in confining the stream throughout this reach. The interstate highway parallels the streams on river left in some places as close as 100 feet. There is evidence of a former railroad grade within the reach, and bank/floodplain material appears to be non-native fill material in places. A tall berm influences confinement on the bottom end of the reach.

Description of stream channel conditions:
Stream reach has a slightly steeper slope with riffle/pool system despite the relative confinement, although the reach is mostly riffle with only a few lateral scour pools at meanders and some small step pool formation intermixed. The slope and confinement has created a B4 type channel, although the stream would likely be a C4 type channel without the presence of the highway. Very few pools exist with suitable spawning gravels. Substrate is mostly fine particles, and stream is highly embedded. No significant woody debris noted in this reach.

Description of streambank erosion conditions:
Eroding streambanks in this reach occur on bends and are usually tall with medium to large cobbles mixed with silt and clays. Cobbles provide some limited bank protection at the toe of these banks. Vegetation is mixed, although little vegetation is suitable for bank stabilization. Non-native floodplain material and modifications from the transportation corridor may also be affecting the unconsolidated nature of the banks and increasing bank erosion rate.

Description of riparian vegetation conditions:
Ground cover consists of rushes, sedges, and snake grass along bank edges with grasses and forbs on low lying benches. Understory consists of willow, dogwood, and small cottonwoods in

the riparian area, and cinquefoil along the stream edge. Canopy consists of large conifers along the riparian buffer. All willow species were less than 15’ tall.

3.3.3 Boulder River

BLDR 12-04

Description of human impacts and their severity:
This reach is significantly confined and altered from the interstate highway on river right and the local access road on river left. These two transportation corridors have left the channel as a high gradient chute with limited sinuosity, armored banks, and high width/depth ratios. Debris and garbage from the two roads are in the banks and stream channel. Road sanding in the winter may also be affecting the system due to the road’s proximity to the stream. Historic mining activity has occurred in the immediate local watershed.

Description of stream channel conditions:
Stream channel is overwidened, entrenched, and mostly homogeneous in character throughout the 1500’ reach. The stream in this reach is a F4/B4c type channel, although the potential stream type is likely C4 if the stream were able to access its entire floodplain. Large cobble and boulders dominate the substrate. Very little pool habitat exists due to lack of LWD and meanders. Pools that do exist are typically small and formed downstream from large boulders. Suitable spawning gravels are very uncommon. Substrate is embedded and coated with a film of brown algae. Stream is entrenched with very little room for lateral movement due to the roads and bank armor.

Description of streambank erosion conditions:
This site has essentially no streambank erosion. Only two eroding banks were recorded, both in the lowest cell. The lack of eroding banks is due to heavy armoring from rip-rap and large cobbles, and due to channel straightening. One eroding bank occurs where the stream meets a section of old road fill, and the other is a slowly eroding clayey bank bound by alder and rushes.

Description of riparian vegetation conditions:
This site has almost no preferable wetland species. Vegetation is non-existent throughout the left bank with only a few alder, birch and willow. River right has slightly better vegetation with mixed willows at the stream edge. Invasive weeds and grasses are common throughout the reach, likely as a result of the stream’s proximity to roads.

BLDR 13-04

Description of human impacts and their severity:
This site has irrigated hay ground and grazing present throughout the reach. Several banks have been armored with rip-rap to slow erosion, with varying levels of success. An automobile has been dumped in the river just upstream of the reach. Noxious weeds are present within the riparian area. The watershed has historically been mined, although impacts are not observed in the reach. Two irrigation returns near the top of the reach may be influencing erosion locally.

Description of stream channel conditions:
Stream is a meandering C4 type channel with short, poorly developed riffles and long lateral scour pools on outside meander bends. The channel is slightly overwidened in places, and evidence of braiding exists in the upper part of the reach. The lower end of the reach has pools with poorly developed tails and minimal spawning gravels; however, the upper reach has pools with well developed tails and good spawning gravels. Substrate has a high percentage of fines and is moderately embedded. Site has minimal woody debris and good point bar development.

Description of streambank erosion conditions:
Site has numerous long, near vertical, actively eroding banks, mainly occurring on outside meander bends. Several attempts have been made to slow erosion with rip-rap, but in several places the river has undercut the rip-rap, causing it to slump into the stream channel. Very little stabilizing vegetation exists along the riparian corridor, and predominantly fine bank material is exacerbating erosion throughout the reach. NBS is generally moderate to high on bends, but straight sections with low NBS also show evidence of streambank erosion.

Description of riparian vegetation conditions:
Ground cover has rushes where banks are not eroding and few sedges. Grasses are prevalent on higher banks. Understory is fairly sparse with some areas populated by mature willow and birch. The canopy has large cottonwoods throughout the riparian corridor.

BLDR 13-10
Description of human impacts and their severity:
This site is heavily impacted by grazing. The riparian corridor contains almost all grass with very few willow and cottonwoods. The downstream end of the reach is just upstream of a road crossing, although road effects do not appear to impact the reach. Irrigation is prevalent throughout the Boulder River watershed, and flow fluctuations and changes in stream energy may be impacting streambank stability throughout the watershed.

Description of stream channel conditions:
This reach is a meandering C4 type channel that is split in cells 2 and 5 due to large woody debris. Riffles are typically short and poorly developed, although better riffle habitat exists in split channels. Most pools are long lateral scour pools on outside meander bends. Pool tails generally have good spawning habitat; however, most pool tails are used as animal crossings and there is evidence of excess fines due to trampling. Large woody debris is found throughout the reach, and is affecting channel form in cells 2 and 5. Reach has good point bar development with lots of evidence of braiding.

Description of streambank erosion conditions:
Near vertical eroding banks exist throughout almost the entire 1500 foot reach, especially on long outside meander bends. Two primary bank types exist, including one with predominantly silty/clayey substrate, and one with cobble substrate near the toe. NBS is consistent throughout the reach except where it is affected by LWD or transverse bars. Riparian fencing exists in the upper cells, but erosion is threatening to remove the fence within several years, and the riparian area within the fence appears to be more heavily grazed than the area outside. No naturally

occurring erosion exists within this reach. All streambank erosion is attributed to riparian grazing or possibly flow impacts related to irrigation.

Description of riparian vegetation conditions:
Ground cover is predominantly grasses on the high banks, although many banks are sloughing into the stream channel. Sedges and rushes are rare. Understory is moderately populated by willow, although little recruitment exists due to grazing. Canopy is dominated by cottonwood with a few tall willows. Lower portion of the reach has a dense understory which became thinner in the upper cells.

BLDR 13-23
Description of human impacts and their severity:
This reach is in the valley bottom of the Boulder River and is largely affected by agricultural practices in the area. Irrigated hay production exists directly adjacent to the stream, and irrigation practices upstream of this reach may affect bank stability in this area. Cattle paths exist in some parts of the reach with isolated bank trampling.

Description of stream channel conditions:
The stream is a C4 type channel dominated by pool and run conditions. Outside bends are characterized by compound pools that have limited spawning gravel in pool tails. Substrate is predominantly fine except for gravels in riffles and a few pool tails. A few transverse bars exist on inside bends. One rip-rap structure exists in cell 3 to protect an outside bend.

Description of streambank erosion conditions:
Site has several near vertical actively eroding banks on outside meander bends that have almost all fine substrate and little supporting vegetation. Most banks are actively eroding, although one slowly eroding bank occurs where willow vegetation stabilizes the banks. One extremely tall (14.5’) eroding bank contributes a large amount of sediment to the stream.

Description of riparian vegetation conditions:
This reach generally has good ground cover with grasses on upper banks and sedges/rushes on sloping banks near the stream edge. Understory has willow, birch and alder, predominantly in the upper part of the reach. Understory vegetation has been cleared in lower portions of the reach to accommodate agricultural practices. Canopy is generally lacking, although some cottonwood and aspen occur within the reach.

BLDR 13-33
Description of human impacts and their severity:
This reach occurs in the valley bottom of the Boulder River, and may be affected by irrigation practices upstream. The road on river left encroaches the stream in several places. Riparian grazing was not evident within this reach, but may have historically occurred. The road is the primary human influence within this reach.

Description of stream channel conditions:
This reach is dominated by pool/run conditions with deep compound pools on outside meander bends. Pool tails have embedded cobbles and gravels with very little suitable spawning habitat. Riffles were uncommon and typically very short.

Description of streambank erosion conditions:
Four bank types were noted in this reach, dominated by long actively eroding streambanks on outside meander bends with limited surface protection. Some slowly eroding banks exist on straight channel sections with significant vegetation and high root density. One tall (11') eroding bank occurs where the road closely parallels the stream.

Description of riparian vegetation conditions:
Ground cover is sedges and rushes on sloping banks near the stream edge, and grasses and forbs on upper banks where understory vegetation does not cause significant shading. Understory is dominated by dense willows along stream edge. The canopy is almost non-existent throughout the reach, but some spruce occurs in the upper part of the reach. The reach is mostly dominated by dense willow vegetation.

3.3.4 Cataract Creek

CATA 18-01
Description of human impacts and their severity:
Some riparian logging has occurred on river right of this reach, and historic placer mining has occurred as evidenced by large rock piles within the floodplain. The immediate watershed has a significant amount of historic mining activity, although recent human disturbance appears to be relatively minor. Trenches, pits, rock walls and abandoned roads occur throughout the reach.

Description of stream channel conditions:
The stream is a B4 type channel through this reach, characterized by a step-pool system with large gravel, cobble, and boulder substrate. Because of the high gradient, this reach is basically one long riffle/run with intermixed pocket pools formed by boulders and LWD. Pools provide good habitat for fish due to their depth, but little spawning gravels exist. Fine substrate exists in the few slow water areas with some embeddedness.

Description of streambank erosion conditions:
This site has very little streambank erosion, with only one evaluated eroding streambank. Banks were heavily armored and composed of hard packed clay, binding root mass and overgrown mosses throughout. The banks are typical of what would be expected in a high gradient, coarse bed stream.

Description of riparian vegetation conditions:
Ground cover was dominated by moss and grasses with a few sedges and forbs. Willow and birch were prevalent in the understory, especially on river right. The canopy was dominated by late successional forest of lodgepole and spruce, with good recruitment of young spruce trees.

3.3.5 Elkhorn Creek

ELKH 23-01

Description of human impacts and their severity:

Human impacts are evident throughout this reach, including a forest road parallel to and downstream of the reach, and a rough access road that parallels the stream as close as 5'. Fire pits and camp sites are scattered throughout the reach, and signs of cattle or animal trampling occur on both sides of the stream. Tree stumps in the riparian and upland areas suggest logging or mining activity has previously occurred in the area. The stream appears to have been altered or confined to its present channel, possibly to accommodate the construction of the forest road.

Description of stream channel conditions:

The stream channel is a typical B4 type channel with long riffles and small step-pool features associated with LWD and boulders. The channel appears slightly overwidened in several places. Pools are generally not well developed with only a few good pools created by LWD jams or boulders. Substrate is a mix of large gravel and cobble with some large boulders. Some spawning gravels do exist, but fines are also collecting in some pool tails.

Description of streambank erosion conditions:

Streambank erosion is relatively minor and characterized by small, slowly eroding, undercut banks that occur at knick points from boulders, LWD, or tight meander bends. The erosion is likely influenced by the reduction of riparian vegetation and animal crossings within the stream. Hoof shear was observed, and some banks appeared to be trampled more than others.

Description of riparian vegetation conditions:

The ground cover contained sedges, rushes, grasses and forbs throughout the reach, with evidence of hummocking. The understory includes a diverse mix of birch, alder, willow and aspen. The canopy is dominated by mature spruce with cottonwoods and aspen in the upper portion of the reach.

ELKH 28-01

Description of human impacts and their severity:

Evidence of cattle grazing occurs throughout this reach, with multiple cattle paths crossing the stream. A clearing occurred on river left in the lower portion of the reach, possibly to accommodate cattle. A large crib structure was also observed in the upper reach which may have served as a cattle pen. A road parallels the stream on river left, and another road crosses the stream at the bottom end of the reach.

Description of stream channel conditions:

Stream is a B4 type channel with lateral scour pools and poorly developed riffles. The channel is overwidened in places due to trampling, and may also be downcutting as evidenced by decadent alder and willow on high banks. Most surveyed cross sections occurred at cattle crossings that resembled riffles. Substrate consists of large gravel and cobble with a few large boulders. Very few pools had suitable spawning gravels.

Description of streambank erosion conditions:
Eroding streambanks typically occur where cattle paths create low angle crossings with poor stabilizing vegetation. Several tall eroding banks also occur where riparian vegetation has died and is falling into the channel. Dead woody vegetation provides some surface protection, but the banks often have poor root depth and density and are composed of fine substrate.

Description of riparian vegetation conditions:
Ground cover is a mix of sedges and grasses with some forbs. Most of the ground cover was classified as wetland species. Understory is dominated by alder and willow with some birch and aspen. Understory is dense and provides significant shading. Canopy is composed of alder and birch with some aspen, juniper, and spruce in the lower cells.

3.3.6 High Ore Creek

HIOR 09-01
Description of human impacts and their severity:
Human impacts exist throughout this reach; including a road parallel to the stream, hoof shear from cattle grazing, fire rings, an outhouse, an old road crossing, and various debris. The area around the reach appears to have been cleared at some point, possibly for logging or mining, and there is evidence of historic placer mining. Stream clarity was very murky at the time of sampling. Forest fires, mining, and reclamation activities in the upper watershed may also be affecting streambank stability at this reach.

Description of stream channel conditions:
Stream is a narrow C4b type channel dominated by long, fast riffles and few pools. Occasional channel braids were observed. Substrate is a mix of small to mid-size gravel and cobble with a few boulders. Fines were common in areas of slower water.

Description of streambank erosion conditions:
Only one eroding streambank was identified in this reach, which was a tall, poorly vegetated bank where LWD directs stream flow into the bank. Banks were quite stable despite limited riparian vegetation, possibly because the floodplain has been significantly flattened and few true banks exist. Hoof shear and human traffic is evident along the stream, although it doesn't appear to significantly affect stream erosion.

Description of riparian vegetation conditions:
Ground cover is lush with rushes, sedges and moss along the stream edge and grasses and forbs on upper banks. Understory was sparse in the lower reach, but becomes denser upstream with aspen, alder and willow. The canopy is dominated by mature spruce forest with good aspen recruitment and mature aspens in the upper reach.

HIOR 15-01

Description of human impacts and their severity:
A road parallels the stream for the duration of this reach, typically within 30'. Historic mining or logging may have occurred within the reach, and was prevalent in the upper watershed. Very little streamside vegetation exists. The stream channel was previously restored, and there is still evidence of coir fabric and wooden stakes along the stream. The reach is fenced on both sides and there is no evidence of current grazing.

Description of stream channel conditions:
This reach contains a narrow reconstructed stream that resembles an E4b type channel with numerous boulders and plunge pools and very little LWD. Most pools were short and were followed by long riffles. Substrate is predominately large gravels that are embedded with fines. Very few spawning gravels exist in pool tails.

Description of streambank erosion conditions:
Infrequent short stretches of slowly eroding bank were observed, but overall, banks were well vegetated and stable. Eroding banks were typically found at bends or where LWD or boulders confine flow to one side of the channel.

Description of riparian vegetation conditions:
Ground cover has abundant grass throughout the reach, with sedges and rushes in the lower portions, and some knapweed, mustard and sagebrush. Understory was moderately populated with willow, aspen and birch. The canopy was predominantly spruce with some juniper and aspen.

3.3.7 Little Boulder River

LBLR 32-01

Description of human impacts and their severity:
This reach is paralleled by a forest road on river left within 10-100'. Signs of light cattle grazing exist in the upper reach. Historic logging and mining likely occurred in the upper watershed, although there is no direct evidence near the stream. A high percentage of fines occur in the stream channel, which may be from the adjacent road or naturally derived from the weathered granitic geology.

Description of stream channel conditions:
Stream is a cascading B4 type channel with many large boulders, cobbles, and infrequent LWD that has a large influence on channel form where it does occur. Pools are poorly developed with minimal spawning gravels. Two terraces were noted at approximately 4' and 10' in height, suggesting the stream has been downcutting. A high percentage of fine substrate occurred in pools and slower water; however, it may be sourced from local geology. Undercut banks provide good cover in some places. The stream splits in the upper cell. This reach appears in relatively good condition for this type of B channel.

Description of streambank erosion conditions:
This reach has several slowly eroding banks that generally occur at meander bends or where LWD and boulders have deflected flow into the bank. Banks are well vegetated with a dense root structure that helps stability. Undercut banks are not uncommon, especially in areas where the stream is altered by large boulders or stabilized by mature coniferous trees. NBS is increased by mid-channel boulders and LWD that deflects flow.

Description of riparian vegetation conditions:
Ground cover is predominantly rushes and mosses with some grasses and forbs on higher banks. Understory includes a diverse group of deciduous species, including willow, gooseberry, birch, aspen and snowberry. Overstory includes mature spruce with juniper, cottonwood and birch.

LBLR 37-01
Description of human impacts and their severity:
Most human impacts in this reach are associated with the forest road that parallels the stream and recreational activities in the area. A stream ford occurs at station 600 that was accessed by ATVs during the stream survey. Man-made debris was also found in many places, including road signs and tires. Historic logging or mining activity in the upper watershed may also affect this reach.

Description of stream channel conditions:
The stream channel is entrenched by the road on river left and an elevated sandy terrace on river right, creating an F4 type stream channel (although the potential stream type is likely C4). Substrate is predominantly small gravel with a high percentage of fines. Stream has wide meanders with deep pools on outside bends and interspersed riffles. Reach has deep transverse bars that directly flow into deep scouring troughs in some of the straight portions of the reach. Spawning gravels do exist, although they are often marginal and somewhat embedded. Pool habitat is good, and LWD was infrequent.

Description of streambank erosion conditions:
Reach has numerous eroding banks, typically occurring on outside meander bends. A tall sandy terrace occurs on river right that is actively eroding in several places. Most eroding banks are provided some surface protection from living and dead willows.

Description of riparian vegetation conditions:
Ground cover is predominantly sedges and rushes with grasses prevalent in the upper part of the reach. Spotted knapweed was present throughout. Understory is dominated by birch and willow, with dead willows common along the bank. The canopy was non-existent, with no individual tree taller than 15'.

3.3.8 Lowland Creek

LOWL 08-01
Description of human impacts and their severity:
Human impacts in this reach appear to be minimal; however, the impoundment upstream (Maney Lake) may have some effect on the flow regime of this reach. Some cattle grazing is evident, but

effects appear to be minimal. Willow growth appears to be unaffected by grazing. A road parallels the stream on river left, but does not appear to be confining the stream. Upper hillslopes show evidence of historic logging, but are presently well vegetated.

Description of stream channel conditions:
Stream is a small C4 type channel, although its potential stream type is likely E4. Stream has tight meander bends with deep pool formation that is generally associated with mid-channel boulders. Substrate is mostly medium sized gravels with sporadic boulders and little embeddedness. Some transverse bar formation occurs in the lower cells of this reach.

Description of streambank erosion conditions:
Banks are predominantly stable throughout this reach, with dense vegetation and some willow growth. Most bank erosion appears naturally derived, with undercut banks on outside meander bends that occasionally slump into the stream. The most severe erosion occurs where transverse bars or mid-channel boulders deflect flow into the streambank.

Description of riparian vegetation conditions:
Ground cover is dense with abundant grasses, rushes and sedges. A large number of forbs also exist. Understory is predominantly willow ranging from 1' to 15' tall. Canopy included a few coniferous trees at riparian edge, but no willows were taller than 15'.

3.3.9 McCarty Creek

MCCA 22-01
Description of human impacts and their severity:
Signs of grazing exist throughout this reach, particularly in the lower sections. Historic beaver activity is also noted. A road is not far from the riparian channel on river right, and power lines cross the stream just below the reach. Upper watershed may have historically been logged, although no direct evidence exists within the reach. A small reservoir exists upstream which may have some impact on the entrenchment and downcutting of this reach.

Description of stream channel conditions:
Stream is a narrow, shallow, entrenched, B5/G5 type channel, although it should potentially be a B4 type channel. The stream has decent riffle and pool habitat for its size. Stream has good cover from woody vegetation, and it periodically runs subsurface where mature root masses hold the bank together. The site has abundant woody debris, but much of it is dead vegetation that has been abandoned by the downcutting stream channel. The immediate riparian corridor is thick with brush, and many undercut banks exist throughout the reach.

Description of streambank erosion conditions:
This reach has many slowly and actively eroding banks which are near vertical or undercut. Eroding banks generally occur where woody vegetation has died, or on tight meander bends. Erosion appears partially due to the severe downcutting observed in this reach.

Description of riparian vegetation conditions:
Ground cover is mostly grasses and forbs where the understory has not shaded out the ground cover. Bull thistle was observed within the reach. The understory was very thick, with living and dead willow, birch, aspen and juniper. Understory appears to be dying from age or abandonment by the downcutting stream channel. The canopy is dominated by aspen, with a few birch and juniper over 15' tall. The riparian corridor is primarily spruce.

3.3.10 Muskrat Creek

MUSK 18-01-02
Description of human impacts and their severity:
This site is located on USFS land with a forest road within 100 yards of the reach. A campsite exists at the top end of the reach within a clearing. Hoof shear was observed in several places along this reach, and old stumps on adjacent hill slopes indicate past logging. Cleared or grazed vegetation has left the banks unstable at a few locations in the upper portion of the reach, although these are rare.

Description of stream channel conditions:
Reach is a B4 type channel with large boulders throughout long riffles. Short pools exist with poorly developed tails and minimal spawning gravels that are typically embedded with fines. Some fish habitat is provided by small pocket pools near boulders. LWD exists throughout the reach and appears to influence channel form. The channel splits in the lower portion of the cell due to a LWD jam.

Description of streambank erosion conditions:
This reach has a mix of slowly and actively eroding banks. Slowly eroding banks are generally well vegetated undercut banks with natural sources of erosion. Actively eroding banks are generally found on outside meander bends and are influenced by LWD. One large mass wasting site occurs within this reach that is presently separated from the main channel. However, during high flow the stream will likely reach this bank and continue erosion unless flow is directed elsewhere.

Description of riparian vegetation conditions:
Ground cover is mostly grasses and forbs with a few sedges and rushes, although many areas are shaded out by dense understory. The understory is thickest in the upper cells, and dominated by alder, willow and birch. The canopy in the upper reach is moderately sparse with cottonwood and spruce, and is thicker in the lower reach with spruce and Ponderosa pine.

MUSK 22-08
Description of human impacts and their severity:
The stream in this reach has been moved from its natural channel to accommodate the adjacent hay pasture. Evidence of the excavated channel exists along river left. Some debris was observed within the stream, including lumber and bricks. A road runs perpendicular to the channel downstream of the reach, which may be restricting movement of groundwater and creating seeps

with the stream channel. Several seeps or irrigation returns were observed in the lower end of the reach.

Description of stream channel conditions:
This reach is a straight, man-made channel that presently resembles a C4 type channel, although its potential stream type is likely a meandering E4 type channel. Reach has poorly developed features, including very few riffles, long runs with some micro-pool habitat, significant fine substrate, low sinuosity, and very little spawning habitat. Shallow groundwater seepage was noted throughout the reach.

Description of streambank erosion conditions:
This site has numerous slowly eroding banks that are characterized by thick vegetation, fine substrate, and low NBS due to the straight channel. Some eroding banks occur where groundwater seepage is softening the streambank.

Description of riparian vegetation conditions:
Ground cover in this reach is very thick with intermixed grasses and sedges along the stream edge. No rushes were observed. Grass is over 3' tall in some places, but traditional understory is generally absent. No canopy exists within the reach, although tall willows were observed downstream of the reach and left of the river channel where the stream's historic channel likely resides.

3.3.11 North Fork Little Boulder River

NFLB 42-01
Description of human impacts and their severity:
A forest road parallels the stream closely on river left, and a short access road also parallels the stream on river right. Metal piping was found in the lower portions of the reach, and a non-functioning diversion structure or dam was found in the upper portion of the reach. Other signs of human activity were observed within this reach, including fire rings, concrete, lumber and fence posts. The reach is naturally confined by the steep valley type, but confinement is further exacerbated by the two neighboring roads.

Description of stream channel conditions:
The stream is a steep (4-10% slope), cascading, B4a type stream channel with numerous large boulders. The potential stream type is likely an A4, but entrenchment is presently more similar to a B type channel. Not many true riffles occur, and pools were often deep with poorly developed tails and minimal spawning gravel. Multiple split channels exist due to boulders and LWD. Fine material occurs in pools and slow water, but it is likely naturally derived from the local granitic geology.

Description of streambank erosion conditions:
This reach has eleven actively eroding streambanks that are generally associated with LWD or boulders that direct streamflow into the bank. Eroding banks are generally short and near vertical or overhanging. The boulder dominated system provides good surface protection, along with the abundant LWD and dense natural vegetation.

Description of riparian vegetation conditions:
Ground cover along this reach is mostly rock or bare ground due to the high amount of shading, although some grasses do occur. Understory is composed of a diverse variety of shrubs and deciduous trees. Overstory is predominantly spruce with some aspen and birch.

3.3.12 Nursery Creek

NURS 07-01
Description of human impacts and their severity:
A forest fire passed through this site approximately 5-10 years ago, and the reach now has many standing or fallen dead trees. Cattle trampling is also evident within this reach, along with signs of browse. Despite the human impacts, the stream channel appears relatively healthy with only moderate grazing impacts.

Description of stream channel conditions:
This reach is potentially a B4 type stream channel, although it currently resembles an E5b type channel with moderate entrenchment, low width/depth ratio, and sandy substrate. The reach has long riffles and short plunge pools created by wood. Numerous LWD exists throughout the channel, which seems to have an effect on channel form. Pool tails had marginal spawning gravels, but may be appropriate for the small fish that would occupy this size of stream.

Description of streambank erosion conditions:
This reach has seven slowly eroding streambanks that are generally associated with seeps, LWD, or cattle trampling, although eroding banks within this reach are generally quite short in length. Lush wetland vegetation stabilizes the banks throughout most of the reach.

Description of riparian vegetation conditions:
The ground cover on this side is predominantly dense sedges with few grasses or rushes. Thistle was also observed within the reach. Understory is mostly alder and scrub maple, although aspen and Ponderosa pine were observed outside the riparian corridor. The canopy is lacking through most of the reach due to previous fire, although a few tall Ponderosa pines do occur.

3.3.13 Uncle Sam Gulch

USGU 10-01
Description of human impacts and their severity:
Human impacts are abundant in this reach, including evidence of past grazing, riparian logging, an old road bed, wood structures, and campfire rings. LWD appears to be intentionally fallen into the stream channel, possible to divert the stream.

Description of stream channel conditions:
This reach currently resembles a C4b type channel, although its potential stream type is likely B4. The stream channel is dominated by a series of LWD controlled step pools, some of which may be natural, but others that appear to be intentionally located. Channel pattern is slightly

sinuous with few true riffles. Most of the stream is pool/run type features with a high percentage of fines. The stream is braided in the upper portion of the reach, and there is evidence of a historic stream channel on river right. Substrate is highly embedded throughout the reach.

Description of streambank erosion conditions:
This reach has eight slowly eroding streambanks that are bound by clay substrate and dense root mass from mature coniferous trees. Eroding banks generally occur in isolated sections at knick points from LWD.

Description of riparian vegetation conditions:
Ground cover in this reach is mostly thick duff with a few bunch grasses and sedges. Understory is composed of small willow with some birch and coniferous trees. Canopy consists of lodgepole and spruce with some beetled-killed trees present.

3.4 Sampling Parameter Summaries by Individual Reach

The following **Figures 3-13** to **3-21** display statistical boxplots of stream channel and riparian zone parameters that were measured in each of the monitored sites. Individual reaches are also grouped by reach type and displayed below the reach names on each boxplot.

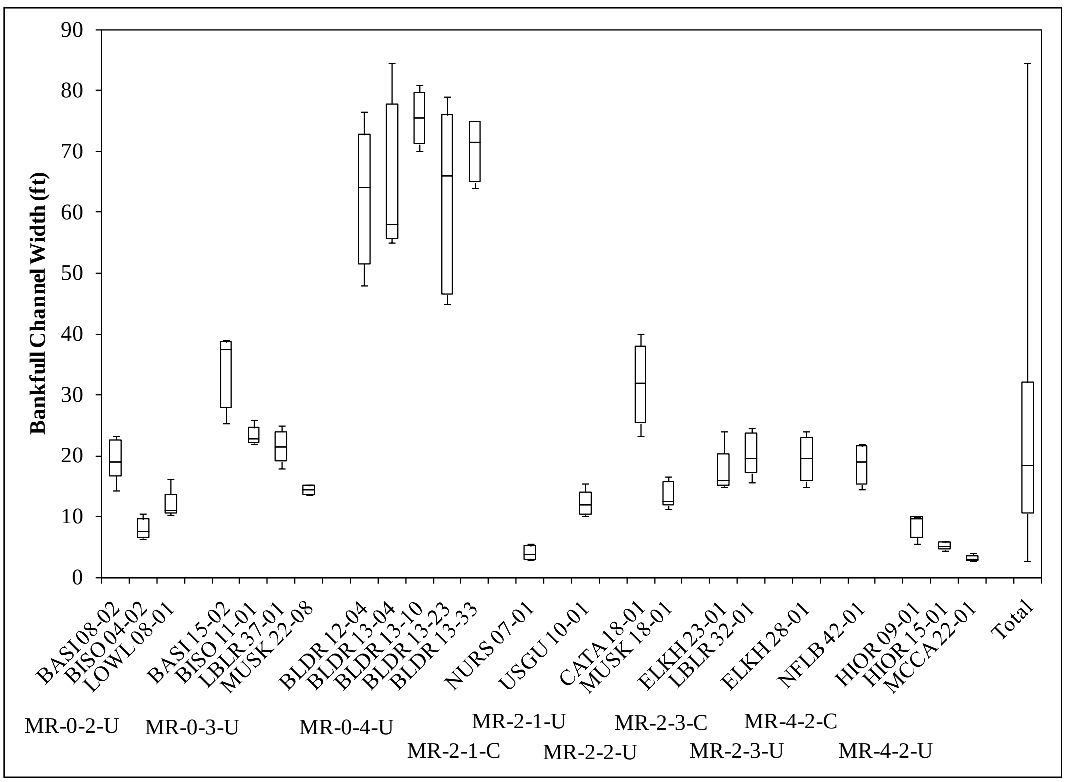

Figure 3-13. Bankfull channel width by reach.

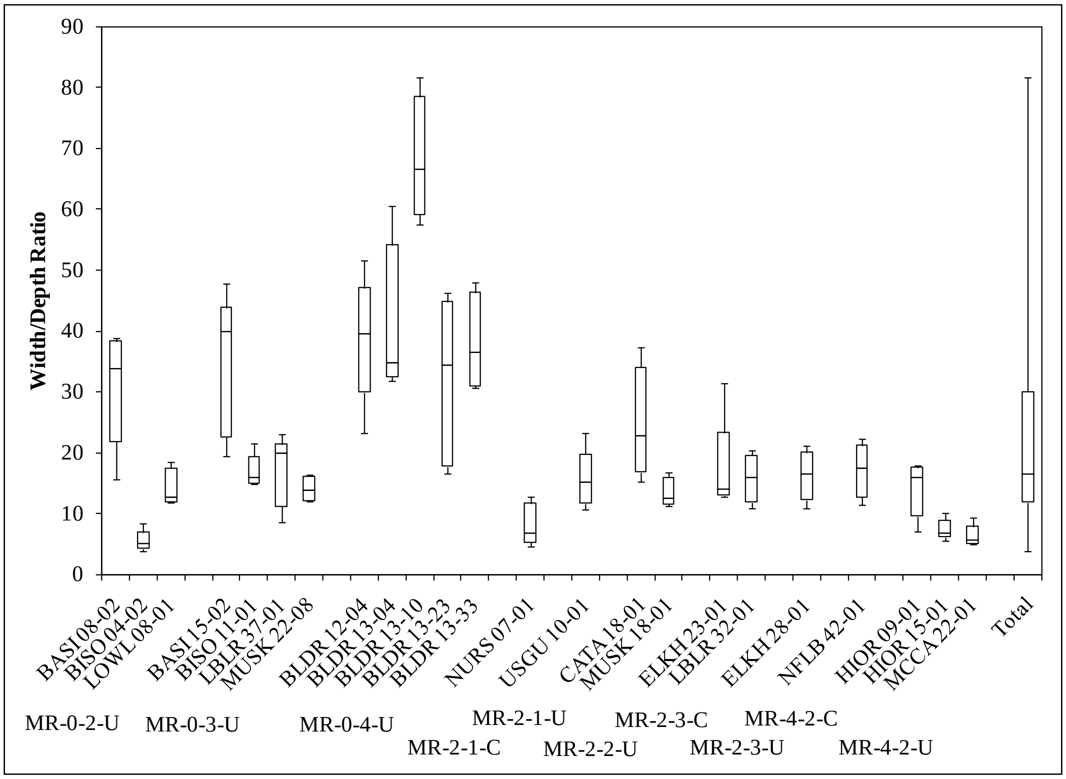

Figure 3-14. Width/depth ratio by reach.

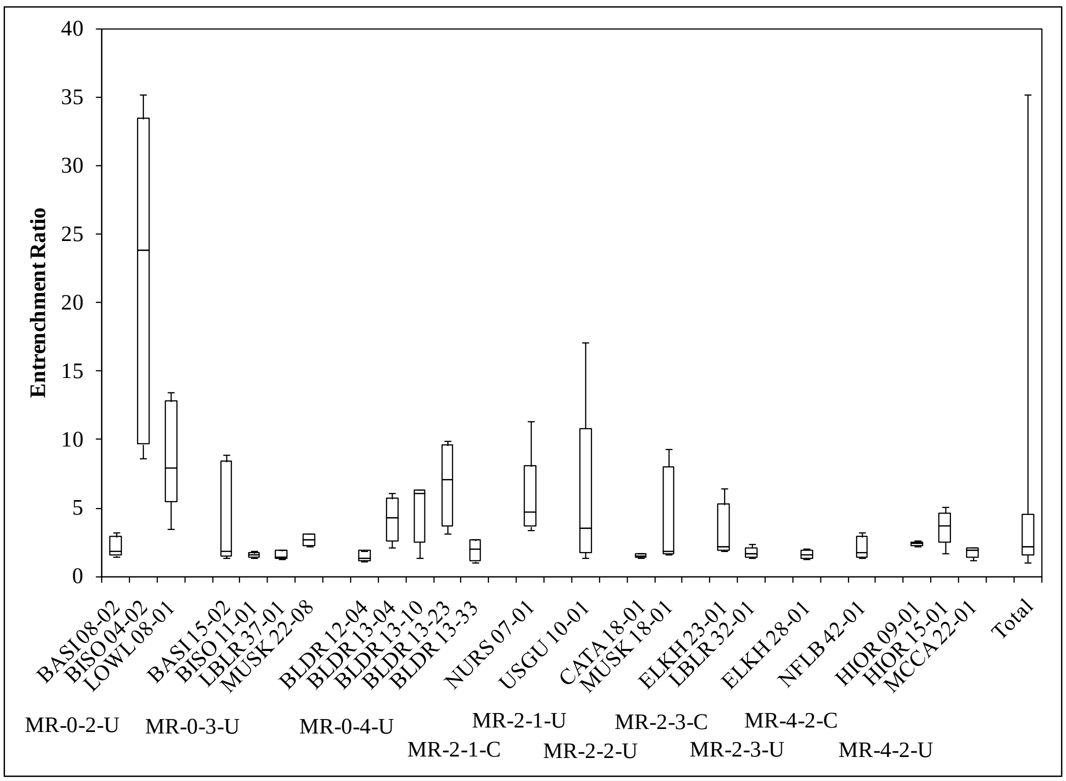

Figure 3-15. Entrenchment ratio by reach.

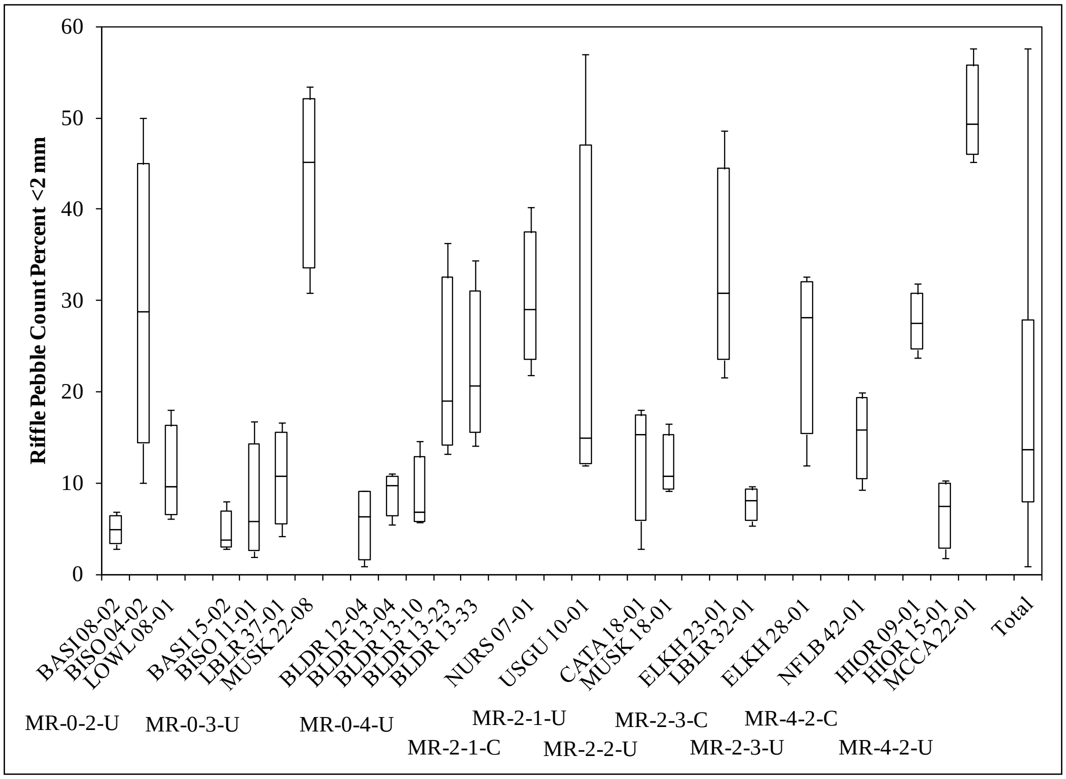

Figure 3-16. Riffle pebble count (% <2 mm) by reach.

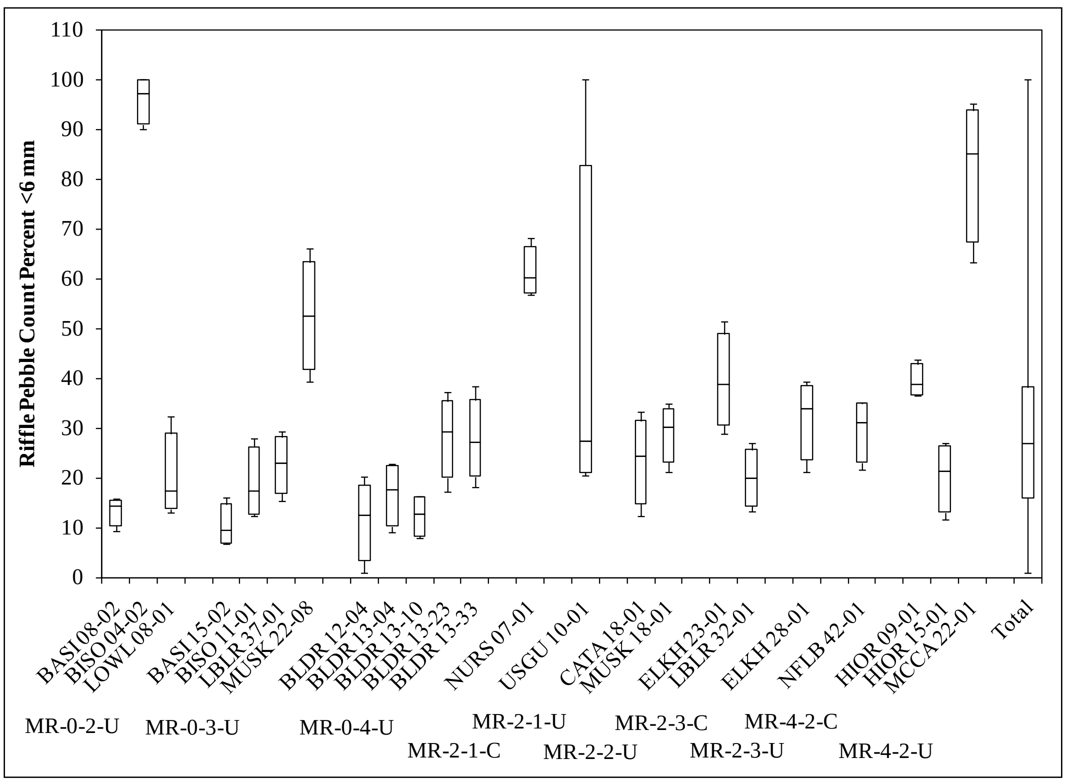

Figure 3-17. Riffle pebble count (% <6 mm) by reach.

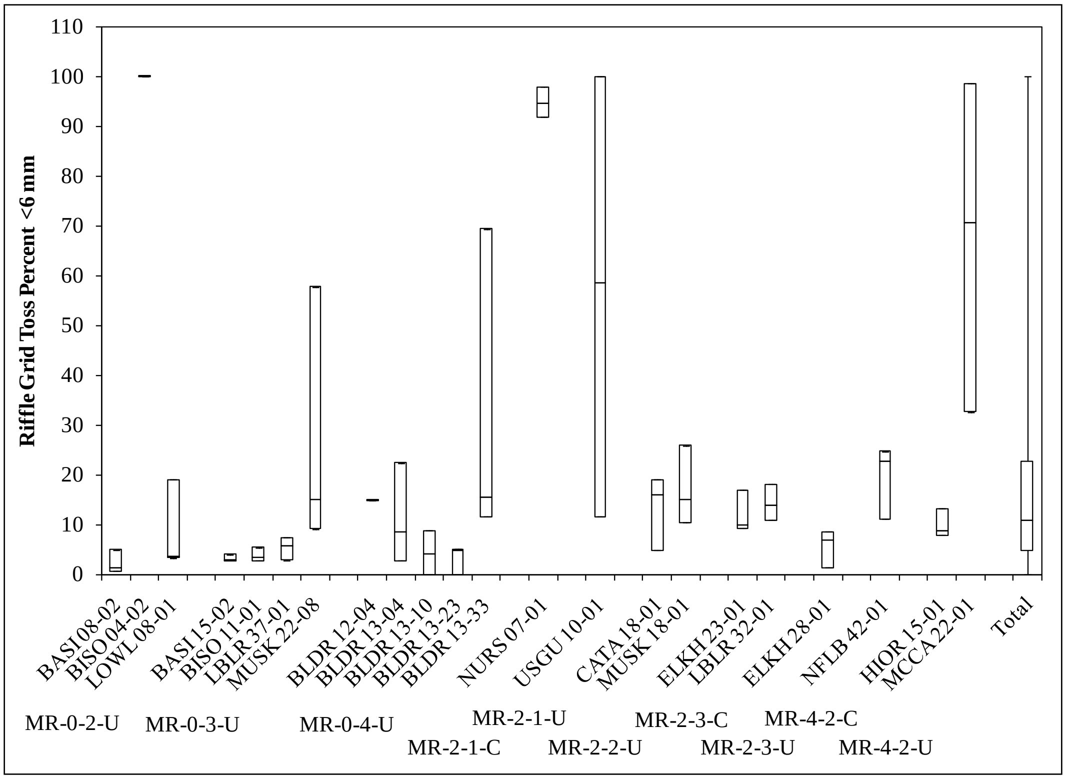

Figure 3-18. Riffle grid toss (% <6 mm) by reach.

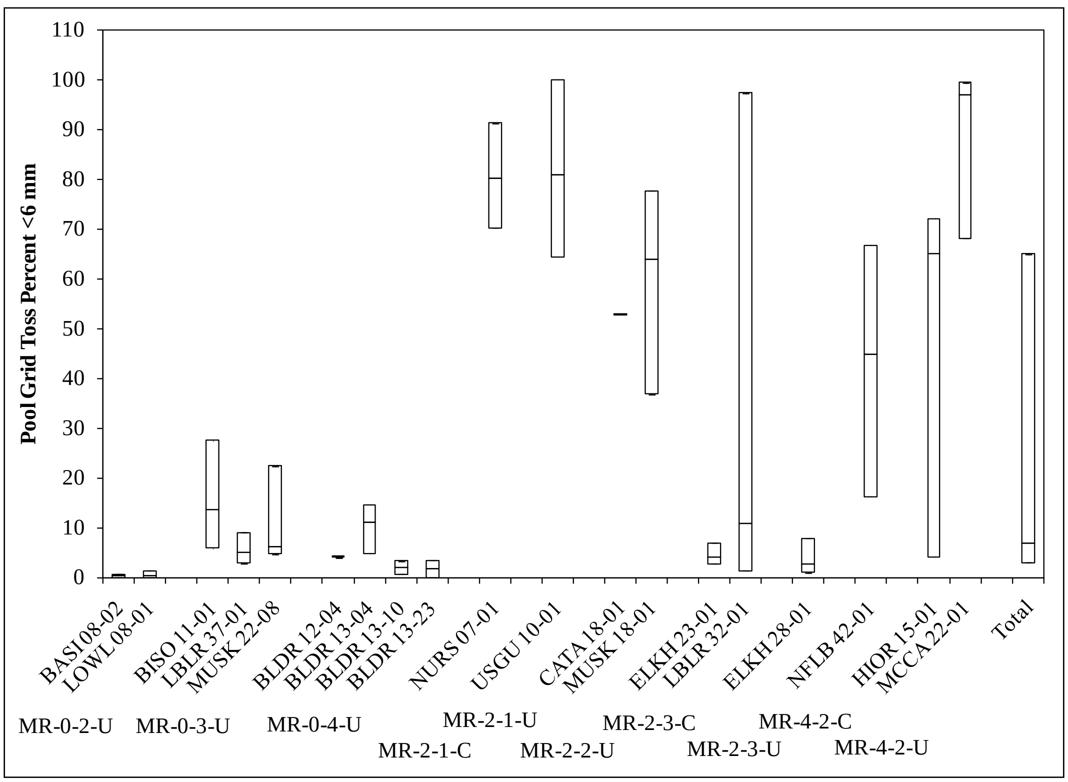

Figure 3-19. Pool grid toss (% <6 mm) by reach.

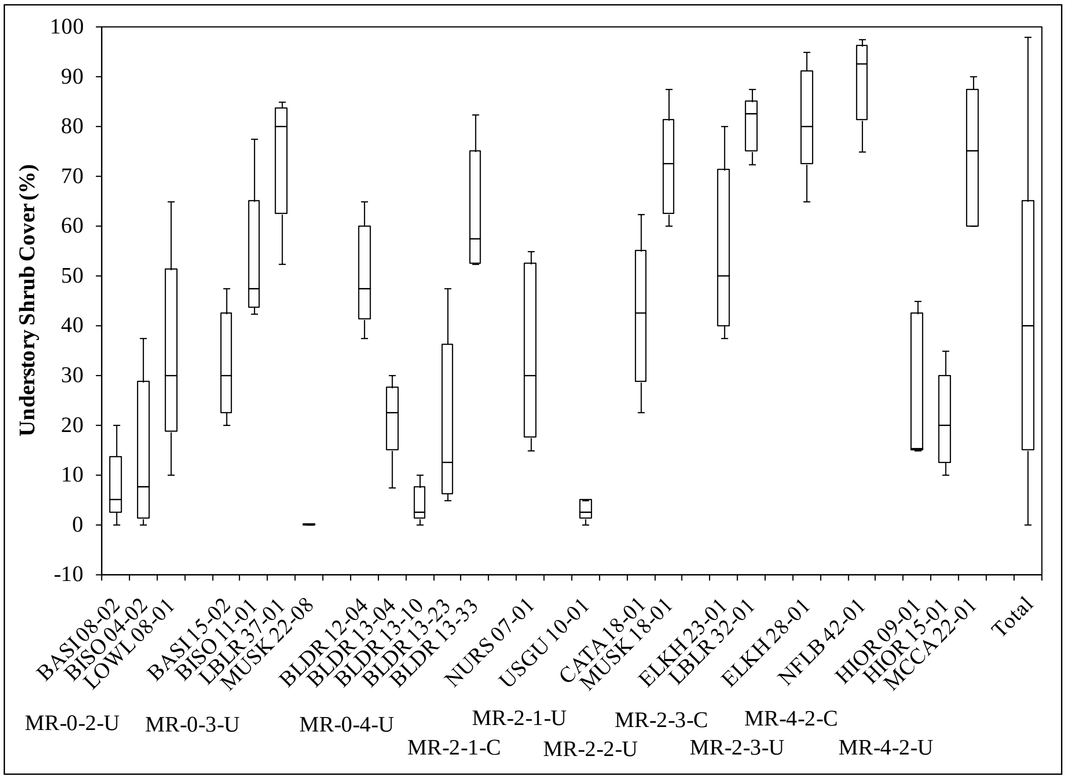

Figure 3-20. Greenline understory shrub cover (%) by reach.

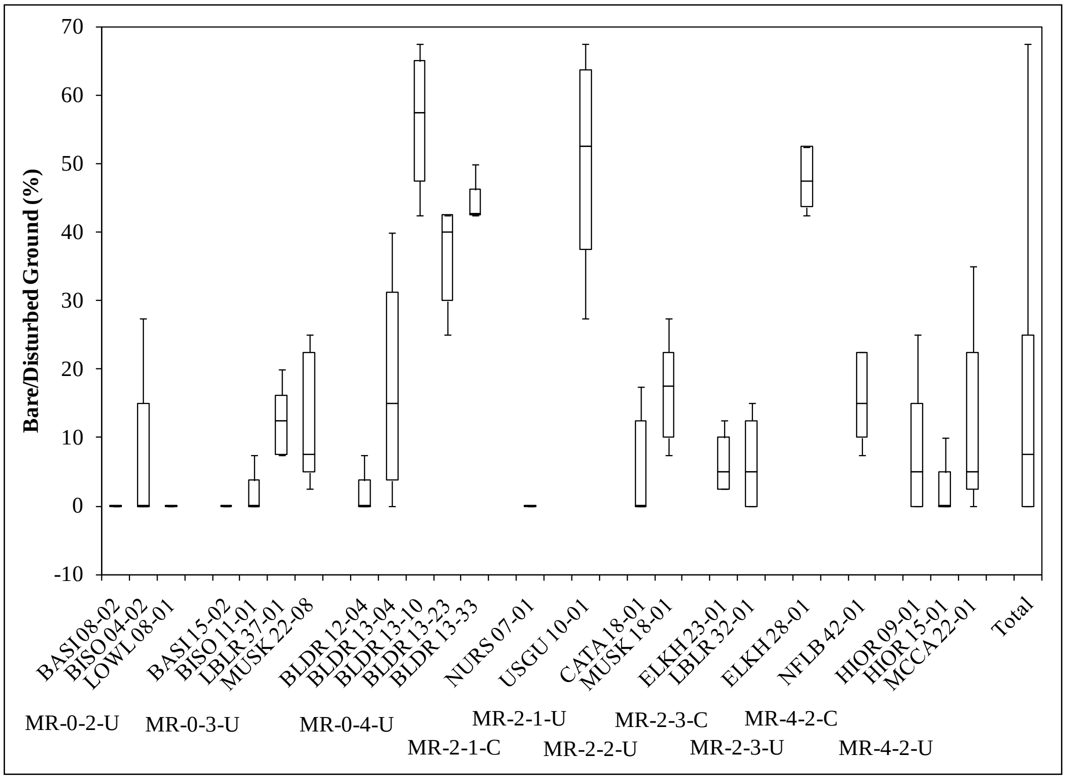

Figure 3-21. Greenline bare/disturbed ground (%) by reach.

4.0 Streambank Erosion Source Assessment

For each monitoring reach assessed during the study, measurements were collected to calculate the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) in accordance with guidelines provided in *Watershed Assessment of River Stability and Sediment Supply* (Rosgen 2006). These measurements were used in conjunction with streambank length and erosion source notes to determine sediment loads per 1,000 feet within each surveyed reach.

For sites within the Boulder-Elkhorn TPA, eroding banks were identified as "actively eroding" or "slowly eroding" based on conditions observed in the field. Actively eroding banks typically show evidence of recent erosion, such as slumping banks, exposed soil, or trampling by animals. Slowly eroding banks show evidence of chronic erosion, but often have some form of surface protection, such as cobble or vegetation. The designation of "active" versus "slow" is independent of the BEHI or NBS determinations, so sediment loads from actively eroding banks may not necessarily be higher than loads from slowly eroding banks. The banks selected for evaluation provide a representative sample of conditions throughout the reach, and banks which are similar to the evaluated banks are measured and recorded as "additional banks". At each eroding bank, photos were taken from locations perpendicular and upstream/downstream of the streambank. Photos were labeled according to the streambank site and position of the photo.

4.1 Field Measurements and Loading Calculations

4.1.1 Field Measurements

Within each sampled reach, eroding streambanks were identified by the field team and supporting measurements were recorded for the following metrics:

- Bank condition (includes actively eroding or slowly eroding/undercut/vegetated banks)
- Bank height
- Bankfull height
- Root depth
- Root density
- Bank angle
- Surface protection
- Material adjustments
- Bankfull mean depth
- Near bank maximum depth
- Stationing
- Mean height
- Bank composition (size classes)
- Hoof shear presence
- Sources of streambank instability (%): transportation, grazing, cropland, irrigation, natural, urban, railroad

4.1.2 Determination of BEHI Scores

To determine the BEHI score for each eroding bank, the following parameters are used:

- Bank height/bankfull height
- Root depth/bank height
- Weighted root density (root density * root depth/bank height)
- Bank angle
- Surface protection

These five bank erosion parameters are used to determine a numerical BEHI index score that ranks erosion potential from very low to extreme based on relationships provided by Rosgen (2006) (**Table 4-1**).

Table 4-1. BEHI score and rating system for individual parameters.

Parameter		Very Low	Low	Moderate	High	Very High	Extreme
Bank Height Ratio	Value	1.0 – 1.1	1.11 – 1.19	1.2 – 1.5	1.6 – 2.0	2.1 – 2.8	> 2.8
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Root Depth Ratio	Value	1.0 – 0.9	0.89 – 0.5	0.49 – 0.3	0.29 – 0.15	0.14 – 0.05	<0.05
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Weighted Root Density	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 5	<5
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Bank Angle	Value	0 – 20	21 – 60	61 – 80	81 – 90	91 – 119	>119
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Surface Protection	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 10	<10
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10

After obtaining the BEHI index score for each individual parameter, the index scores are summed to produce a total BEHI score. Bank material factors are then considered, and total BEHI scores may be adjusted up or down. Banks comprised of bedrock, boulders, or cobble have very low erosion potential, and total BEHI scores for banks composed of these materials may be adjusted down by up to 10 points. Banks composed of cobble and/or gravel with a high fraction of sand have increased erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points depending on the amount of sand present and whether the sandy material is exposed to erosion. Stratified banks containing layers of unstable material also have greater erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points if stratified banks are present. After all material adjustments are made to the total BEHI score, the erosion potential is ranked from very low to extreme based on the scale provided below (**Table 4-2**). Photos of example streambanks with each BEHI rating are provided in **Attachment D**.

Table 4-2. Total BEHI score and rating system.

Rating	Very Low	Low	Moderate	High	Very High	Extreme
Score	<10	10 - 19.9	20 - 29.9	30 - 39.9	40 - 45	>45

4.1.3 Near Bank Stress (NBS) Determination

To calculate Near Bank Stress (NBS) for each eroding bank, the following relationship is used:

NBS = Near Bank Maximum Bankfull Depth (ft) / Bankfull Mean Depth (ft)

As with the BEHI scores, the resulting NBS values correspond to a categorical rating that ranks the erosion potential from very low to extreme (**Table 4-3)**. If appropriate measurements are not recorded for NBS determination, the NBS rating is estimated in the field or from photos using best professional judgment.

Table 4-3. Near bank stress (NBS) rating system.

NBS Value	Rating
< 1.0	very low
1.0 - 1.5	low
1.51 - 1.8	moderate
1.81 - 2.5	high
2.51 - 3.0	very high
> 3.0	extreme

4.1.4 Retreat Rate

Once respective BEHI and NBS ratings are found for each eroding bank, the ratings are used to derive the average retreat rate of each streambank based on empirical relationships derived from Yellowstone National Park by Rosgen (2006). The average retreat rates (ft/yr) based on BEHI and NBS ratings are provided below in **Table 4-4**.

Table 4-4. Streambank retreat rate (ft/yr) based on BEHI and NBS rating.

	Near Bank Stress					
BEHI	Very Low	Low	Moderate	High	Very High	Extreme
Very Low	0.002	0.004	0.009	0.021	0.05	0.12
Low	0.02	0.04	0.10	0.24	0.57	1.37
Moderate	0.10	0.17	0.28	0.47	0.79	1.33
High-Very High	0.37	0.53	0.76	1.09	1.57	2.26
Extreme	0.98	1.21	1.49	1.83	2.25	2.76

4.1.5 Sediment Loading Calculation

Once retreat rate is determined from the BEHI and NBS ratings, the dimensions of the eroding stream bank are used to find the total mass eroding from each bank per year. The total mass eroded from each streambank is calculated using the following equation:

*mass eroded (tons/yr) = bank length (ft) * bank height (ft) * retreat rate (ft/yr) * material density (tons/ft^3)*

The sediment load from each streambank is filtered into two bank erosion type categories including actively eroding banks or slowly eroding/undercut/vegetated banks. The total loads for each bank erosion type and for the entire reach are then calculated in tons of sediment per year per 1000 feet of reach.

4.2 Sediment Loading Results by Assessment Reach

The following sections provide sediment loading results for each sampled stream. One data table is included for each stream which includes data from each reach summarizing bank erosion and sediment loading for each bank erosion type (active or slowly eroding) and for the total reach. Information provided includes the number of eroding banks identified, the mean BEHI rating for each erosion type, the percent of reach that has eroding streambanks, the sediment load per 1000 feet, and the percent contribution from each erosion source present. The percentage of reach with eroding streambanks was calculated by summing the total footage of eroding banks (active and slow) and dividing the total by the total bank footage in the reach, including both right and left banks (i.e., a 1000’ reach has 2000’ of bank). Identified sources of streambank erosion within the Boulder-Elkhorn TPA included transportation, riparian grazing, cropland, mining, silviculture, irrigation (or changes in stream energy), natural sources, or those classified as “other”; however, each erosion source may not be present at all sample sites.

4.2.1 Sediment Loading Results for Basin Creek

4.2.1.1 BASI 08-02

Only three eroding banks were identified in this reach, including two actively eroding banks and one slowly eroding bank. Banks are typically armored with cobbles and large gravel. The stream channel is overwidened through this reach. Typical eroding streambank conditions are depicted for this reach in **Figure 4-1** and sediment loading results are provided in **Table 4-5**.

Figure 4-1. Typical eroding streambank conditions in Basin Creek Reach 08-02.

4.2.1.2 BASI 15-02

This reach had seven eroding banks, including four actively eroding and three slowly eroding. Actively eroding banks were typically associated with meander bends that direct flow into the bank and have limited stabilizing vegetation, possibly as a result of prior logging activity. Slowly eroding banks were accompanied by dense mature vegetation on the banks, including established willow and fir trees. Typical eroding streambank conditions are depicted in **Figure 4-2** and sediment loading results are provided in **Table 4-5**.

Figure 4-2. Typical eroding streambank conditions in Basin Creek Reach 15-02.

Table 4-5. Sediment loading results for Basin Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Mining	Silvi-culture	Natural	Other
BASI 08-02	Slow	1	moderate	0.8	0.2	10.0	10.0	0.0	80.0	0.0
	Active	2	high	3.3	7.4	30.0	50.0	0.0	20.0	0.0
	Total	3	high	4.1	7.6	29.6	49.1	0.0	21.3	0.0
BASI 15-02	Slow	3	moderate	2.2	1.1	3.1	30.0	16.9	50.0	0.0
	Active	4	high	7.8	21.9	0.0	30.0	20.0	20.0	30.0
	Total	7	high	10.0	23.0	0.2	30.0	19.8	21.5	28.5

4.2.2 Sediment Loading Results for Bison Creek

4.2.2.1 BISO 04-02

This reach has four actively eroding banks and thirteen slowly eroding banks. Actively eroding banks were generally low angled with no surface protection and exposed sandy substrate. Some areas had hummocking from being trampled by cattle. Slowly eroding banks were typically overhanging but well vegetated. Typical eroding streambank conditions are depicted for this reach in **Figure 4-3** and sediment loading results are provided in **Table 4-6**.

Figure 4-3. Typical eroding streambank conditions in Bison Creek Reach 04-02.

4.2.2.2 BISO 11-01

This reach had one slowly eroding bank and seven actively eroding banks. Actively eroding banks are typically tall and located on meander bends with little stabilizing vegetation and large cobble substrate armoring the toe. Slowly eroding banks are overhanging but bound by roots of mature vegetation. Typical eroding streambank conditions are depicted for this reach in **Figure 4-4** and sediment loading results are provided in **Table 4-6**.

Figure 4-4. Typical eroding streambank conditions in Bison Creek Reach 11-01.

Table 4-6. Sediment loading results for Bison Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Transpor-tation	Riparian Grazing	Natural
BISO 04-02	Slow	13	high	9.5	8.7	0.0	50.0	50.0
	Active	4	high	2.4	1.6	0.0	72.4	27.6
	Total	17	high	11.9	10.3	0.0	53.6	46.4
BISO 11-01	Slow	1	moderate	2.6	1.5	80.0	0.0	20.0
	Active	7	high	10.4	19.1	80.0	0.0	20.0
	Total	8	high	13.0	20.6	80.0	0.0	20.0

4.2.3 Sediment Loading Results for Boulder River

4.2.3.1 BLDR 12-04

This reach has only two slowly eroding banks, mainly because the channel is armored with rip-rap and large cobbles to protect the neighboring roads. One eroding bank occurs where the stream hits an area of road fill, and the other contains hard packed clay and is bound by mature alders and rushes. Typical eroding streambank conditions are depicted for this reach in **Figure 4-5** and sediment loading results are provided in **Table 4-7**. The left photo shows an example of a slowly eroding bank within this reach, and the right photo shows an example of the rip-rap stabilization within this reach.

Figure 4-5. Typical eroding streambank conditions in Boulder River Reach 12-04.

4.2.3.2 BLDR 13-04

This reach has twelve eroding banks, including ten active and two slowly eroding. The actively eroding banks are typically long, near vertical banks, generally with a clayey composition but sometimes with poorly placed rip-rap material that has slumped into the stream channel. Slowly eroding banks were low angled and had some vegetative cover. Typical eroding streambank conditions are depicted for this reach in **Figure 4-6** and sediment loading results are provided in **Table 4-7**.

Figure 4-6. Typical eroding streambank conditions in Boulder River Reach 13-04.

4.2.3.3 BLDR 13-10

Reach BLDR 13-10 has thirteen actively eroding banks that typically occur along outside meander bends. Eroding banks are near vertical and have either a silty/clayey substrate that is slumping into the stream channel, or they have a cobble layer near the toe that provides some armoring against erosion. Typical eroding streambank conditions are depicted for this reach in **Figure 4-7** and sediment loading results are provided in **Table 4-7**.

Figure 4-7. Typical eroding streambank conditions in Boulder River Reach 13-10.

4.2.3.4 BLDR 13-23

This reach has ten eroding banks, nine of which were actively eroding. Eroding banks are generally near vertical slumping banks with silty/clayey substrate, and one bank is very tall

(14.5’). One slowly eroding bank was identified, which had substantial willow growth that helps stabilize the bank. This reach had the highest loading rate of all sampled reaches. Typical eroding streambank conditions are depicted for this reach in **Figure 4-8** and sediment loading results are provided in **Table 4-7**.

Figure 4-8. Typical eroding streambank conditions in Boulder River Reach 13-23.

4.2.3.5 BLDR 13-33

This reach has twelve actively eroding banks and three slowly eroding banks. Actively eroding banks were typically slumping banks that occur on outside meander bends with little surface protection. One tall (11’) actively eroding bank occurs where the stream closely parallels the road. The slowly eroding banks occur on straight sections where vegetation is established and root density is higher. Typical eroding streambank conditions are depicted for this reach in **Figure 4-9** and sediment loading results are provided in **Table 4-7**.

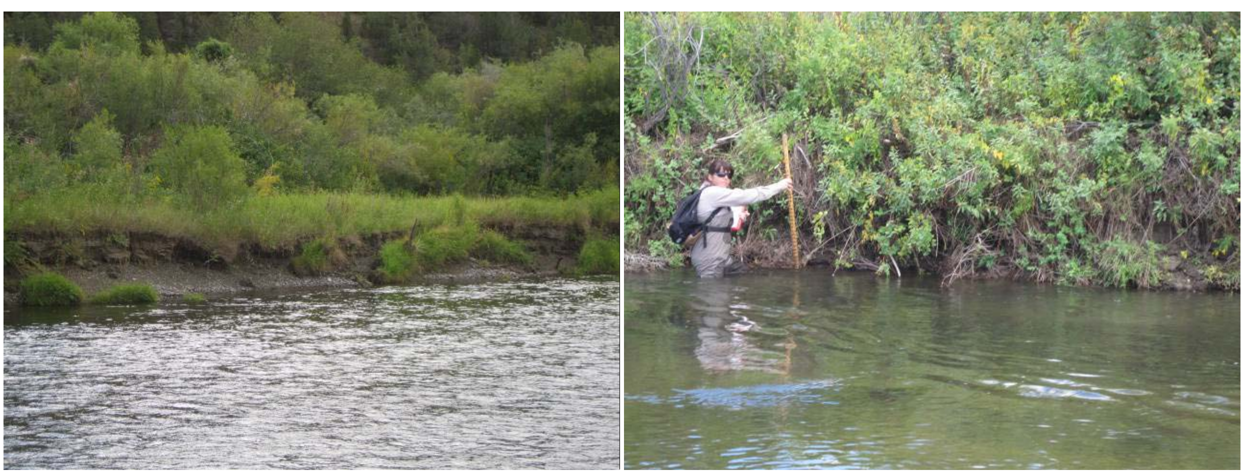

Figure 4-9. Typical eroding streambank conditions in Boulder River Reach 13-33.

Table 4-7. Sediment loading results for Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)					
						Transp-ortation	Riparian Grazing	Crop-land	Irrig-ation	Natural	Other
BLDR 12-04	Slow	2	mod.	0.6	0.3	100.0	0.0	0.0	0.0	0.0	0.0
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	2	mod.	0.6	0.3	100.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-04	Slow	2	mod.	1.0	0.6	0.0	7.4	92.6	0.0	0.0	0.0
	Active	10	high	15.8	36.5	0.0	19.9	79.0	1.2	0.0	0.0
	Total	12	mod.	16.8	37.0	0.0	19.7	79.2	1.2	0.0	0.0
BLDR 13-10	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Active	13	mod.	41.3	27.9	0.0	80.0	0.0	20.0	0.0	0.0
	Total	13	mod.	41.3	27.9	0.0	80.0	0.0	20.0	0.0	0.0
BLDR 13-23	Slow	1	mod.	1.6	0.8	0.0	30.0	30.0	20.0	20.0	0.0
	Active	9	high	30.8	78.8	0.0	30.0	30.0	20.0	20.0	0.0
	Total	10	high	32.4	79.6	0.0	30.0	30.0	20.0	20.0	0.0
BLDR 13-33	Slow	3	mod.	6.2	6.7	0.0	0.0	0.0	30.0	50.0	20.0
	Active	12	high	32.5	65.3	9.4	0.0	0.0	28.1	46.2	16.2
	Total	15	high	38.7	72.0	8.5	0.0	0.0	28.3	46.6	16.6

4.2.4 Sediment Loading Results for Cataract Creek

4.2.4.1 CATA 18-01

Only one eroding streambank was identified in this reach, which was a slowly eroding undercut bank. Most banks in this high gradient reach are composed of hard packed clay and are armored with binding root masses and overgrown moss. Typical eroding streambank conditions are depicted in **Figure 4-10** and sediment loading results are provided in **Table 4-8**.

Figure 4-10. Typical eroding streambank conditions in Cataract Creek Reach 18-01.

Table 4-8. Sediment loading results for Cataract Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)
						Mining
CATA 18-01	Slow	1	moderate	0.9	0.6	100.0
	Active	0		0.0	0.0	0.0
	Total	1	moderate	0.9	0.6	100.0

4.2.5 Sediment Loading Results for Elkhorn Creek

4.2.5.1 ELKH 23-01

Seven slowly eroding banks were identified in reach ELKH 23-01. Eroding banks were typically short in length, well vegetated, and occur at knick points coming from boulders, LWD, or tight stream meanders. In several places, the erosion is influenced by reduction of vegetation and bank trampling from hoof shear. Typical eroding streambank conditions are depicted in **Figure 4-11** and sediment loading results are provided in **Table 4-9**.

Figure 4-11. Typical eroding streambank conditions in Elkhorn Creek Reach 23-01.

4.2.5.2 ELKH 28-01

This reach had thirteen actively eroding banks with three primary bank types. Eroding banks included tall, steep banks that are partially protected by dead woody vegetation, low angle banks at stream crossings that are trampled by cattle, and a few slumping vegetated banks on outside meander bends. Typical eroding streambank conditions are depicted in **Figure 4-12** and sediment loading results are provided in **Table 4-9**.

Figure 4-12. Typical eroding streambank conditions in Elkhorn Creek Reach 28-01.

Table 4-9. Sediment loading results for Elkhorn Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Riparian Grazing	Irrigation	Natural	Other
ELKH 23-01	Slow	7	moderate	2.6	1.6	48.7	51.1	0.0	0.0	0.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	7	moderate	2.6	1.6	48.7	51.1	0.0	0.0	0.3
ELKH 28-01	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Active	13	moderate	8.7	8.6	0.0	70.9	5.9	9.7	13.4
	Total	13	moderate	8.7	8.6	0.0	70.9	5.9	9.7	13.4

4.2.6 Sediment Loading Results for High Ore Creek

4.2.6.1 HIOR 09-01

Only one eroding streambank was identified in this reach, which is a tall, poorly vegetated bank where LWD directs stream flow into the bank. Banks are quite stable despite limited riparian vegetation, possibly because floodplain has been significantly flattened and few tall banks exist. Typical eroding streambank conditions are shown in **Figure 4-13** and sediment loading results are provided in **Table 4-10**.

Figure 4-13. Typical eroding streambank conditions in High Ore Creek Reach 09-01.

4.2.6.2 HIOR 15-01

This reach has six slowly eroding banks and one actively eroding bank. Slowly eroding banks are short, overhanging banks with good riparian vegetation. The actively eroding bank is taller with exposed soil, but bound by roots. Typical eroding streambank conditions are shown in **Figure 4-14** and sediment loading results are provided in **Table 4-10**.

Figure 4-14. Typical eroding streambank conditions in High Ore Creek Reach 15-01.

Table 4-10. Sediment loading results for High Ore Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)			
						Transpor-tation	Riparian Grazing	Natural	Other
HIOR 09-01	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0
	Active	1	high	0.6	1.3	20.0	60.0	0.0	20.0
	Total	1	high	0.6	1.3	20.0	60.0	0.0	20.0
HIOR 15-01	Slow	6	moderate	3.8	1.2	50.0	0.0	20.0	30.0
	Active	1	moderate	1.0	0.2	50.0	0.0	20.0	30.0
	Total	7	moderate	4.8	1.4	50.0	0.0	20.0	30.0

4.2.7 Sediment Loading Results for Little Boulder River

4.2.7.1 LBLR 32-01

This site has eleven slowly eroding banks that are typically near vertical with woody vegetation and a dense root mass that helps stabilize the banks. Undercut banks are not uncommon, especially in areas where stream is altered by large boulders or stabilized by mature coniferous trees. Typical eroding streambank conditions are depicted in **Figure 4-15** and sediment loading results are provided in **Table 4-11**.

Figure 4-15. Typical eroding streambank conditions in Little Boulder River Reach 32-01.

4.2.7.2 LBLR 37-01

This reach has ten eroding streambanks, including two actively eroding and eight slowly eroding. Slowly eroding banks are typically found on outside bends, but have significant surface protection from dead and living willows. One actively eroding bank occurs where the stream abuts a tall sandy terrace. Typical eroding streambank conditions are depicted in **Figure 4-16** and sediment loading results are provided in **Table 4-11**.

Figure 4-16. Typical eroding streambank conditions in Little Boulder River Reach 37-01.

Table 4-11. Sediment loading results for Little Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Riparian Grazing	Mining	Silvi-culture	Natural
LBLR 32-01	Slow	11	low	7.5	1.6	18.6	0.0	18.7	16.3	46.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	11	low	7.5	1.6	18.6	0.0	18.7	16.3	46.3
LBLR 37-01	Slow	8	moderate	7.9	16.1	80.0	9.1	0.0	0.0	10.9
	Active	2	high	2.2	9.4	79.4	1.3	0.0	0.0	19.4
	Total	10	moderate	10.0	25.5	79.7	6.2	0.0	0.0	14.0

4.2.8 Sediment Loading Results for Lowland Creek

4.2.8.1 LOWL 08-01

Fourteen slowly eroding streambanks were identified in this reach. Banks are typically well vegetated with sedges and grasses, but are often undercut and slumping into the stream channel on outside meander bends. Typical eroding streambank conditions are depicted in **Figure 4-17** and sediment loading results are provided in **Table 4-12**.

Figure 4-17. Typical eroding streambank conditions in Lowland Creek Reach 08-01.

Table 4-12. Sediment loading results for Lowland Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Natural	Other
LOWL 08-01	Slow	14	high	8.4	7.9	90.0	10.0
	Active	0		0.0	0.0	0.0	0.0
	Total	14	high	8.4	7.9	90.0	10.0

4.2.9 Sediment Loading Results for McCarty Creek

4.2.9.1 MCCA 22-01

This reach has eleven slowly eroding banks and seven actively eroding banks. Slowly eroding banks are typically near vertical or undercut with stabilizing vegetation. Actively eroding banks occur where woody vegetation has died, or on tight meander bends. Erosion appears partially due to the severe downcutting observed in this reach. Typical eroding streambank conditions are depicted in **Figure 4-18** and sediment loading results are provided in **Table 4-13**.

Figure 4-18. Typical eroding streambank conditions in McCarty Creek Reach 22-01.

Table 4-13. Sediment loading results for McCarty Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Riparian Grazing	Silvi-culture	Natural
MCCA 22-01	Slow	11	high	12.0	14.0	66.9	21.0	12.2
	Active	7	high	5.0	4.6	68.8	12.6	18.6
	Total	18	high	17.0	18.6	67.4	18.9	13.8

4.2.10 Sediment Loading Results for Muskrat Creek

4.2.10.1 MUSK 18-01-02

This reach has six slowly eroding banks and seven actively eroding banks. Slowly eroding banks are generally well vegetated undercut banks with natural sources of erosion. Actively eroding banks are generally found on outside meander bends and are influenced by LWD. One large mass wasting site occurs within this reach that is presently separated from the main channel. However, during high flow the stream will likely reach this bank and continue erosion unless flow is directed elsewhere. Typical eroding streambank conditions are depicted in **Figure 4-19** and sediment loading results are provided in **Table 4-14**. The left photo shows an example of slowly eroding conditions found within this reach and the right photos shows the mass wasting site that is presently separated from the main channel.

Figure 4-19. Typical eroding streambank conditions in Muskrat Creek Reach 18-01-02.

4.2.10.2 MUSK 22-08

This site has numerous slowly eroding banks that are generally well vegetated with low NBS due to the straight channel. Some eroding banks are associated with seeps that occur from irrigation recharge. Typical eroding streambank conditions are depicted in **Figure 4-20** and sediment loading results are provided in **Table 4-14**.

Figure 4-20. Typical eroding streambank conditions in Muskrat Creek Reach 22-08.

Table 4-14. Sediment loading results for Muskrat Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Riparian Grazing	Irrigation	Natural
MUSK 18-01-02	Slow	6	low	3.1	0.6	67.8	0.0	32.2
	Active	7	moderate	2.8	1.8	63.5	0.0	36.5
	Total	13	moderate	5.9	2.3	64.6	0.0	35.4
MUSK 22-08	Slow	30	moderate	17.7	6.1	0.0	100.0	0.0
	Active	0		0.0	0.0	0.0	0.0	0.0
	Total	30	moderate	17.7	6.1	0.0	100.0	0.0

4.2.11 Sediment Loading Results for North Fork Little Boulder River

4.2.11.1 NFLB 42-01

This reach has eleven actively eroding streambanks that are generally associated with LWD or boulders that direct streamflow into the bank. Eroding banks are generally short and near vertical or overhanging. Typical eroding streambank conditions are depicted in **Figure 4-21** and sediment loading results are provided in **Table 4-15**.

Figure 4-21. Typical eroding streambank conditions in North Fork Little Boulder 42-01.

Table 4-15. Sediment loading results for North Fork Little Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Transpor-tation	Natural
NFLB 42-01	Slow	0		0.0	0.0	0.0	0.0
	Active	11	moderate	4.5	2.8	26.8	73.2
	Total	11	moderate	4.5	2.8	26.8	73.2

4.2.12 Sediment Loading Results for Nursery Creek

4.2.12.1 NURS 07-01

This reach has seven slowly eroding streambanks that are generally associated with seeps, LWD, or cattle trampling. Lush wetland vegetation stabilizes the banks throughout most of the reach. Typical eroding streambank conditions are depicted in **Figure 4-22** and sediment loading results are provided in **Table 4-16**.

Figure 4-22. Typical eroding streambank conditions in Nursery Creek Reach 07-01.

Table 4-16. Sediment loading results for Nursery Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Riparian Grazing	Natural
NURS 07-01	Slow	7	moderate	2.4	0.4	30.1	69.9
	Active	0		0.0	0.0	0.0	0.0
	Total	7	moderate	2.4	0.4	30.1	69.9

4.2.13 Sediment Loading Results for Uncle Sam Gulch

4.2.13.1 USGU 10-01

This reach has eight slowly eroding streambanks that are bound by clay substrate and dense root mass from mature coniferous trees. Eroding banks generally occur in isolated sections at knick points from LWD. Typical eroding streambank conditions are depicted in **Figure 4-23** and sediment loading results are provided in **Table 4-17**.

Figure 4-23. Typical eroding streambank conditions in Uncle Sam Gulch Reach 10-01.

Table 4-17. Sediment loading results for Uncle Sam Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)			
						Transpor-tation	Mining	Natural	Other
USGU 10-01	Slow	8	moderate	3.9	1.7	30.0	30.0	17.7	22.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0
	Total	8	moderate	3.9	1.7	30.0	30.0	17.7	22.3

4.3 Sediment Loading Results by Reach Type

The following sections provide sediment loading results organized by reach type. Data provided includes sediment load per 1000 feet for each bank type (active, slow and total) and the dominant influence (anthropogenic or natural). If <75% of the bank erosion-influenced load was attributed to natural sources, the load is considered to be anthropogenically influenced.

4.3.1 Sediment Loading Results for Reach Type MR-0-2-U

Three sites were sampled of reach type MR-0-2-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 2nd order streams within unconfined valleys. Loading results are provided below in **Table 4-18**.

Table 4-18. Sediment loading results for reach type MR-0-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
BASI 08-02	moderate	high	high	0.8	3.3	4.1	0.2	7.4	7.6
BISO 04-02	high	high	high	9.5	2.4	11.9	8.7	1.6	10.3
LOWL 08-01	high		high	8.4	0.0	8.4	7.9	0.0	7.9
Reach Type Average	**moderate**	**high**	**high**	**6.2**	**1.9**	**8.1**	**5.6**	**3.0**	**8.6**

4.3.2 Sediment Loading Results for Reach Type MR-0-3-U

Four reaches were sampled of reach type MR-0-3-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 3rd order streams within unconfined valleys. Loading results are provided below in **Table 4-19**.

Table 4-19. Sediment loading results for reach type MR-0-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
BASI 15-02	moderate	high	high	2.2	7.8	10.0	1.1	21.9	23.0
BISO 11-01	moderate	high	high	2.6	10.4	13.0	1.5	19.1	20.6
LBLR 37-01	moderate	high	moderate	7.9	2.2	10.0	16.1	9.4	25.5
MUSK 22-08	moderate		moderate	17.7	0.0	17.7	6.1	0.0	6.1
Reach Type Average	**moderate**	**high**	**high**	**7.6**	**5.1**	**12.7**	**6.2**	**12.6**	**18.8**

4.3.3 Sediment Loading Results for Reach Type MR-0-4-U

Five reaches were sampled of reach type MR-0-4-U, all on the Boulder River. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 4th order streams within unconfined valley types. Loading results are provided below in **Table 4-20**.

Table 4-20. Sediment loading results for reach type MR-0-4-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
BLDR 12-04	moderate		moderate	0.6	0.0	0.6	0.3	0.0	0.3
BLDR 13-04	moderate	high	moderate	1.0	15.8	16.8	0.6	36.5	37.0
BLDR 13-10		moderate	moderate	0.0	41.3	41.3	0.0	27.9	27.9
BLDR 13-23	moderate	high	high	1.6	30.8	32.4	0.8	78.8	79.6
BLDR 13-33	moderate	high	high	6.2	32.5	38.7	6.7	65.3	72.0
Reach Type Average	**moderate**	**high**	**moderate**	**1.9**	**24.1**	**26.0**	**1.7**	**41.7**	**43.4**

4.3.4 Sediment Loading Results for Reach Type MR-2-1-C

One site was sampled of reach type MR-2-1-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 1st order streams within confined valleys. Loading results are provided below in **Table 4-21**.

Table 4-21. Sediment loading results for reach type MR-2-1-C.									
Reach ID	**Mean BEHI Rating**			**Percent of Reach with Eroding Bank**			**Total Sediment Load per 1000 Feet (Tons/Year)**		
	Slow	**Active**	**Total**	**Slow**	**Active**	**Total**	**Slow**	**Active**	**Total**
NURS 07-01	moderate		moderate	2.4	0.0	2.4	0.4	0.0	0.4
Reach Type Average	**moderate**		**moderate**	**2.4**	**0.0**	**2.4**	**0.4**	**0.0**	**0.4**

4.3.5 Sediment Loading Results for Reach Type MR-2-1-U

One site was sampled of reach type MR-2-1-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 1st order streams within unconfined valley types. Loading results are provided below in **Table 4-22**.

Table 4-22. Sediment loading results for reach type MR-2-1-U.									
Reach ID	**Mean BEHI Rating**			**Percent of Reach with Eroding Bank**			**Total Sediment Load per 1000 Feet (Tons/Year)**		
	Slow	**Active**	**Total**	**Slow**	**Active**	**Total**	**Slow**	**Active**	**Total**
USGU 10-01	moderate		moderate	3.9	0.0	3.9	1.7	0.0	1.7
Reach Type Average	**moderate**		**moderate**	**3.9**	**0.0**	**3.9**	**1.7**	**0.0**	**1.7**

4.3.6 Sediment Loading Results for Reach Type MR-2-2-U

Two sites were sampled of reach type MR-2-2-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table 4-23**.

Table 4-23. Sediment loading results for reach type MR-2-2-U.									
Reach ID	**Mean BEHI Rating**			**Percent of Reach with Eroding Bank**			**Total Sediment Load per 1000 Feet (Tons/Year)**		
	Slow	**Active**	**Total**	**Slow**	**Active**	**Total**	**Slow**	**Active**	**Total**
CATA 18-01	moderate		moderate	0.9	0.0	0.9	0.6	0.0	0.6
MUSK 18-01-02	low	moderate	moderate	3.1	2.8	5.9	0.6	1.8	2.3
Reach Type Average	**moderate**	**moderate**	**moderate**	**2.0**	**1.4**	**3.4**	**0.6**	**0.9**	**1.5**

4.3.7 Sediment Loading Results for Reach Type MR-2-3-C

Two reaches were sampled of reach type MR-2-3-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 3rd order streams within confined valley types. Loading results are provided below in **Table 4-24**.

Table 4-24. Sediment loading results for reach type MR-2-3-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ELKH 23-01	moderate		moderate	2.6	0.0	2.6	1.6	0.0	1.6
LBLR 32-01	low		low	7.5	0.0	7.5	1.6	0.0	1.6
Reach Type Average	**moderate**		**moderate**	**5.0**	**0.0**	**5.0**	**1.6**	**0.0**	**1.6**

4.3.8 Sediment Loading Results for Reach Type MR-2-3-U

One reach was sampled of reach type MR-2-3-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 3rd order streams within unconfined valley types. Loading results are provided below in **Table 4-25**.

Table 4-25. Sediment loading results for reach type MR-2-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ELKH 28-01		moderate	moderate	0.0	8.7	8.7	0.0	8.6	8.6
Reach Type Average		**moderate**	**moderate**	**0.0**	**8.7**	**8.7**	**0.0**	**8.6**	**8.6**

4.3.9 Sediment Loading Results for Reach Type MR-4-2-C

One reach was sampled of reach type MR-4-2-C. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within confined valley types. Loading results are provided below in **Table 4-26**.

Table 4-26. Sediment loading results for reach type MR-4-2-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
NFLB 42-01		moderate	moderate	0.0	4.5	4.5	0.0	2.8	2.8
Reach Type Average		**moderate**	**moderate**	**0.0**	**4.5**	**4.5**	**0.0**	**2.8**	**2.8**

4.3.10 Sediment Loading Results for Reach Type MR-4-2-U

Three reaches were sampled of reach type MR-4-2-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table 4-27**.

Table 4-27. Sediment loading results for reach type MR-4-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
HIOR 09-01		high	high	0.0	0.6	0.6	0.0	1.3	1.3
HIOR 15-01	moderate	moderate	moderate	3.8	1.0	4.8	1.2	0.2	1.4
MCCA 22-01	high	high	high	12.0	5.0	17.0	14.0	4.6	18.6
Reach Type Average	**moderate**	**high**	**high**	**5.3**	**2.2**	**7.5**	**5.1**	**2.0**	**7.1**

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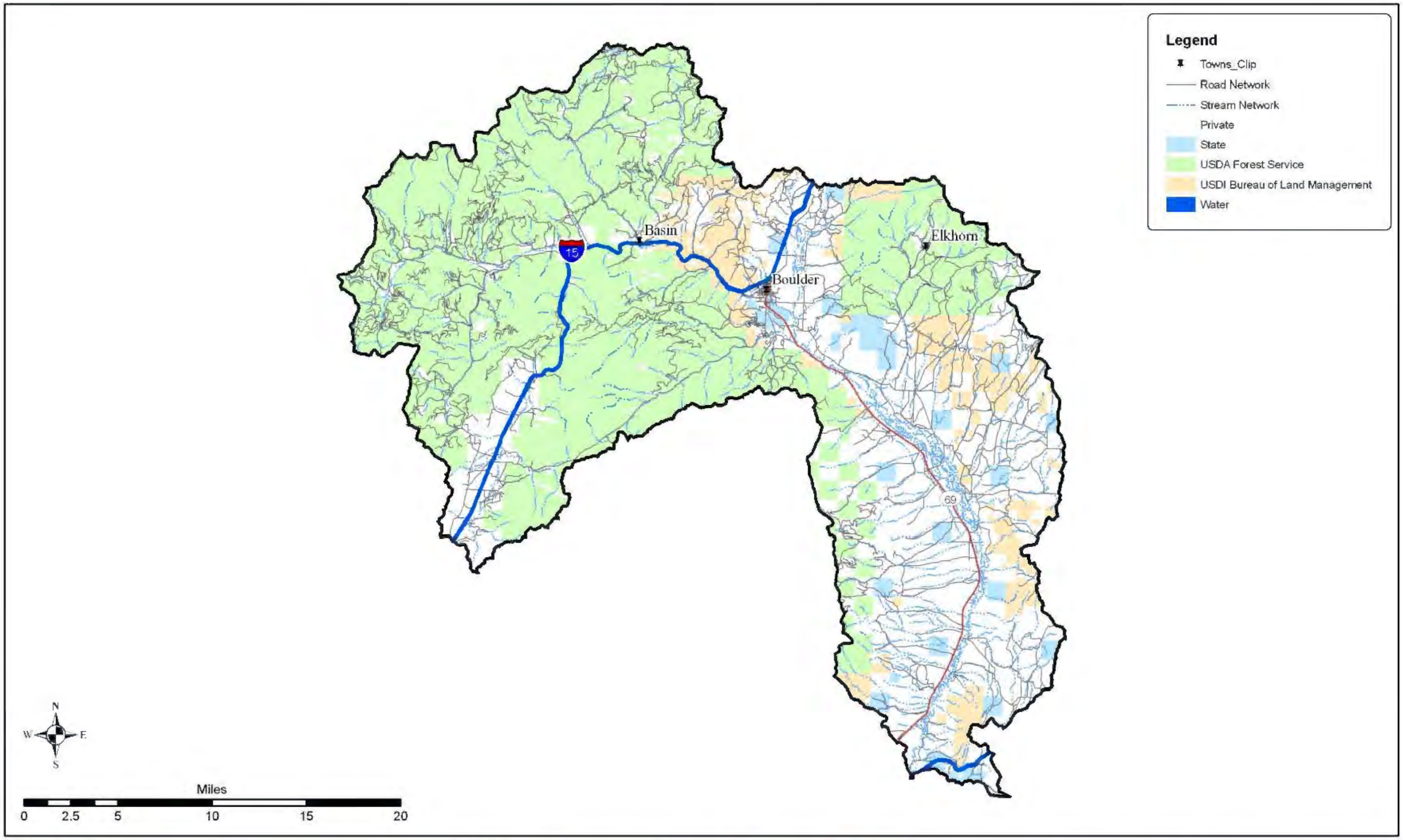
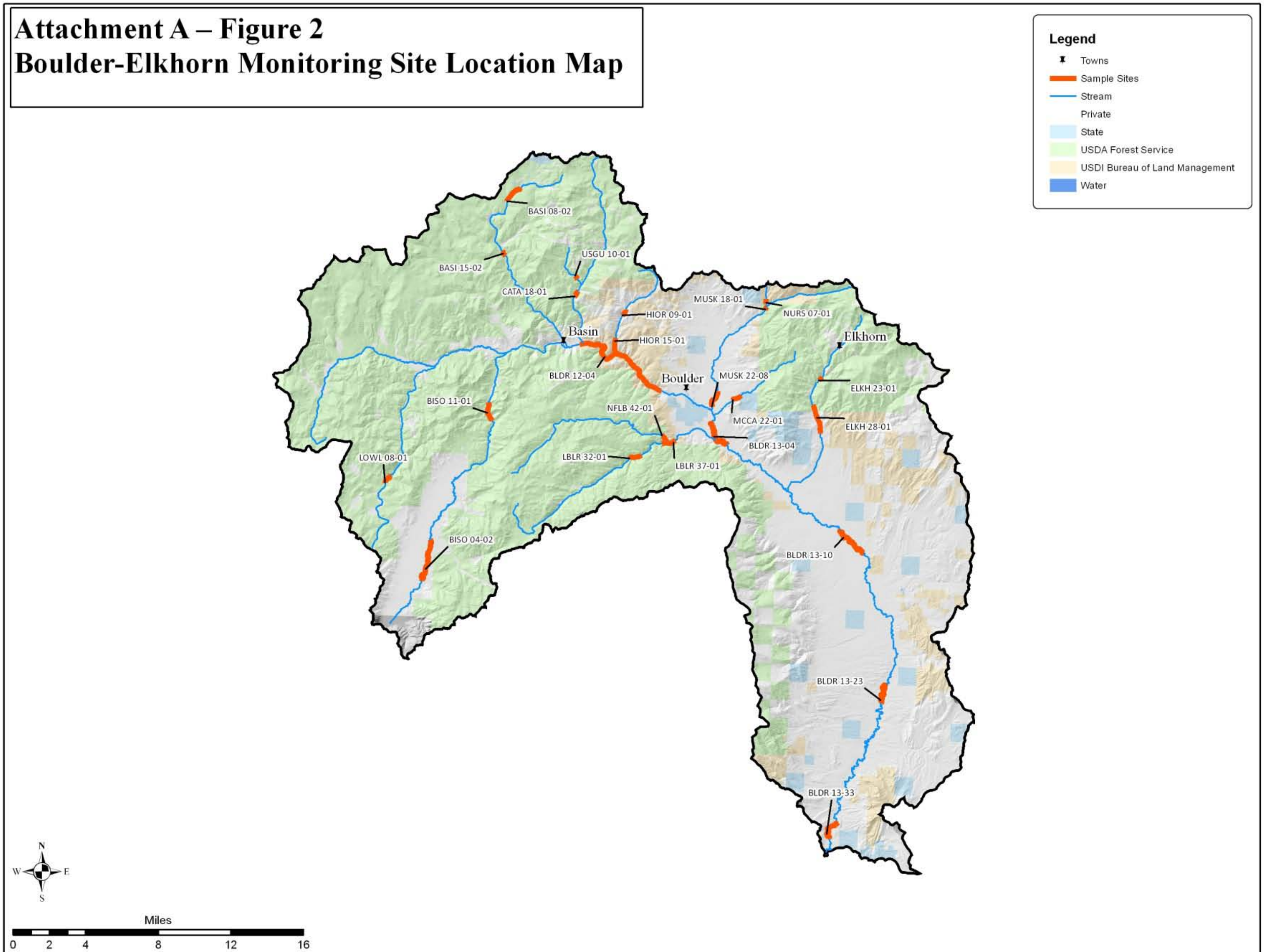
ATTACHMENT A – Maps



Attachment A – Figure 1
Boulder-Elkhorn TMDL Planning Area

Attachment A – Figure 2
Boulder-Elkhorn Monitoring Site Location Map



ATTACHMENT B – Field Data Sheets

Aerial Stratification Data														
Stream	Reach	Reach ID	Primary Ecoregion	Secondary Ecoregion	Strahler Stream Order	Confinement	Gradient	Reach Type	Break Trigger	Left Bank Dominant Land Use	Right Bank Dominant Land Us	Left Bank Vegetation	Right Bank Vegetation	Length (feet)
Basin Creek	08-02	BASI 08-02	17ai		2	U	<2	MR-0-2-U	STREAM ORDER	FOREST	ROAD	MATURE CONIFEROUS	MATURE CONIFEROUS	5840
Basin Creek	15-02	BASI 15-02	17ai		3	U	<2	MR-0-3-U	STREAM ORDER	FOREST	FOREST	MATURE CONIFEROUS	MATURE CONIFEROUS	1820
Bison Creek	04-02	BISO 04-02	17ai		2	U	<2	MR-0-2-U	SAME AS ABOVE LAKE	HAY/PASTURE	HAY/PASTURE	GRASS	GRASS	15601
Bison Creek	11-01	BISO 11-01	17ai		3	U	<2	MR-0-3-U	GRADIENT	ROAD	ROAD	SHRUBS	SHRUBS	6191
Boulder River	12-04	BLDR 12-04	17ai		4	U	<2	MR-0-4-U	STREAM ORDER	ROAD	ROAD	SHRUBS	SHRUBS	34322
Boulder River	13-04	BLDR 13-04	17w	17ai	4	U	<2	MR-0-4-U	ECOREGION	HAY/PASTURE	HAY/PASTURE	GRASS	GRASS	11603
Boulder River	13-10	BLDR 13-10	17w	17ai	4	U	<2	MR-0-4-U	ECOREGION	HAY/PASTURE	HAY/PASTURE	SHRUBS	SHRUBS	13771
Boulder River	13-23	BLDR 13-23	17w	17ai	4	U	<2	MR-0-4-U	ECOREGION	HAY/PASTURE	HAY/PASTURE	SHRUBS	SHRUBS	8815
Boulder River	13-33	BLDR 13-33	17w	17ai	4	U	<2	MR-0-4-U	ECOREGION	HAY/PASTURE	HAY/PASTURE	MATURE DECIDUOUS	MATURE DECIDUOUS	7426
Cataract Creek	18-01	CATA 18-01	17ai		2	U	2-<4	MR-2-2-U	GRADIENT	FOREST	FOREST	MATURE CONIFEROUS	MATURE CONIFEROUS	1756
Elkhorn Creek	23-01	ELKH 23-01	17ai		3	C	2-<4	MR-2-3-C	GRADIENT	FOREST	ROAD	MATURE CONIFEROUS	GRASS	1396
Elkhorn Creek	28-01	ELKH 28-01	17y	17ai	3	U	2-<4	MR-2-3-U	GRADIENT	ROAD	RANGE	SHRUBS	SHRUBS	8725
High Ore Creek	09-01	HIOR 09-01	17ai		2	U	4-10	MR-4-2-U	STREAM ORDER	FOREST	ROAD	MATURE CONIFEROUS	MATURE CONIFEROUS	2078
High Ore Creek	15-01	HIOR 15-01	17ai		2	U	4-10	MR-4-2-U	CONFINEMENT	ROAD	FOREST	MATURE CONIFEROUS	MATURE CONIFEROUS	4744
Little Boulder River	32-01	LBLR 32-01	17ai		3	C	2-<4	MR-2-3-C	CONFINEMENT	ROAD	FOREST	MATURE CONIFEROUS	MATURE CONIFEROUS	3751
Little Boulder River	37-01	LBLR 37-01	17ai		3	U	<2	MR-0-3-U	GRADIENT	ROAD	FOREST	SHRUBS	SHRUBS	4479
Lowland Creek	08-01	LOWL 08-01	17ai		2	U	<2	MR-0-2-U	STREAM ORDER	ROAD	FOREST	GRASS	GRASS	3216
McCarty Creek	22-01	MCCA 22-01	17w	17ai	2	U	4-10	MR-4-2-U	GRADIENT	FOREST	RANGE	MATURE DECIDUOUS	MATURE DECIDOUOUS	2893
Muskrat Creek	18-01	MUSK 18-01	17w	17ai	2	U	2-<4	MR-2-2-U	GRADIENT	FOREST	ROAD	GRASS	GRASS	757
Muskrat Creek	22-08	MUSK 22-08	17w	17ai	3	U	<2	MR-0-3-U	STREAM ORDER	RANGE	HAY/PASTURE	GRASS	GRASS	5544
Little Boulder River, North Fork	42-01	NFLB 42-01	17ai		2	C	4-10	MR-4-2-C	GRADIENT	ROAD	FOREST	MATURE CONIFEOUS	MATURE CONIFEROUS	2354
Nursery Creek	07-01	NURS 07-01	17w		1	C	2-<4	MR-2-1-C	GRADIENT	HARVEST/FIRE	HARVEST/FIRE	GRASS	GRASS	1114
Uncle Sam Gulch	10-01	USGU 10-01	17ai		1	U	2-<4	MR-2-1-U	GRADIENT	FOREST	FOREST	MATURE CONIFEROUS	MATURE CONIFEROUS	1195

Site Information												
Stream	Reach ID	Date	Reach Type	Existing Stream Type	Estimated Potential Stream Type	Downstream End Latitude	Downstream End Longitude	Upstream End Latitude	Upstream End Longitude	Site Length (Feet)	Field Slope (Percent)	Calculated Sinuosity
Basin Creek	BASI 08-02	09/01/10	MR-0-2-U	B4	B4	46.38491	-112.33311	46.38672	-112.33081	1000	3.0	1.1
Bison Creek	BASI 15-02	09/01/10	MR-0-3-U	B4	B4	46.34250	-112.33901	46.34367	-112.33990	1000	2.0	2.1
Bison Creek	BISO 04-02	08/31/10	MR-0-2-U	E5	E5	46.10108	-112.40875	46.09958	-112.40974	1000	0.5	1.7
Bison Creek	BISO 11-01	08/31/10	MR-0-3-U	B4	C4	46.21615	-112.34830	46.21418	-112.34857	1000	2.3	1.4
Boulder River	BLDR 12-04	09/01/10	MR-0-4-U	F4	C4	46.25748	-112.18534	46.25946	-112.18952	1500	2.0	1.2
Boulder River	BLDR 13-04	09/07/10	MR-0-4-U	C4	C4	46.19402	-112.07522	46.19649	-112.07695	1500	1.8	1.5
Boulder River	BLDR 13-10	09/08/10	MR-0-4-U	C4	C4	46.11440	-111.91971	46.11618	-111.92218	1500	1.8	1.7
Boulder River	BLDR 13-23	09/10/10	MR-0-4-U	C4	C4	46.99763	-111.88619	46.99916	-111.88312	2000	1.5	2.1
Boulder River	BLDR 13-33	09/10/10	MR-0-4-U	C4	C4	45.89354	-111.93216	45.89744	-111.93298	2000	1.0	1.4
Cataract Creek	CATA 18-01	09/02/10	MR-2-2-U	B4	B4	46.30839	-112.25232	46.31019	-112.25045	1000	3.5	1.2
Elkhorn Creek	ELKH 23-01	09/09/10	MR-2-3-C	B4	B4	46.24644	-111.97005	46.24807	-111.96755	1000	2.5	1.2
Elkhorn Creek	ELKH 28-01	09/09/10	MR-2-3-U	B4	B4	46.22431	-111.97269	46.22651	-111.97335	1000	2.5	1.2
High Ore Creek	HIOR 09-01	09/09/10	MR-4-2-U	C4b	C4b	46.29639	-112.19476	46.29734	-112.19394	500	2.5	1.2
High Ore Creek	HIOR 15-01	09/02/10	MR-4-2-U	E4b	B4	46.26786	-112.20482	46.26947	-112.20480	500	4.0	1.0
Little Boulder River	LBLR 32-01	09/03/10	MR-2-3-C	B4	B4	46.18256	-112.17122	46.18152	-112.17431	1000	3.0	1.2
Little Boulder River	LBLR 37-01	09/03/10	MR-0-3-U	F4	C4	46.19542	-112.13231	46.19370	-112.13413	1000	1.8	1.3
Lowland Creek	LOWL 08-01	08/31/10	MR-0-2-U	C4	C4	46.15639	-112.46110	46.15517	-112.46252	1000	1.3	1.7
McCarty Creek	MCCA 22-01	09/07/10	MR-4-2-U	B5/G5	B4	46.22895	-112.06711	46.22999	-112.06657	500	4.0	1.2
Muskrat Creek	MUSK 18-01-02	09/08/10	MR-2-2-U	B4	B4	46.30081	-112.03442	46.30224	-112.03241	1000	2.5	1.4
Muskrat Creek	MUSK 22-08	09/07/10	MR-0-3-U	C4	E4	46.22889	-112.09052	46.23153	-112.08995	1000	0.5	1.0
North Fork Little Boulder River	NFLB 42-01	09/03/10	MR-4-2-C	B4a	A4	46.19537	-112.14173	46.19726	-112.14331	1000	5.0	1.3
Nursery Creek	NURS 07-01	09/08/10	MR-2-1-C	E5b	B4	46.30826	-112.03240	46.30946	-112.03243	500	2.5	1.1
Uncle Sam Gulch	USGU 10-01	09/02/10	MR-2-1-U	C4b	B4	46.32258	-112.25100	46.32459	-112.25260	1000	2.5	1.2

Channel Cross Section Data													
Reach ID	Date	Reach Type	Cell	Latitude	Longitude	Feature	Bankfull Channel Width	Cross-Sectional Area	Bankfull Mean Depth	Width / Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio
BASI 08-02	09/01/10	MR-0-2-U	1	46.38497	-112.33308	riffle	14.4	13.2	0.9	15.7	1.3	20.4	1.4
BASI 08-02	09/01/10	MR-0-2-U	2	46.38542	-112.33251	riffle	19.0	12.9	0.7	27.9	1.1	33.0	1.7
BASI 08-02	09/01/10	MR-0-2-U	3	46.38479	-112.33171	riffle	23.3	14.3	0.6	37.9	1.2	60.3	2.6
BASI 08-02	09/01/10	MR-0-2-U	4	46.38634	-112.33134	riffle	19.0	9.3	0.5	38.8	1.3	61.0	3.2
BASI 08-02	09/01/10	MR-0-2-U	5	46.38664	-112.33099	riffle	22.0	14.3	0.7	33.8	1.2	40.0	1.8
BASI 15-02	09/01/10	MR-0-3-U	1	46.34252	-112.33906	riffle	38.5	37.1	1.0	40.0	1.5	63.5	1.6
BASI 15-02	09/01/10	MR-0-3-U	2	46.34287	-112.33932	riffle	25.4	33.3	1.3	19.4	1.6	225.9	8.9
BASI 15-02	09/01/10	MR-0-3-U	3	46.34314	-112.33972	riffle	39.0	31.8	0.8	47.8	1.7	53.0	1.4
BASI 15-02	09/01/10	MR-0-3-U	4	46.34308	-112.34003	riffle	37.5	35.2	0.9	40.0	1.4	297.5	7.9
BASI 15-02	09/01/10	MR-0-3-U	5	46.34343	-112.33994	riffle	30.5	35.9	1.2	25.9	1.8	56.5	1.9
BISO 04-02	08/31/10	MR-0-2-U	1	46.10104	-112.40881	riffle	8.7	13.8	1.6	5.5	1.9	93.7	10.8
BISO 04-02	08/31/10	MR-0-2-U	2	46.10045	-112.40938	riffle	6.3	10.4	1.6	3.8	2.1	54.3	8.6
BISO 04-02	08/31/10	MR-0-2-U	3	46.10026	-112.40948	riffle	6.8	9.8	1.4	4.7	1.9	215.8	31.7
BISO 04-02	08/31/10	MR-0-2-U	4	46.09990	-112.40926	riffle	7.6	11.2	1.5	5.1	2.0	267.6	35.2
BISO 04-02	08/31/10	MR-0-2-U	5	46.09979	-112.40958	riffle	10.5	13.0	1.2	8.5	1.6	250.5	23.9
BISO 11-01	08/31/10	MR-0-3-U	1	46.21615	-112.34816	riffle	23.2	31.2	1.3	17.3	2.2	32.2	1.4
BISO 11-01	08/31/10	MR-0-3-U	2	46.21536	-112.34827	riffle	22.8	32.6	1.4	15.9	2.0	33.8	1.5
BISO 11-01	08/31/10	MR-0-3-U	3	46.21495	-112.34800	riffle	22.4	33.9	1.5	14.8	2.4	35.4	1.6
BISO 11-01	08/31/10	MR-0-3-U	4	46.21448	-112.34821	riffle	22.0	31.8	1.4	15.2	2.2	42.0	1.9
BISO 11-01	08/31/10	MR-0-3-U	5	46.21425	-112.34840	riffle	26.0	31.5	1.2	21.5	2.1	40.0	1.5
BLDR 12-04	09/01/10	MR-0-4-U	1	46.25753	-112.18541	riffle	64.0	111.9	1.7	36.6	2.3	79.0	1.2
BLDR 12-04	09/01/10	MR-0-4-U	2	46.25750	-112.18536	riffle	76.6	113.8	1.5	51.6	2.0	86.6	1.1
BLDR 12-04	09/01/10	MR-0-4-U	3	46.25912	-112.18721	riffle	48.0	99.0	2.1	23.3	2.5	64.0	1.3
BLDR 12-04	09/01/10	MR-0-4-U	4	46.25918	-112.18759	riffle	55.2	76.9	1.4	39.6	2.1	105.2	1.9
BLDR 12-04	09/01/10	MR-0-4-U	5	46.25944	-112.18864	riffle	69.0	111.8	1.6	42.6	2.7	132.0	1.9
BLDR 13-04	09/07/10	MR-0-4-U	1	46.19411	-112.07543	riffle	58.0	96.2	1.7	35.0	2.5	262.0	4.5
BLDR 13-04	09/07/10	MR-0-4-U	2	46.19501	-112.07580	riffle	58.0	97.6	1.7	34.5	2.6	124.5	2.1
BLDR 13-04	09/07/10	MR-0-4-U	4	46.19617	-112.07590	riffle	55.0	94.9	1.7	31.9	2.3	335.0	6.1
BLDR 13-04	09/07/10	MR-0-4-U	5	46.19632	-112.07696	riffle	84.5	118.0	1.4	60.5	2.5	344.5	4.1
BLDR 13-10	09/08/10	MR-0-4-U	1	46.11453	-111.91987	riffle	70.0	85.2	1.2	57.5	1.9	97.0	1.4
BLDR 13-10	09/08/10	MR-0-4-U	2	46.11474	-111.92073	riffle	76.0	90.1	1.2	64.1	2.4	476.0	6.3
BLDR 13-10	09/08/10	MR-0-4-U	4	46.11593	-111.92179	riffle	81.0	95.0	1.2	69.0	2.0	481.0	5.9
BLDR 13-10	09/08/10	MR-0-4-U	5	46.11605	-111.92231	riffle	75.0	68.9	0.9	81.7	1.9	475.0	6.3
BLDR 13-23	09/10/10	MR-0-4-U	1	45.99785	-111.88647	riffle	79.0	134.6	1.7	46.4	3.1	339.0	4.3
BLDR 13-23	09/10/10	MR-0-4-U	2	45.99810	-111.88521	riffle	45.0	122.5	2.7	16.5	4.2	445.0	9.9
BLDR 13-23	09/10/10	MR-0-4-U	3	45.99786	-111.88447	riffle	48.0	121.3	2.5	19.0	3.7	448.0	9.3
BLDR 13-23	09/10/10	MR-0-4-U	4	45.99815	-111.88293	riffle	73.0	123.0	1.7	43.3	3.1	228.0	3.1
BLDR 13-23	09/10/10	MR-0-4-U	5	45.99920	-111.88317	riffle	66.0	126.9	1.9	34.3	3.8	466.0	7.1
BLDR 13-33	09/10/10	MR-0-4-U	1	45.89373	-111.93190	riffle	75.0	136.9	1.8	41.1	2.4	77.0	1.0
BLDR 13-33	09/10/10	MR-0-4-U	2	45.89496	-111.93178	riffle	75.0	117.0	1.6	48.1	2.1	109.0	1.5
BLDR 13-33	09/10/10	MR-0-4-U	4	45.89621	-111.93340	riffle	68.0	150.3	2.2	30.8	3.1	168.0	2.5
BLDR 13-33	09/10/10	MR-0-4-U	5	45.89727	-111.93317	riffle	64.0	128.9	2.0	31.8	2.9	174.0	2.7
CATA 18-01	09/02/10	MR-2-2-U	1	46.30837	-112.25205	riffle	40.0	42.8	1.1	37.4	2.3	55.0	1.4
CATA 18-01	09/02/10	MR-2-2-U	2	46.30892	-112.25102	riffle	23.3	35.6	1.5	15.2	2.3	40.3	1.7
CATA 18-01	09/02/10	MR-2-2-U	3	46.30893	-112.25081	riffle	31.7	46.9	1.5	21.4	2.1	48.7	1.5
CATA 18-01	09/02/10	MR-2-2-U	5	46.30995	-112.25032	riffle	32.2	43.0	1.3	24.1	2.4	49.2	1.5
ELKH 23-01	09/09/10	MR-2-3-C	1	46.24647	-111.96993	riffle	14.8	17.1	1.2	12.8	1.7	94.8	6.4
ELKH 23-01	09/09/10	MR-2-3-C	2	46.24696	-111.96943	riffle	24.0	18.4	0.8	31.4	1.9	99.0	4.1
ELKH 23-01	09/09/10	MR-2-3-C	3	46.24715	-111.96901	riffle	16.7	20.0	1.2	13.9	2.1	30.7	1.8
ELKH 23-01	09/09/10	MR-2-3-C	4	46.24750	-111.96822	riffle	15.5	18.3	1.2	13.1	1.7	33.5	2.2
ELKH 23-01	09/09/10	MR-2-3-C	5	46.24780	-111.96786	riffle	16.0	16.7	1.0	15.3	1.7	32.0	2.0

Channel Cross Section Data													
Reach ID	Date	Reach Type	Cell	Latitude	Longitude	Feature	Bankfull Channel Width	Cross-Sectional Area	Bankfull Mean Depth	Width / Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio
ELKH 28-01	09/09/10	MR-2-3-U	2	46.22473	-111.97313	riffle	14.8	20.1	1.4	10.9	1.9	23.8	1.6
ELKH 28-01	09/09/10	MR-2-3-U	3	46.22530	-111.97335	riffle	24.0	27.1	1.1	21.2	1.9	30.0	1.3
ELKH 28-01	09/09/10	MR-2-3-U	4	46.22589	-111.97293	riffle	19.0	21.9	1.2	16.5	2.1	31.0	1.6
ELKH 28-01	09/09/10	MR-2-3-U	5	46.22589	-111.97293	riffle	20.0	24.4	1.2	16.4	1.9	41.0	2.1
HIOR 09-01	09/09/10	MR-4-2-U	1	46.29642	-112.19467	riffle	9.7	5.2	0.5	18.0	1.1	21.2	2.2
HIOR 09-01	09/09/10	MR-4-2-U	2	46.29670	-112.19432	riffle	10.0	6.3	0.6	15.9	1.0	26.5	2.7
HIOR 09-01	09/09/10	MR-4-2-U	3	46.29676	-112.19416	riffle	10.0	5.8	0.6	17.2	1.1	24.0	2.4
HIOR 09-01	09/09/10	MR-4-2-U	4	46.29700	-112.19392	riffle	5.6	4.5	0.8	7.0	1.5	13.6	2.4
HIOR 09-01	09/09/10	MR-4-2-U	5	46.29727	-112.19393	riffle	7.7	4.9	0.6	12.1	1.1	17.7	2.3
HIOR 15-01	09/02/10	MR-4-2-U	1	46.26781	-112.20490	riffle	5.0	3.7	0.7	6.8	1.0	21.0	4.2
HIOR 15-01	09/02/10	MR-4-2-U	2	46.26859	-112.20454	riffle	5.5	3.9	0.7	7.9	1.1	9.5	1.7
HIOR 15-01	09/02/10	MR-4-2-U	3	46.26882	-112.20504	riffle	4.8	3.5	0.7	6.7	1.1	15.8	3.3
HIOR 15-01	09/02/10	MR-4-2-U	4	46.26884	-112.20480	riffle	6.0	3.6	0.6	10.1	0.9	22.0	3.7
HIOR 15-01	09/02/10	MR-4-2-U	5	46.26916	-112.20487	riffle	4.4	3.5	0.8	5.6	1.1	22.4	5.1
LBLR 32-01	09/03/10	MR-2-3-C	1	46.18246	-112.17119	riffle	24.5	29.3	1.2	20.5	1.7	41.5	1.7
LBLR 32-01	09/03/10	MR-2-3-C	2	46.18238	-112.17239	riffle	15.6	22.5	1.4	10.8	2.2	21.6	1.4
LBLR 32-01	09/03/10	MR-2-3-C	3	46.18208	-112.17278	riffle	23.0	28.2	1.2	18.8	1.9	43.0	1.9
LBLR 32-01	09/03/10	MR-2-3-C	4	46.18151	-112.17349	riffle	19.5	24.0	1.2	15.9	1.9	28.0	1.4
LBLR 32-01	09/03/10	MR-2-3-C	5	46.18148	-112.17426	riffle	18.9	27.7	1.5	12.9	2.4	44.9	2.4
LBLR 37-01	09/03/10	MR-0-3-U	1	46.19541	-112.13235	riffle	21.4	23.1	1.1	19.8	1.7	30.4	1.4
LBLR 37-01	09/03/10	MR-0-3-U	2	46.19476	-112.13314	riffle	23.0	26.7	1.2	19.8	1.7	31.0	1.3
LBLR 37-01	09/03/10	MR-0-3-U	3	46.19446	-112.13327	riffle	18.0	37.6	2.1	8.6	1.9	35.0	1.9
LBLR 37-01	09/03/10	MR-0-3-U	4	46.19420	-112.13370	riffle	25.0	27.2	1.1	23.0	2.1	46.0	1.8
LBLR 37-01	09/03/10	MR-0-3-U	5	46.19402	-112.13412	riffle	20.2	29.7	1.5	13.7	1.9	25.2	1.2
LOWL 08-01	08/31/10	MR-0-2-U	1	46.15632	-112.46108	riffle	10.8	9.6	0.9	12.1	1.4	130.8	12.1
LOWL 08-01	08/31/10	MR-0-2-U	2	46.15602	-112.46175	riffle	10.4	8.5	0.8	12.7	1.4	82.4	7.9
LOWL 08-01	08/31/10	MR-0-2-U	3	46.15586	-112.46164	riffle	11.0	10.2	0.9	11.8	1.5	83.0	7.5
LOWL 08-01	08/31/10	MR-0-2-U	4	46.15564	-112.46190	riffle	16.2	14.2	0.9	18.5	1.2	56.2	3.5
LOWL 08-01	08/31/10	MR-0-2-U	5	46.15540	-112.46229	riffle	11.2	7.6	0.7	16.5	1.3	151.2	13.5
MCCA 22-01	09/07/10	MR-4-2-U	1	46.22900	-112.06759	riffle	4.0	1.7	0.4	9.3	0.7	8.6	2.2
MCCA 22-01	09/07/10	MR-4-2-U	2	46.22919	-112.06732	riffle	2.7	1.1	0.4	6.4	0.8	5.1	1.9
MCCA 22-01	09/07/10	MR-4-2-U	3	46.22956	-112.06702	riffle	3.2	1.9	0.6	5.3	0.8	5.3	1.7
MCCA 22-01	09/07/10	MR-4-2-U	4	46.22966	-112.06699	riffle	3.0	1.8	0.6	5.1	0.7	3.5	1.2
MCCA 22-01	09/07/10	MR-4-2-U	5	46.22992	-112.06662	riffle	3.0	1.6	0.5	5.7	0.7	6.2	2.1
MUSK 18-01-02	09/08/10	MR-2-2-U	1	46.30082	-112.03436	riffle	12.5	13.8	1.1	11.3	1.5	22.5	1.8
MUSK 18-01-02	09/08/10	MR-2-2-U	2	46.30122	-112.03417	riffle	16.5	16.3	1.0	16.7	1.4	28.5	1.7
MUSK 18-01-02	09/08/10	MR-2-2-U	3	46.30155	-112.03367	riffle	15.0	14.7	1.0	15.3	1.6	24.0	1.6
MUSK 18-01-02	09/08/10	MR-2-2-U	4	46.30186	-112.03000	riffle	12.5	12.5	1.0	12.5	1.6	116.5	9.3
MUSK 18-01-02	09/08/10	MR-2-2-U	5	46.30227	-112.03268	riffle	11.3	10.7	0.9	11.9	1.6	76.3	6.8
MUSK 22-08	09/07/10	MR-0-3-U	1	46.22893	-112.09051	riffle	14.7	18.0	1.2	12.0	1.9	44.7	3.0
MUSK 22-08	09/07/10	MR-0-3-U	2	46.22951	-112.09013	riffle	15.2	14.0	0.9	16.4	1.5	33.7	2.2
MUSK 22-08	09/07/10	MR-0-3-U	3	46.23025	-112.09007	riffle	13.6	14.8	1.1	12.5	1.5	31.6	2.3
MUSK 22-08	09/07/10	MR-0-3-U	5	46.23112	-112.09004	riffle	14.0	13.0	0.9	15.1	1.5	44.0	3.1
NFLB 42-01	09/03/10	MR-4-2-C	1	46.19553	-112.14189	riffle	22.0	21.8	1.0	22.2	1.1	32.0	1.5
NFLB 42-01	09/03/10	MR-4-2-C	2	46.19579	-112.14221	riffle	17.6	18.8	1.1	16.5	1.6	23.6	1.3
NFLB 42-01	09/03/10	MR-4-2-C	3	46.19608	-112.14257	riffle	14.5	18.3	1.3	11.5	2.2	46.5	3.2
NFLB 42-01	09/03/10	MR-4-2-C	5	46.19697	-112.14337	riffle	20.2	22.3	1.1	18.3	1.6	40.2	2.0
NURS 07-01	09/08/10	MR-2-1-C	1	46.30841	-112.03241	riffle	3.8	2.2	0.6	6.7	0.9	17.8	4.7
NURS 07-01	09/08/10	MR-2-1-C	2	46.30860	-112.03242	riffle	2.8	1.7	0.6	4.7	1.0	31.8	11.4
NURS 07-01	09/08/10	MR-2-1-C	3	46.30899	-112.03237	riffle	3.0	1.5	0.5	6.0	1.0	12.0	4.0
NURS 07-01	09/08/10	MR-2-1-C	4	46.30925	-112.03238	riffle	5.0	2.4	0.5	10.6	0.9	24.0	4.8
NURS 07-01	09/08/10	MR-2-1-C	5	46.30945	-112.03239	riffle	5.5	2.4	0.4	12.8	0.7	18.5	3.4
USGU 10-01	09/02/10	MR-2-1-U	1	46.32273	-112.25109	riffle	10.6	10.4	1.0	10.8	1.3	37.6	3.5
USGU 10-01	09/02/10	MR-2-1-U	2	46.32319	-112.25169	riffle	12.0	9.5	0.8	15.2	1.2	55.0	4.6
USGU 10-01	09/02/10	MR-2-1-U	3	46.32323	-112.25211	riffle	10.1	8.1	0.8	12.6	1.1	13.6	1.3
USGU 10-01	09/02/10	MR-2-1-U	4	46.32410	-112.25212	riffle	12.8	10.0	0.8	16.4	1.4	218.8	17.1
USGU 10-01	09/02/10	MR-2-1-U	5	46.32417	-112.25223	riffle	15.4	10.2	0.7	23.2	1.4	33.4	2.2

Riffle Substrate Data								
Reach ID	Date	Reach Type	Cell	Riffle Pebble Count D50	Riffle Pebble Count Percent <2mm	Riffle Pebble Count Percent <6mm	Riffle Grid Toss Percent <6mm	Riffle Stability Index
BASI 08-02	09/01/10	MR-0-2-U	1	31	3	9	1	
BASI 08-02	09/01/10	MR-0-2-U	2	51	7	16		
BASI 08-02	09/01/10	MR-0-2-U	3	31	5	14	1	
BASI 08-02	09/01/10	MR-0-2-U	5	33	5	15	5	
BASI 15-02	09/01/10	MR-0-3-U	1	32	4	11	3	96
BASI 15-02	09/01/10	MR-0-3-U	2	46	4	8		
BASI 15-02	09/01/10	MR-0-3-U	3	29	3	7	3	
BASI 15-02	09/01/10	MR-0-3-U	5	42	8	16	4	
BISO 04-02	08/31/10	MR-0-2-U	1	3	28	94	100	
BISO 04-02	08/31/10	MR-0-2-U	2	2	30	100		
BISO 04-02	08/31/10	MR-0-2-U	3	2	50	100	100	
BISO 04-02	08/31/10	MR-0-2-U	5	3	10	90	100	
BISO 11-01	08/31/10	MR-0-3-U	1	50	5	14	3	
BISO 11-01	08/31/10	MR-0-3-U	2	60	2	12		
BISO 11-01	08/31/10	MR-0-3-U	3	23	17	28	5	
BISO 11-01	08/31/10	MR-0-3-U	5	52	7	21	3	
BLDR 12-04	09/01/10	MR-0-4-U	1	38	9	20		
BLDR 12-04	09/01/10	MR-0-4-U	2	68	4	11		
BLDR 12-04	09/01/10	MR-0-4-U	3	51	9	14		
BLDR 12-04	09/01/10	MR-0-4-U	5	110	1	1	15	
BLDR 13-04	09/07/10	MR-0-4-U	1	52	11	23	22	
BLDR 13-04	09/07/10	MR-0-4-U	3	42	10	21		67
BLDR 13-04	09/07/10	MR-0-4-U	4	41	10	14	9	
BLDR 13-04	09/07/10	MR-0-4-U	5	42	5	9	3	
BLDR 13-10	09/08/10	MR-0-4-U	1	38	6	10	9	
BLDR 13-10	09/08/10	MR-0-4-U	2	40	6	16		90
BLDR 13-10	09/08/10	MR-0-4-U	4	31	7	8	4	
BLDR 13-10	09/08/10	MR-0-4-U	5	28	15	16	0	
BLDR 13-23	09/10/10	MR-0-4-U	1	20	13	17	5	
BLDR 13-23	09/10/10	MR-0-4-U	3	20	21	30		
BLDR 13-23	09/10/10	MR-0-4-U	4	19	17	29	0	
BLDR 13-23	09/10/10	MR-0-4-U	5	28	36	37	5	
BLDR 13-33	09/10/10	MR-0-4-U	1	19	20	27	12	
BLDR 13-33	09/10/10	MR-0-4-U	2	78	14	18		
BLDR 13-33	09/10/10	MR-0-4-U	4	10	34	39	69	
BLDR 13-33	09/10/10	MR-0-4-U	5	13	21	27	16	
CATA 18-01	09/02/10	MR-2-2-U	1	29	15	33	5	
CATA 18-01	09/02/10	MR-2-2-U	2	125	3	12		
CATA 18-01	09/02/10	MR-2-2-U	3	61	16	26	16	
CATA 18-01	09/02/10	MR-2-2-U	5	130	18	23	19	
ELKH 23-01	09/09/10	MR-2-3-C	1	20	22	29	17	
ELKH 23-01	09/09/10	MR-2-3-C	2	2	49	51		
ELKH 23-01	09/09/10	MR-2-3-C	3	20	32	36	10	
ELKH 23-01	09/09/10	MR-2-3-C	5	20	29	41	9	
ELKH 28-01	09/09/10	MR-2-3-U	1	22	12	21	1	
ELKH 28-01	09/09/10	MR-2-3-U	2	20	26	32		
ELKH 28-01	09/09/10	MR-2-3-U	3	11	30	36	9	
ELKH 28-01	09/09/10	MR-2-3-U	5	17	33	39	7	

Riffle Substrate Data								
Reach ID	Date	Reach Type	Cell	Riffle Pebble Count D50	Riffle Pebble Count Percent <2mm	Riffle Pebble Count Percent <6mm	Riffle Grid Toss Percent <6mm	Riffle Stability Index
HIOR 09-01	09/09/10	MR-4-2-U	1	10	27	40		
HIOR 09-01	09/09/10	MR-4-2-U	2	10	28	44		
HIOR 09-01	09/09/10	MR-4-2-U	3	19	24	37		
HIOR 09-01	09/09/10	MR-4-2-U	5	20	32	37		
HIOR 15-01	09/02/10	MR-4-2-U	1	21	9	25	8	
HIOR 15-01	09/02/10	MR-4-2-U	2	30	6	27		
HIOR 15-01	09/02/10	MR-4-2-U	3	30	2	12	9	
HIOR 15-01	09/02/10	MR-4-2-U	5	40	10	18	13	
LBLR 32-01	09/03/10	MR-2-3-C	1	54	8	18	14	
LBLR 32-01	09/03/10	MR-2-3-C	2	100	8	22		
LBLR 32-01	09/03/10	MR-2-3-C	3	26	10	27	11	
LBLR 32-01	09/03/10	MR-2-3-C	5	105	5	13	18	
LBLR 37-01	09/03/10	MR-0-3-U	1	23	12	25	6	
LBLR 37-01	09/03/10	MR-0-3-U	2	38	4	15		
LBLR 37-01	09/03/10	MR-0-3-U	3	16	17	29	3	
LBLR 37-01	09/03/10	MR-0-3-U	5	33	9	21	7	
LOWL 08-01	08/31/10	MR-0-2-U	1	19	6	13	19	
LOWL 08-01	08/31/10	MR-0-2-U	2	25	11	19		
LOWL 08-01	08/31/10	MR-0-2-U	3	23	8	16	3	
LOWL 08-01	08/31/10	MR-0-2-U	5	17	18	32	3	
MCCA 22-01	09/07/10	MR-4-2-U	1	1	58	90	99	
MCCA 22-01	09/07/10	MR-4-2-U	2	2	49	95		
MCCA 22-01	09/07/10	MR-4-2-U	3	2	50	63	71	
MCCA 22-01	09/07/10	MR-4-2-U	5	2	45	80	33	
MUSK 18-01-02	09/08/10	MR-2-2-U	1	15	9	29	26	
MUSK 18-01-02	09/08/10	MR-2-2-U	2	17	10	31		
MUSK 18-01-02	09/08/10	MR-2-2-U	3	10	17	35	15	
MUSK 18-01-02	09/08/10	MR-2-2-U	5	35	12	21	10	
MUSK 22-08	09/07/10	MR-0-3-U	1	4	48	55	58	
MUSK 22-08	09/07/10	MR-0-3-U	2	2	53	66		
MUSK 22-08	09/07/10	MR-0-3-U	3	8	42	50	9	
MUSK 22-08	09/07/10	MR-0-3-U	5	12	31	39	15	
NFLB 42-01	09/03/10	MR-4-2-C	1	27	17	28	11	
NFLB 42-01	09/03/10	MR-4-2-C	2	27	9	22		
NFLB 42-01	09/03/10	MR-4-2-C	3	25	20	35	25	
NFLB 42-01	09/03/10	MR-4-2-C	5	30	14	34	23	
NURS 07-01	09/08/10	MR-2-1-C	1	4	40	62	92	
NURS 07-01	09/08/10	MR-2-1-C	2	4	29	59		
NURS 07-01	09/08/10	MR-2-1-C	3	4	29	57	95	
NURS 07-01	09/08/10	MR-2-1-C	5	4	22	68	98	
USGU 10-01	09/02/10	MR-2-1-U	1	2	57	100	100	
USGU 10-01	09/02/10	MR-2-1-U	3	22	17	31		
USGU 10-01	09/02/10	MR-2-1-U	4	32	12	20	12	
USGU 10-01	09/02/10	MR-2-1-U	5	38	12	23	59	

Pool and Large Woody Debris Data																				
Reach ID	Date	Reach Type	Cell	Mean Residual Pool Depth	Number of Pools per 1000 Feet	Number of Individual Pieces of LWD per 1000 Feet	Number of LWD Aggregates per 1000 Feet	Total Number of LWD per 1000 Feet	Number of Pools per 500 Feet	Number of Individual Pieces of LWD per 500 Feet	Number of LWD Aggregates per 500 Feet	Total Number of LWD per 500 Feet	Number of Pools per 1500 Feet	Number of Individual Pieces of LWD per 1500 Feet	Number of LWD Aggregates per 1500 Feet	Total Number of LWD per 1500 Feet	Number of Pools per 2000 Feet	Number of Individual Pieces of LWD per 2000 Feet	Number of LWD Aggregates per 2000 Feet	Total Number of LWD per 2000 Feet
BASI 08-02	09/01/10	MR-0-2-U	1-5	0.95	20	17	12	72												
BASI 15-02	09/01/10	MR-0-3-U	1-5	1.87	12	13	4	39												
BISO 04-02	08/31/10	MR-0-2-U	1-5	1.06	14	3	0	12												
BISO 11-01	08/31/10	MR-0-3-U	1-5	0.81	13	1	0	15												
BLDR 12-04	09/01/10	MR-0-4-U	1-5	1.32	6	0	1	16					9	0	1	25				
BLDR 13-04	09/07/10	MR-0-4-U	1-5	1.73	5	2	1	3					8	3	1	4				
BLDR 13-10	09/08/10	MR-0-4-U	1-5	3.02	5	2	7	37					7	3	10	56				
BLDR 13-23	09/10/10	MR-0-4-U	1-5	2.55	4	0	1	3									8	0	1	6.5
BLDR 13-33	09/10/10	MR-0-4-U	1-5	2.52	5	3	3	14									9	6	5	27
CATA 18-01	09/02/10	MR-2-2-U	1-5	1.04	26	12	4	30												
ELKH 23-01	09/09/10	MR-2-3-C	1-5	0.85	15	18	14	97												
ELKH 28-01	09/09/10	MR-2-3-U	1-5	0.80	21	16	17	206												
HIOR 09-01	09/09/10	MR-4-2-U	1-5	0.63	20	26	6	96	10	13	3	48								
HIOR 15-01	09/02/10	MR-4-2-U	1-5	0.62	24	16	0	32	12	8	0	16								
LBLR 32-01	09/03/10	MR-2-3-C	1-5	0.89	13	10	1	14												
LBLR 37-01	09/03/10	MR-0-3-U	1-5	1.75	13	5	0	11												
LOWL 08-01	08/31/10	MR-0-2-U	1-5	0.89	19	1	0	36												
MCCA 22-01	09/07/10	MR-4-2-U	1-5	0.38	36	30	16	272	18	15	8	136								
MUSK 18-01-02	09/08/10	MR-2-2-U	1-5	0.88	16	40	12	102												
MUSK 22-08	09/07/10	MR-0-3-U	1-5	0.65	8	1	0	1												
NFLB 42-01	09/03/10	MR-4-2-C	1-5	1.40	17	12	4	26												
NURS 07-01	09/08/10	MR-2-1-C	1-5	0.56	26	44	6	124	13	22	3	62								
USGU 10-01	09/02/10	MR-2-1-U	1-5	0.79	25	38	21	147												

Fine Sediment in Pool Tail-outs					
Reach ID	**Date**	**Reach Type**	**Cell**	**Pool Grid Toss Percent <6mm**	**Spawning Gravels Present (Y or ?)**
BASI 08-02	09/01/10	MR-0-2-U	2	1	Y
BASI 08-02	09/01/10	MR-0-2-U	4	0	Y
BISO 11-01	08/31/10	MR-0-3-U	2	7	Y
BISO 11-01	08/31/10	MR-0-3-U	3	20	Y
BISO 11-01	08/31/10	MR-0-3-U	3	30	Y
BISO 11-01	08/31/10	MR-0-3-U	3	6	Y
BLDR 12-04	09/01/10	MR-0-4-U	2	4	Y
BLDR 13-04	09/07/10	MR-0-4-U	2	11	?
BLDR 13-04	09/07/10	MR-0-4-U	2	14	Y
BLDR 13-04	09/07/10	MR-0-4-U	3	16	Y
BLDR 13-04	09/07/10	MR-0-4-U	4	5	Y
BLDR 13-04	09/07/10	MR-0-4-U	5	5	Y
BLDR 13-10	09/08/10	MR-0-4-U	1	3	Y
BLDR 13-10	09/08/10	MR-0-4-U	2	9	Y
BLDR 13-10	09/08/10	MR-0-4-U	2	0	Y
BLDR 13-10	09/08/10	MR-0-4-U	2	1	Y
BLDR 13-10	09/08/10	MR-0-4-U	3	1	Y
BLDR 13-10	09/08/10	MR-0-4-U	4	3	Y
BLDR 13-10	09/08/10	MR-0-4-U	5	2	Y
BLDR 13-23	09/10/10	MR-0-4-U	1	0	Y
BLDR 13-23	09/10/10	MR-0-4-U	3	3	Y
CATA 18-01	09/02/10	MR-2-2-U	1	53	Y
ELKH 23-01	09/09/10	MR-2-3-C	1	11	Y
ELKH 23-01	09/09/10	MR-2-3-C	2	6	Y
ELKH 23-01	09/09/10	MR-2-3-C	2	3	Y
ELKH 23-01	09/09/10	MR-2-3-C	3	7	Y
ELKH 23-01	09/09/10	MR-2-3-C	3	1	Y
ELKH 23-01	09/09/10	MR-2-3-C	3	4	Y
ELKH 23-01	09/09/10	MR-2-3-C	4	3	Y
ELKH 28-01	09/09/10	MR-2-3-U	1	4	Y
ELKH 28-01	09/09/10	MR-2-3-U	2	3	Y
ELKH 28-01	09/09/10	MR-2-3-U	3	1	Y
ELKH 28-01	09/09/10	MR-2-3-U	5	12	Y
ELKH 28-01	09/09/10	MR-2-3-U	5	1	Y
HIOR 15-01	09/02/10	MR-4-2-U	1	4	Y
HIOR 15-01	09/02/10	MR-4-2-U	4	72	Y
HIOR 15-01	09/02/10	MR-4-2-U	5	65	Y
LBLR 32-01	09/03/10	MR-2-3-C	1	97	Y
LBLR 32-01	09/03/10	MR-2-3-C	3	1	Y
LBLR 32-01	09/03/10	MR-2-3-C	5	11	Y
LBLR 37-01	09/03/10	MR-0-3-U	1	5	?
LBLR 37-01	09/03/10	MR-0-3-U	1	10	Y
LBLR 37-01	09/03/10	MR-0-3-U	1	70	Y
LBLR 37-01	09/03/10	MR-0-3-U	2	3	Y
LBLR 37-01	09/03/10	MR-0-3-U	2	3	Y
LBLR 37-01	09/03/10	MR-0-3-U	3	3	Y
LBLR 37-01	09/03/10	MR-0-3-U	3	5	Y
LBLR 37-01	09/03/10	MR-0-3-U	3	3	Y
LBLR 37-01	09/03/10	MR-0-3-U	4	7	Y
LBLR 37-01	09/03/10	MR-0-3-U	4	3	Y
LBLR 37-01	09/03/10	MR-0-3-U	5	5	Y
LBLR 37-01	09/03/10	MR-0-3-U	5	10	Y

no data for BASI 15-02
no data for BISO 04-02
no data for BLDR 13-33
no data for HIOR 09-01

Fine Sediment in Pool Tail-outs					
Reach ID	Date	Reach Type	Cell	Pool Grid Toss Percent <6mm	Spawning Gravels Present (Y or ?)
LOWL 08-01	08/31/10	MR-0-2-U	1	1	Y
LOWL 08-01	08/31/10	MR-0-2-U	1	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	1	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	1	1	Y
LOWL 08-01	08/31/10	MR-0-2-U	1	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	2	1	Y
LOWL 08-01	08/31/10	MR-0-2-U	2	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	2	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	3	0	Y
LOWL 08-01	08/31/10	MR-0-2-U	3	1	Y
LOWL 08-01	08/31/10	MR-0-2-U	4	1	Y
LOWL 08-01	08/31/10	MR-0-2-U	4	12	Y
LOWL 08-01	08/31/10	MR-0-2-U	4	10	Y
LOWL 08-01	08/31/10	MR-0-2-U	5	0	Y
MCCA 22-01	09/07/10	MR-4-2-U	1	98	?
MCCA 22-01	09/07/10	MR-4-2-U	1	99	?
MCCA 22-01	09/07/10	MR-4-2-U	1	98	?
MCCA 22-01	09/07/10	MR-4-2-U	2	100	?
MCCA 22-01	09/07/10	MR-4-2-U	2	100	?
MCCA 22-01	09/07/10	MR-4-2-U	2	96	?
MCCA 22-01	09/07/10	MR-4-2-U	3	93	?
MCCA 22-01	09/07/10	MR-4-2-U	4	32	?
MCCA 22-01	09/07/10	MR-4-2-U	5	78	?
MCCA 22-01	09/07/10	MR-4-2-U	5	40	Y
MUSK 18-01-02	09/08/10	MR-2-2-U	1	23	Y
MUSK 18-01-02	09/08/10	MR-2-2-U	1	71	Y
MUSK 18-01-02	09/08/10	MR-2-2-U	2	71	Y
MUSK 18-01-02	09/08/10	MR-2-2-U	4	97	Y
MUSK 18-01-02	09/08/10	MR-2-2-U	4	57	?
MUSK 18-01-02	09/08/10	MR-2-2-U	5	41	?
MUSK 22-08	09/07/10	MR-0-3-U	3	6	Y
MUSK 22-08	09/07/10	MR-0-3-U	3	5	Y
MUSK 22-08	09/07/10	MR-0-3-U	5	22	?
NFLB 42-01	09/03/10	MR-4-2-C	1	29	Y
NFLB 42-01	09/03/10	MR-4-2-C	3	69	?
NFLB 42-01	09/03/10	MR-4-2-C	4	61	Y
NFLB 42-01	09/03/10	MR-4-2-C	5	12	Y
NURS 07-01	09/08/10	MR-2-1-C	1	69	?
NURS 07-01	09/08/10	MR-2-1-C	2	86	?
NURS 07-01	09/08/10	MR-2-1-C	3	93	?
NURS 07-01	09/08/10	MR-2-1-C	4	75	?
USGU 10-01	09/02/10	MR-2-1-U	1	100	Y
USGU 10-01	09/02/10	MR-2-1-U	1	100	Y
USGU 10-01	09/02/10	MR-2-1-U	3	58	Y
USGU 10-01	09/02/10	MR-2-1-U	4	93	?
USGU 10-01	09/02/10	MR-2-1-U	4	69	?
USGU 10-01	09/02/10	MR-2-1-U	4	67	?

Riparian Greenline Data									
Reach ID	**Date**	**Reach Type**	**Cell**	**Percent Understory Shrub Cover**	**Percent Bare/Disturbed Ground**	**Percent Riprap**	**Percent Overstory Canopy Cover**	**Right Bank Mean Riparian Zone Width**	**Left Bank Mean Riparian Zone Width**
BASI 08-02	09/01/10	MR-0-2-U	1	8	0	0	30	44	103
BASI 08-02	09/01/10	MR-0-2-U	2	20	0	0	23	24	115
BASI 08-02	09/01/10	MR-0-2-U	3	5	0	0	5	83	68
BASI 08-02	09/01/10	MR-0-2-U	4	0	0	0	15	71	80
BASI 08-02	09/01/10	MR-0-2-U	5	5	0	0	28	85	70
BASI 15-02	09/01/10	MR-0-3-U	1	25	0	0	30	58	188
BASI 15-02	09/01/10	MR-0-3-U	2	20	0	0	18	163	123
BASI 15-02	09/01/10	MR-0-3-U	3	38	0	0	23	143	165
BASI 15-02	09/01/10	MR-0-3-U	4	48	0	0	13	140	140
BASI 15-02	09/01/10	MR-0-3-U	5	30	0	0	28	198	44
BISO 04-02	08/31/10	MR-0-2-U	1	38	0	0	0	115	16
BISO 04-02	08/31/10	MR-0-2-U	2	8	0	0	0	150	11
BISO 04-02	08/31/10	MR-0-2-U	3	3	3	0	0	145	23
BISO 04-02	08/31/10	MR-0-2-U	4	20	0	0	0	148	41
BISO 04-02	08/31/10	MR-0-2-U	5	0	28	0	0	175	35
BISO 11-01	08/31/10	MR-0-3-U	1	78	0	0	0	170	35
BISO 11-01	08/31/10	MR-0-3-U	2	53	0	0	10	198	48
BISO 11-01	08/31/10	MR-0-3-U	3	43	0	0	3	55	193
BISO 11-01	08/31/10	MR-0-3-U	4	48	0	0	5	58	140
BISO 11-01	08/31/10	MR-0-3-U	5	45	8	0	0	80	21
BLDR 12-04	09/01/10	MR-0-4-U	1	55	0	5	0	34	14
BLDR 12-04	09/01/10	MR-0-4-U	2	38	0	35	0	83	10
BLDR 12-04	09/01/10	MR-0-4-U	3	48	0	30	0	70	12
BLDR 12-04	09/01/10	MR-0-4-U	4	65	0	23	0	53	23
BLDR 12-04	09/01/10	MR-0-4-U	5	45	8	0	0	21	120
BLDR 13-04	09/07/10	MR-0-4-U	1	23	0	50	0	195	200
BLDR 13-04	09/07/10	MR-0-4-U	2	30	23	0	8	200	200
BLDR 13-04	09/07/10	MR-0-4-U	3	23	40	10	0	200	200
BLDR 13-04	09/07/10	MR-0-4-U	4	25	8	3	0	200	200
BLDR 13-04	09/07/10	MR-0-4-U	5	8	15	0	0	200	200
BLDR 13-10	09/08/10	MR-0-4-U	1	3	43	5	18	72	198
BLDR 13-10	09/08/10	MR-0-4-U	2	10	63	0	0	103	197
BLDR 13-10	09/08/10	MR-0-4-U	3	0	53	0	0	197	113
BLDR 13-10	09/08/10	MR-0-4-U	4	5	68	0	5	142	158
BLDR 13-10	09/08/10	MR-0-4-U	5	3	58	0	0	75	192
BLDR 13-23	09/10/10	MR-0-4-U	1	13	43	0	0	24	200
BLDR 13-23	09/10/10	MR-0-4-U	2	8	40	0	0	26	144
BLDR 13-23	09/10/10	MR-0-4-U	3	5	43	0	0	90	100
BLDR 13-23	09/10/10	MR-0-4-U	4	48	25	5	0	56	46
BLDR 13-23	09/10/10	MR-0-4-U	5	25	35	0	0	46	105
BLDR 13-33	09/10/10	MR-0-4-U	1	83	43	0	0	200	70
BLDR 13-33	09/10/10	MR-0-4-U	2	68	43	0	0	200	94
BLDR 13-33	09/10/10	MR-0-4-U	3	53	43	0	0	200	200
BLDR 13-33	09/10/10	MR-0-4-U	4	53	43	0	0	200	200
BLDR 13-33	09/10/10	MR-0-4-U	5	58	50	0	5	200	154
CATA 18-01	09/02/10	MR-2-2-U	1	43	0	0	15	65	200
CATA 18-01	09/02/10	MR-2-2-U	2	63	0	0	38	53	200
CATA 18-01	09/02/10	MR-2-2-U	3	48	0	0	8	55	200
CATA 18-01	09/02/10	MR-2-2-U	4	35	8	0	40	68	145
CATA 18-01	09/02/10	MR-2-2-U	5	23	18	0	38	58	150
ELKH 23-01	09/09/10	MR-2-3-C	1	43	3	0	5	70	200
ELKH 23-01	09/09/10	MR-2-3-C	2	38	3	0	0	60	200
ELKH 23-01	09/09/10	MR-2-3-C	3	80	8	0	5	60	200
ELKH 23-01	09/09/10	MR-2-3-C	4	63	5	0	10	50	200
ELKH 23-01	09/09/10	MR-2-3-C	5	50	13	0	18	30	200

Riparian Greenline Data									
Reach ID	Date	Reach Type	Cell	Percent Understory Shrub Cover	Percent Bare/Disturbed Ground	Percent Riprap	Percent Overstory Canopy Cover	Right Bank Mean Riparian Zone Width	Left Bank Mean Riparian Zone Width
ELKH 28-01	09/09/10	MR-2-3-U	1	65	45	0	18	200	95
ELKH 28-01	09/09/10	MR-2-3-U	2	80	48	0	15	200	60
ELKH 28-01	09/09/10	MR-2-3-U	3	88	53	0	28	200	60
ELKH 28-01	09/09/10	MR-2-3-U	4	80	53	0	0	200	58
ELKH 28-01	09/09/10	MR-2-3-U	5	95	43	0	0	200	115
HIOR 09-01	09/09/10	MR-4-2-U	1	15	5	0	35	200	65
HIOR 09-01	09/09/10	MR-4-2-U	2	15	25	0	35	200	60
HIOR 09-01	09/09/10	MR-4-2-U	3	15	5	0	0	200	55
HIOR 09-01	09/09/10	MR-4-2-U	4	45	0	0	35	200	40
HIOR 09-01	09/09/10	MR-4-2-U	5	40	0	0	35	200	40
HIOR 15-01	09/02/10	MR-4-2-U	1	15	0	0	0	200	20
HIOR 15-01	09/02/10	MR-4-2-U	2	10	0	0	5	200	30
HIOR 15-01	09/02/10	MR-4-2-U	3	20	10	0	40	200	35
HIOR 15-01	09/02/10	MR-4-2-U	4	25	0	0	5	200	28
HIOR 15-01	09/02/10	MR-4-2-U	5	35	0	0	15	200	25
LBLR 32-01	09/03/10	MR-2-3-C	1	83	10	0	35	200	88
LBLR 32-01	09/03/10	MR-2-3-C	2	88	15	0	28	200	83
LBLR 32-01	09/03/10	MR-2-3-C	3	78	0	0	28	200	88
LBLR 32-01	09/03/10	MR-2-3-C	4	83	0	0	15	200	95
LBLR 32-01	09/03/10	MR-2-3-C	5	73	5	0	8	200	113
LBLR 37-01	09/03/10	MR-0-3-U	1	85	13	0	0	200	21
LBLR 37-01	09/03/10	MR-0-3-U	2	83	13	0	0	200	26
LBLR 37-01	09/03/10	MR-0-3-U	3	73	20	0	0	200	43
LBLR 37-01	09/03/10	MR-0-3-U	4	53	8	0	0	200	31
LBLR 37-01	09/03/10	MR-0-3-U	5	80	8	0	0	200	49
LOWL 08-01	08/31/10	MR-0-2-U	1	10	0	0	0	18	183
LOWL 08-01	08/31/10	MR-0-2-U	2	28	0	0	0	108	118
LOWL 08-01	08/31/10	MR-0-2-U	3	38	0	0	0	15	175
LOWL 08-01	08/31/10	MR-0-2-U	4	30	0	0	0	26	179
LOWL 08-01	08/31/10	MR-0-2-U	5	65	0	0	0	85	148
MCCA 22-01	09/07/10	MR-4-2-U	1	85	5	0	45	200	200
MCCA 22-01	09/07/10	MR-4-2-U	2	75	0	0	50	200	200
MCCA 22-01	09/07/10	MR-4-2-U	3	60	10	0	35	200	200
MCCA 22-01	09/07/10	MR-4-2-U	4	90	35	0	20	200	200
MCCA 22-01	09/07/10	MR-4-2-U	5	60	5	0	45	200	200
MUSK 18-01-02	09/08/10	MR-2-2-U	1	65	8	0	3	100	200
MUSK 18-01-02	09/08/10	MR-2-2-U	2	73	13	0	18	100	200
MUSK 18-01-02	09/08/10	MR-2-2-U	3	88	18	0	20	100	200
MUSK 18-01-02	09/08/10	MR-2-2-U	4	60	28	0	18	100	200
MUSK 18-01-02	09/08/10	MR-2-2-U	5	75	18	0	8	100	200
MUSK 22-08	09/07/10	MR-0-3-U	1	0	20	0	0	200	200
MUSK 22-08	09/07/10	MR-0-3-U	2	0	25	0	0	200	200
MUSK 22-08	09/07/10	MR-0-3-U	3	0	8	0	0	200	200
MUSK 22-08	09/07/10	MR-0-3-U	4	0	8	0	0	200	200
MUSK 22-08	09/07/10	MR-0-3-U	5	0	3	0	0	200	200
NFLB 42-01	09/03/10	MR-4-2-C	1	93	23	0	23	100	100
NFLB 42-01	09/03/10	MR-4-2-C	2	75	8	0	8	100	100
NFLB 42-01	09/03/10	MR-4-2-C	3	98	15	0	33	100	100
NFLB 42-01	09/03/10	MR-4-2-C	4	88	23	0	35	100	100
NFLB 42-01	09/03/10	MR-4-2-C	5	95	13	0	3	100	100
NURS 07-01	09/08/10	MR-2-1-C	1	15	0	0	5	200	200
NURS 07-01	09/08/10	MR-2-1-C	2	20	0	0	0	200	200
NURS 07-01	09/08/10	MR-2-1-C	3	50	0	0	0	200	200
NURS 07-01	09/08/10	MR-2-1-C	4	30	0	0	0	200	200
NURS 07-01	09/08/10	MR-2-1-C	5	55	0	0	15	200	200
USGU 10-01	09/02/10	MR-2-1-U	1	5	48	0	28	73	143
USGU 10-01	09/02/10	MR-2-1-U	2	5	53	0	23	68	133
USGU 10-01	09/02/10	MR-2-1-U	3	3	68	0	28	123	88
USGU 10-01	09/02/10	MR-2-1-U	4	3	60	5	8	148	63
USGU 10-01	09/02/10	MR-2-1-U	5	0	28	0	63	140	70

Streambank Erosion Data										
Reach ID	Date	Reach Type	Erosion Rate	Number of Banks	Mean BEHI Score	Mean Rating	Length of Eroding Bank (Feet)	Percent of Reach with Eroding Bank	Reach Sediment Load (Tons/Year)	Total Sediment Load per 1000 Feet (Tons/Year)
BASI 08-02	09/01/10	MR-0-2-U	Active	2	34.1	high	65	3.3	7.4	7.4
BASI 08-02	09/01/10	MR-0-2-U	Slow	1	23.0	moderate	16	0.8	0.2	0.2
BASI 08-02	09/01/10	MR-0-2-U	Total	3	30.4	high	81	4.1	7.6	7.6
BASI 15-02	09/01/10	MR-0-3-U	Active	4	36.0	high	156	7.8	21.9	21.9
BASI 15-02	09/01/10	MR-0-3-U	Slow	3	24.1	moderate	44	2.2	1.1	1.1
BASI 15-02	09/01/10	MR-0-3-U	Total	7	30.9	high	200	10.0	23.0	23.0
BISO 04-02	08/31/10	MR-0-2-U	Active	4	36.9	high	47	2.4	1.6	1.6
BISO 04-02	08/31/10	MR-0-2-U	Slow	13	33.2	high	190	9.5	8.7	8.7
BISO 04-02	08/31/10	MR-0-2-U	Total	17	34.1	high	237	11.9	10.3	10.3
BISO 11-01	08/31/10	MR-0-3-U	Active	7	38.0	high	208	10.4	19.1	19.1
BISO 11-01	08/31/10	MR-0-3-U	Slow	1	29.3	moderate	52	2.6	1.5	1.5
BISO 11-01	08/31/10	MR-0-3-U	Total	8	36.9	high	260	13.0	20.6	20.6
BLDR 12-04	09/01/10	MR-0-4-U	Active	0			0	0.0	0.0	0.0
BLDR 12-04	09/01/10	MR-0-4-U	Slow	2	24.9	moderate	19	0.6	0.4	0.3
BLDR 12-04	09/01/10	MR-0-4-U	Total	2	24.9	moderate	19	0.6	0.4	0.3
BLDR 13-04	09/07/10	MR-0-4-U	Active	10	30.8	high	473	15.8	54.7	36.5
BLDR 13-04	09/07/10	MR-0-4-U	Slow	2	24.6	moderate	30	1.0	0.8	0.6
BLDR 13-04	09/07/10	MR-0-4-U	Total	12	29.7	moderate	503	16.8	55.5	37.0
BLDR 13-10	09/08/10	MR-0-4-U	Active	13	25.8	moderate	1240	41.3	41.9	27.9
BLDR 13-10	09/08/10	MR-0-4-U	Slow	0			0	0.0	0.0	0.0
BLDR 13-10	09/08/10	MR-0-4-U	Total	13	25.8	moderate	1240	41.3	41.9	27.9
BLDR 13-23	09/10/10	MR-0-4-U	Active	9	34.3	high	1233	30.8	157.6	78.8
BLDR 13-23	09/10/10	MR-0-4-U	Slow	1	25.2	moderate	62	1.6	1.5	0.8
BLDR 13-23	09/10/10	MR-0-4-U	Total	10	33.4	high	1295	32.4	159.2	79.6
BLDR 13-33	09/10/10	MR-0-4-U	Active	12	33.4	high	1300	32.5	130.6	65.3
BLDR 13-33	09/10/10	MR-0-4-U	Slow	3	29.3	moderate	246	6.2	13.5	6.7
BLDR 13-33	09/10/10	MR-0-4-U	Total	15	32.6	high	1546	38.7	144.1	72.0
CATA 18-01	09/02/10	MR-2-2-U	Active	0			0	0.0	0.0	0.0
CATA 18-01	09/02/10	MR-2-2-U	Slow	1	27.7	moderate	18	0.9	0.6	0.6
CATA 18-01	09/02/10	MR-2-2-U	Total	1	27.7	moderate	18	0.9	0.6	0.6
ELKH 23-01	09/09/10	MR-2-3-C	Active	0			0	0.0	0.0	0.0
ELKH 23-01	09/09/10	MR-2-3-C	Slow	7	27.3	moderate	51	2.6	1.6	1.6
ELKH 23-01	09/09/10	MR-2-3-C	Total	7	27.3	moderate	51	2.6	1.6	1.6
ELKH 28-01	09/09/10	MR-2-3-U	Active	13	28.8	moderate	174	8.7	8.6	8.6
ELKH 28-01	09/09/10	MR-2-3-U	Slow	0			0	0.0	0.0	0.0
ELKH 28-01	09/09/10	MR-2-3-U	Total	13	28.8	moderate	174	8.7	8.6	8.6
HIOR 09-01	09/09/10	MR-4-2-U	Active	1	37.5	high	6	0.6	0.7	1.3
HIOR 09-01	09/09/10	MR-4-2-U	Slow	0			0	0.0	0.0	0.0
HIOR 09-01	09/09/10	MR-4-2-U	Total	1	37.5	high	6	0.6	0.7	1.3
HIOR 15-01	09/02/10	MR-4-2-U	Active	1	28.1	moderate	10	1.0	0.1	0.2
HIOR 15-01	09/02/10	MR-4-2-U	Slow	6	22.7	moderate	38	3.8	0.6	1.2
HIOR 15-01	09/02/10	MR-4-2-U	Total	7	23.5	moderate	48	4.8	0.7	1.4
LBLR 32-01	09/03/10	MR-2-3-C	Active	0			0	0.0	0.0	0.0
LBLR 32-01	09/03/10	MR-2-3-C	Slow	11	19.8	low	149	7.5	1.6	1.6
LBLR 32-01	09/03/10	MR-2-3-C	Total	11	19.8	low	149	7.5	1.6	1.6
LBLR 37-01	09/03/10	MR-0-3-U	Active	2	37.0	high	43	2.2	9.4	9.4
LBLR 37-01	09/03/10	MR-0-3-U	Slow	8	26.6	moderate	157	7.9	16.1	16.1
LBLR 37-01	09/03/10	MR-0-3-U	Total	10	28.7	moderate	200	10.0	25.5	25.5
LOWL 08-01	08/31/10	MR-0-2-U	Active	0			0	0.0	0.0	0.0
LOWL 08-01	08/31/10	MR-0-2-U	Slow	14	30.4	high	167	8.4	7.9	7.9
LOWL 08-01	08/31/10	MR-0-2-U	Total	14	30.4	high	167	8.4	7.9	7.9
MCCA 22-01	09/07/10	MR-4-2-U	Active	7	32.0	high	50	5.0	2.3	4.6
MCCA 22-01	09/07/10	MR-4-2-U	Slow	11	36.2	high	120	12.0	7.0	14.0
MCCA 22-01	09/07/10	MR-4-2-U	Total	18	34.6	high	170	17.0	9.3	18.6
MUSK 18-01-02	09/08/10	MR-2-2-U	Active	7	26.5	moderate	55	2.8	1.8	1.8
MUSK 18-01-02	09/08/10	MR-2-2-U	Slow	6	19.0	low	62	3.1	0.6	0.6
MUSK 18-01-02	09/08/10	MR-2-2-U	Total	13	23.1	moderate	117	5.9	2.3	2.3
MUSK 22-08	09/07/10	MR-0-3-U	Active	0			0	0.0	0.0	0.0
MUSK 22-08	09/07/10	MR-0-3-U	Slow	30	27.1	moderate	353	17.7	6.1	6.1
MUSK 22-08	09/07/10	MR-0-3-U	Total	30	27.1	moderate	353	17.7	6.1	6.1
NFLB 42-01	09/03/10	MR-4-2-C	Active	11	27.5	moderate	89	4.5	2.8	2.8
NFLB 42-01	09/03/10	MR-4-2-C	Slow	0			0	0.0	0.0	0.0
NFLB 42-01	09/03/10	MR-4-2-C	Total	11	27.5	moderate	89	4.5	2.8	2.8
NURS 07-01	09/08/10	MR-2-1-C	Active	0			0	0.0	0.0	0.0
NURS 07-01	09/08/10	MR-2-1-C	Slow	7	22.6	moderate	24	2.4	0.2	0.4
NURS 07-01	09/08/10	MR-2-1-C	Total	7	22.6	moderate	24	2.4	0.2	0.4
USGU 10-01	09/02/10	MR-2-1-U	Active	0			0	0.0	0.0	0.0
USGU 10-01	09/02/10	MR-2-1-U	Slow	8	25.2	moderate	77	3.9	1.7	1.7
USGU 10-01	09/02/10	MR-2-1-U	Total	8	25.2	moderate	77	3.9	1.7	1.7

Streambank Erosion Data																	
Reach ID	**Reach Type**	**Reach Transportation Load (Tons/Year)**	**Transportation Load (Percent)**	**Reach Riparian Grazing Load (Tons/Year)**	**Riparian Grazing Load (Percent)**	**Reach Cropland Load (Tons/Year)**	**Cropland Load (Percent)**	**Reach Mining Load (Tons/Year)**	**Mining Load (Percent)**	**Reach Silviculture Load (Tons/Year)**	**Silviculture Load (Percent)**	**Reach Irrigation Load (Tons/Year)**	**Irrigation Load (Percent)**	**Reach Natural Load (Tons/Year)**	**Natural Load (Percent)**	**Reach "Other" Load (Tons/Year)**	**"Other" Load (Percent)**
BASI 08-02	MR-0-2-U	2.2	30.0	0.0	0.0	0.0	0.0	3.7	50.0	0.0	0.0	0.0	0.0	1.5	20.0	0.0	0.0
BASI 08-02	MR-0-2-U	0.0	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.1	80.0	0.0	0.0
BASI 08-02	MR-0-2-U	2.2	29.6	0.0	0.0	0.0	0.0	3.7	49.1	0.0	0.0	0.0	0.0	1.6	21.3	0.0	0.0
BASI 15-02	MR-0-3-U	0.0	0.0	0.0	0.0	0.0	0.0	6.6	30.0	4.4	20.0	0.0	0.0	4.4	20.0	6.6	30.0
BASI 15-02	MR-0-3-U	0.0	3.1	0.0	0.0	0.0	0.0	0.3	30.0	0.2	16.9	0.0	0.0	0.6	50.0	0.0	0.0
BASI 15-02	MR-0-3-U	0.0	0.2	0.0	0.0	0.0	0.0	6.9	30.0	4.6	19.8	0.0	0.0	4.9	21.5	6.6	28.5
BISO 04-02	MR-0-2-U	0.0	0.0	1.2	72.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	27.6	0.0	0.0
BISO 04-02	MR-0-2-U	0.0	0.0	4.3	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	50.0	0.0	0.0
BISO 04-02	MR-0-2-U	0.0	0.0	5.5	53.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	46.4	0.0	0.0
BISO 11-01	MR-0-3-U	15.3	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	20.0	0.0	0.0
BISO 11-01	MR-0-3-U	1.2	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	20.0	0.0	0.0
BISO 11-01	MR-0-3-U	16.4	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	20.0	0.0	0.0
BLDR 12-04	MR-0-4-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 12-04	MR-0-4-U	0.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 12-04	MR-0-4-U	0.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-04	MR-0-4-U	0.0	0.0	10.9	19.9	43.2	79.0	0.0	0.0	0.0	0.0	0.6	1.2	0.0	0.0	0.0	0.0
BLDR 13-04	MR-0-4-U	0.0	0.0	0.1	7.4	0.8	92.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-04	MR-0-4-U	0.0	0.0	10.9	19.7	44.0	79.2	0.0	0.0	0.0	0.0	0.6	1.2	0.0	0.0	0.0	0.0
BLDR 13-10	MR-0-4-U	0.0	0.0	33.5	80.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	20.0	0.0	0.0	0.0	0.0
BLDR 13-10	MR-0-4-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-10	MR-0-4-U	0.0	0.0	33.5	80.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	20.0	0.0	0.0	0.0	0.0
BLDR 13-23	MR-0-4-U	0.0	0.0	47.3	30.0	47.3	30.0	0.0	0.0	0.0	0.0	31.5	20.0	31.5	20.0	0.0	0.0
BLDR 13-23	MR-0-4-U	0.0	0.0	0.5	30.0	0.5	30.0	0.0	0.0	0.0	0.0	0.3	20.0	0.3	20.0	0.0	0.0
BLDR 13-23	MR-0-4-U	0.0	0.0	47.8	30.0	47.8	30.0	0.0	0.0	0.0	0.0	31.8	20.0	31.8	20.0	0.0	0.0
BLDR 13-33	MR-0-4-U	12.2	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.7	28.1	60.4	46.2	21.2	16.2
BLDR 13-33	MR-0-4-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	30.0	6.7	50.0	2.7	20.0
BLDR 13-33	MR-0-4-U	12.2	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.8	28.3	67.1	46.6	23.9	16.6
CATA 18-01	MR-2-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CATA 18-01	MR-2-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CATA 18-01	MR-2-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELKH 23-01	MR-2-3-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELKH 23-01	MR-2-3-C	0.8	48.7	0.8	51.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
ELKH 23-01	MR-2-3-C	0.8	48.7	0.8	51.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
ELKH 28-01	MR-2-3-U	0.0	0.0	6.1	70.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.9	0.8	9.7	1.2	13.4
ELKH 28-01	MR-2-3-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELKH 28-01	MR-2-3-U	0.0	0.0	6.1	70.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.9	0.8	9.7	1.2	13.4
HIOR 09-01	MR-4-2-U	0.1	20.0	0.4	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.0
HIOR 09-01	MR-4-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HIOR 09-01	MR-4-2-U	0.1	20.0	0.4	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.0
HIOR 15-01	MR-4-2-U	0.1	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	30.0
HIOR 15-01	MR-4-2-U	0.3	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.0	0.2	30.0
HIOR 15-01	MR-4-2-U	0.3	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.0	0.2	30.0
LBLR 32-01	MR-2-3-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LBLR 32-01	MR-2-3-C	0.3	18.6	0.0	0.0	0.0	0.0	0.3	18.7	0.3	16.3	0.0	0.0	0.7	46.3	0.0	0.0
LBLR 32-01	MR-2-3-C	0.3	18.6	0.0	0.0	0.0	0.0	0.3	18.7	0.3	16.3	0.0	0.0	0.7	46.3	0.0	0.0
LBLR 37-01	MR-0-3-U	7.4	79.4	0.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	19.4	0.0	0.0
LBLR 37-01	MR-0-3-U	12.9	80.0	1.5	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	10.9	0.0	0.0
LBLR 37-01	MR-0-3-U	20.3	79.7	1.6	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	14.0	0.0	0.0
LOWL 08-01	MR-0-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LOWL 08-01	MR-0-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	90.0	0.8	10.0
LOWL 08-01	MR-0-2-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	90.0	0.8	10.0
MCCA 22-01	MR-4-2-U	0.0	0.0	1.6	68.8	0.0	0.0	0.0	0.0	0.3	12.6	0.0	0.0	0.4	18.6	0.0	0.0
MCCA 22-01	MR-4-2-U	0.0	0.0	4.7	66.9	0.0	0.0	0.0	0.0	1.5	21.0	0.0	0.0	0.9	12.2	0.0	0.0
MCCA 22-01	MR-4-2-U	0.0	0.0	6.3	67.4	0.0	0.0	0.0	0.0	1.8	18.9	0.0	0.0	1.3	13.8	0.0	0.0
MUSK 18-01-02	MR-2-2-U	0.0	0.0	1.1	63.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	36.5	0.0	0.0
MUSK 18-01-02	MR-2-2-U	0.0	0.0	0.4	67.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	32.2	0.0	0.0
MUSK 18-01-02	MR-2-2-U	0.0	0.0	1.5	64.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	35.4	0.0	0.0
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	100.0	0.0	0.0	0.0	0.0
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	100.0	0.0	0.0	0.0	0.0
NFLB 42-01	MR-4-2-C	0.8	26.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	73.2	0.0	0.0
NFLB 42-01	MR-4-2-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NFLB 42-01	MR-4-2-C	0.8	26.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	73.2	0.0	0.0
NURS 07-01	MR-2-1-C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NURS 07-01	MR-2-1-C	0.0	0.0	0.1	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	69.9	0.0	0.0
NURS 07-01	MR-2-1-C	0.0	0.0	0.1	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	69.9	0.0	0.0
USGU 10-01	MR-2-1-U	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
USGU 10-01	MR-2-1-U	0.5	30.0	0.0	0.0	0.0	0.0	0.5	30.0	0.0	0.0	0.0	0.0	0.3	17.7	0.4	22.3
USGU 10-01	MR-2-1-U	0.5	30.0	0.0	0.0	0.0	0.0	0.5	30.0	0.0	0.0	0.0	0.0	0.3	17.7	0.4	22.3

Streambank Erosion Data							
Reach ID	Reach Type	Coarse Gravel >6mm Load (Tons/Year)	Coarse Gravel >6mm (Percent)	Fine Gravel 6-2mm Load (Tons/Year)	Fine Gravel 6-2mm (Percent)	Sand/Clay <2mm Load (Tons/Year)	Sand/Clay <2mm (Percent)
BASI 08-02	MR-0-2-U	2.1	28.5	3.1	41.5	2.2	30.0
BASI 08-02	MR-0-2-U	0.0	10.0	0.0	20.0	0.1	70.0
BASI 08-02	MR-0-2-U	2.1	28.0	3.1	41.1	2.3	30.9
BASI 15-02	MR-0-3-U	5.9	27.1	8.5	38.9	7.4	34.0
BASI 15-02	MR-0-3-U	0.1	10.0	0.2	20.0	0.8	70.0
BASI 15-02	MR-0-3-U	6.0	26.2	8.7	38.0	8.2	35.8
BISO 04-02	MR-0-2-U	0.2	10.0	0.5	27.9	1.0	62.1
BISO 04-02	MR-0-2-U	0.0	0.0	0.9	10.0	7.8	90.0
BISO 04-02	MR-0-2-U	0.2	1.6	1.3	12.9	8.8	85.6
BISO 11-01	MR-0-3-U	8.0	41.9	7.1	37.1	4.0	21.0
BISO 11-01	MR-0-3-U	0.6	40.0	0.3	20.0	0.6	40.0
BISO 11-01	MR-0-3-U	8.6	41.8	7.4	35.9	4.6	22.3
BLDR 12-04	MR-0-4-U	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 12-04	MR-0-4-U	0.0	6.3	0.1	26.3	0.3	67.4
BLDR 12-04	MR-0-4-U	0.0	6.3	0.1	26.3	0.3	67.4
BLDR 13-04	MR-0-4-U	7.0	12.8	7.4	13.6	40.3	73.6
BLDR 13-04	MR-0-4-U	0.2	20.0	0.2	20.0	0.5	60.0
BLDR 13-04	MR-0-4-U	7.2	12.9	7.6	13.7	40.8	73.4
BLDR 13-10	MR-0-4-U	7.6	18.3	4.2	10.0	30.0	71.7
BLDR 13-10	MR-0-4-U	0.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-10	MR-0-4-U	7.6	18.3	4.2	10.0	30.0	71.7
BLDR 13-23	MR-0-4-U	4.4	2.8	4.4	2.8	148.8	94.4
BLDR 13-23	MR-0-4-U	0.0	0.0	0.0	0.0	1.5	100.0
BLDR 13-23	MR-0-4-U	4.4	2.8	4.4	2.8	150.3	94.4
BLDR 13-33	MR-0-4-U	7.3	5.6	13.1	10.0	110.2	84.4
BLDR 13-33	MR-0-4-U	1.3	10.0	1.3	10.0	10.8	80.0
BLDR 13-33	MR-0-4-U	8.7	6.0	14.4	10.0	121.0	84.0
CATA 18-01	MR-2-2-U	0.0	0.0	0.0	0.0	0.0	0.0
CATA 18-01	MR-2-2-U	0.1	20.0	0.1	10.0	0.4	70.0
CATA 18-01	MR-2-2-U	0.1	20.0	0.1	10.0	0.4	70.0
ELKH 23-01	MR-2-3-C	0.0	0.0	0.0	0.0	0.0	0.0
ELKH 23-01	MR-2-3-C	0.5	30.0	0.3	20.0	0.8	50.0
ELKH 23-01	MR-2-3-C	0.5	30.0	0.3	20.0	0.8	50.0
ELKH 28-01	MR-2-3-U	0.6	6.6	1.5	17.5	6.5	76.0
ELKH 28-01	MR-2-3-U	0.0	0.0	0.0	0.0	0.0	0.0
ELKH 28-01	MR-2-3-U	0.6	6.6	1.5	17.5	6.5	76.0
HIOR 09-01	MR-4-2-U	0.1	10.0	0.1	10.0	0.5	80.0
HIOR 09-01	MR-4-2-U	0.0	0.0	0.0	0.0	0.0	0.0
HIOR 09-01	MR-4-2-U	0.1	10.0	0.1	10.0	0.5	80.0
HIOR 15-01	MR-4-2-U	0.0	0.0	0.0	20.0	0.1	80.0
HIOR 15-01	MR-4-2-U	0.0	0.0	0.1	20.0	0.5	80.0
HIOR 15-01	MR-4-2-U	0.0	0.0	0.1	20.0	0.5	80.0
LBLR 32-01	MR-2-3-C	0.0	0.0	0.0	0.0	0.0	0.0
LBLR 32-01	MR-2-3-C	0.1	6.0	0.2	10.0	1.3	84.0
LBLR 32-01	MR-2-3-C	0.1	6.0	0.2	10.0	1.3	84.0
LBLR 37-01	MR-0-3-U	0.1	1.3	1.9	20.6	7.3	78.1
LBLR 37-01	MR-0-3-U	0.0	0.0	3.2	20.0	12.9	80.0
LBLR 37-01	MR-0-3-U	0.1	0.5	5.2	20.2	20.2	79.3
LOWL 08-01	MR-0-2-U	0.0	0.0	0.0	0.0	0.0	0.0
LOWL 08-01	MR-0-2-U	0.0	0.0	1.6	20.0	6.3	80.0
LOWL 08-01	MR-0-2-U	0.0	0.0	1.6	20.0	6.3	80.0
MCCA 22-01	MR-4-2-U	0.0	0.0	0.5	20.5	1.8	79.5
MCCA 22-01	MR-4-2-U	0.0	0.0	2.1	30.0	4.9	70.0
MCCA 22-01	MR-4-2-U	0.0	0.0	2.6	27.6	6.7	72.4
MUSK 18-01-02	MR-2-2-U	0.5	26.8	0.2	10.0	1.1	63.2
MUSK 18-01-02	MR-2-2-U	0.2	30.0	0.1	20.0	0.3	50.0
MUSK 18-01-02	MR-2-2-U	0.6	27.6	0.3	12.5	1.4	59.9
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	0.0	0.0
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	6.1	100.0
MUSK 22-08	MR-0-3-U	0.0	0.0	0.0	0.0	6.1	100.0
NFLB 42-01	MR-4-2-C	0.6	22.9	0.7	26.3	1.4	50.8
NFLB 42-01	MR-4-2-C	0.0	0.0	0.0	0.0	0.0	0.0
NFLB 42-01	MR-4-2-C	0.6	22.9	0.7	26.3	1.4	50.8
NURS 07-01	MR-2-1-C	0.0	0.0	0.0	0.0	0.0	0.0
NURS 07-01	MR-2-1-C	0.0	10.0	0.0	10.0	0.1	80.0
NURS 07-01	MR-2-1-C	0.0	10.0	0.0	10.0	0.1	80.0
USGU 10-01	MR-2-1-U	0.0	0.0	0.0	0.0	0.0	0.0
USGU 10-01	MR-2-1-U	0.1	3.0	0.5	27.0	1.2	70.0
USGU 10-01	MR-2-1-U	0.1	3.0	0.5	27.0	1.2	70.0

ATTACHMENT C – Photo Log

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	626	bank 1
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	627	bank 1 u/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	628	bank 2
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	629	bank 2 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	630	bank 3
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	631	bank 3 u/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	632	bank 4
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	633	bank 4 u/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	634	bank 5
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	635	bank 5 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	636	bank 6
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	637	bank 6 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	638	bank 7
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	639	bank 7 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	640	bank 8
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	641	bank 8 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	642	bank 9
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	643	bank 9 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	644	bank 10
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	645	bank 10 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	646	bank 11
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	647	bank 11 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	648	bank 12
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	649	bank 12 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	650	bank 13
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	651	bank 13 d/s
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	652	bank 14
Lowland Creek	LOWL 08-01	8/31/2010	BEHI	653	bank 14 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	654	bank 1
Bison Creek	BISO 04-02	8/31/2010	BEHI	655	bank 1 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	656	bank 2
Bison Creek	BISO 04-02	8/31/2010	BEHI	657	bank 2 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	658	bank 3
Bison Creek	BISO 04-02	8/31/2010	BEHI	659	bank 3 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	660	bank 4
Bison Creek	BISO 04-02	8/31/2010	BEHI	661	bank 4 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	662	bank 5
Bison Creek	BISO 04-02	8/31/2010	BEHI	663	bank 5 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	664	bank 6
Bison Creek	BISO 04-02	8/31/2010	BEHI	665	bank 6 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	666	bank 7
Bison Creek	BISO 04-02	8/31/2010	BEHI	667	bank 7 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	668	bank 8
Bison Creek	BISO 04-02	8/31/2010	BEHI	669	bank 8 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	670	bank 9
Bison Creek	BISO 04-02	8/31/2010	BEHI	671	bank 9 d/s

Attachment C - Table C-1. Photo log.					
Stream	**Reach ID**	**Date**	**Camera**	**Photo**	**Description**
Bison Creek	BISO 04-02	8/31/2010	BEHI	672	bank 10
Bison Creek	BISO 04-02	8/31/2010	BEHI	673	bank 10 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	674	bank 11
Bison Creek	BISO 04-02	8/31/2010	BEHI	675	bank 11 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	676	bank 12
Bison Creek	BISO 04-02	8/31/2010	BEHI	677	bank 12 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	678	bank 13
Bison Creek	BISO 04-02	8/31/2010	BEHI	679	bank 13 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	680	bank 14
Bison Creek	BISO 04-02	8/31/2010	BEHI	681	bank 14 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	682	bank 15
Bison Creek	BISO 04-02	8/31/2010	BEHI	683	bank 15 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	684	bank 16
Bison Creek	BISO 04-02	8/31/2010	BEHI	685	bank 16 d/s
Bison Creek	BISO 04-02	8/31/2010	BEHI	686	bank 17
Bison Creek	BISO 04-02	8/31/2010	BEHI	687	bank 17 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	688	bank 1
Bison Creek	BISO 11-01	8/31/2010	BEHI	689	bank 1 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	690	bank 2
Bison Creek	BISO 11-01	8/31/2010	BEHI	691	bank 2 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	692	bank 3
Bison Creek	BISO 11-01	8/31/2010	BEHI	693	bank 3 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	694	bank 4
Bison Creek	BISO 11-01	8/31/2010	BEHI	695	bank 4 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	696	bank 5
Bison Creek	BISO 11-01	8/31/2010	BEHI	697	bank 5 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	698	bank 6
Bison Creek	BISO 11-01	8/31/2010	BEHI	699	bank 6 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	700	bank 7
Bison Creek	BISO 11-01	8/31/2010	BEHI	701	bank 7 d/s
Bison Creek	BISO 11-01	8/31/2010	BEHI	702	bank 8
Bison Creek	BISO 11-01	8/31/2010	BEHI	703	bank 8 d/s
Basin Creek	BASI 08-02	9/1/2010	BEHI	704	bank 1
Basin Creek	BASI 08-02	9/1/2010	BEHI	705	bank 1 d/s
Basin Creek	BASI 08-02	9/1/2010	BEHI	706	bank 2
Basin Creek	BASI 08-02	9/1/2010	BEHI	707	bank 2 d/s
Basin Creek	BASI 08-02	9/1/2010	BEHI	708	bank 3
Basin Creek	BASI 08-02	9/1/2010	BEHI	709	bank 3 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	710	bank 1
Basin Creek	BASI 15-02	9/1/2010	BEHI	711	bank 1 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	712	bank 2
Basin Creek	BASI 15-02	9/1/2010	BEHI	713	bank 2 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	714	bank 3
Basin Creek	BASI 15-02	9/1/2010	BEHI	715	bank 3 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	716	bank 4
Basin Creek	BASI 15-02	9/1/2010	BEHI	717	bank 4 d/s

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Basin Creek	BASI 15-02	9/1/2010	BEHI	718	bank 5
Basin Creek	BASI 15-02	9/1/2010	BEHI	719	bank 5 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	720	bank 6
Basin Creek	BASI 15-02	9/1/2010	BEHI	721	bank 6 d/s
Basin Creek	BASI 15-02	9/1/2010	BEHI	722	bank 7 (discard)
Basin Creek	BASI 15-02	9/1/2010	BEHI	723	bank 7
Basin Creek	BASI 15-02	9/1/2010	BEHI	724	bank 7 u/s
Boulder Creek	BLDR 12-04	9/1/2010	BEHI	725	bank 1
Boulder Creek	BLDR 12-04	9/1/2010	BEHI	726	bank 1 d/s
Boulder Creek	BLDR 12-04	9/1/2010	BEHI	727	bank 2
Boulder Creek	BLDR 12-04	9/1/2010	BEHI	728	bank 2 d/s
Boulder Creek	BLDR 12-04	9/1/2010	BEHI	729	Example of rip-rap in reach
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	730	bank example, straight stretch
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	731	bank example, bend
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	732	bank 1
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	733	bank 1 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	734	bank 2
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	735	bank 2 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	736	lwd jam (cut logs)
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	737	lwd jam (cut logs)
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	738	bank 5
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	739	bank 5 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	740	bank 6
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	741	bank 6 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	742	bank 7
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	743	bank 7 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	744	bank 8
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	745	bank 8 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	746	bank 9
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	747	bank 9 d/s
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	748	old road crossing
Uncle Sam Gulch	USGU 10-01	9/2/2010	BEHI	749	d/s at old road crossing
Cataract Creek	CATA 18-01	9/2/2010	BEHI	750	Const. near Uncle Sam Gul
Cataract Creek	CATA 18-01	9/2/2010	BEHI	751	Const. near Uncle Sam Gul
Cataract Creek	CATA 18-01	9/2/2010	BEHI	752	Const. near Uncle Sam Gul
Cataract Creek	CATA 18-01	9/2/2010	BEHI	753	Const. near Uncle Sam Gul
Cataract Creek	CATA 18-01	9/2/2010	BEHI	754	old placer tailings
Cataract Creek	CATA 18-01	9/2/2010	BEHI	755	old placer tailings
Cataract Creek	CATA 18-01	9/2/2010	BEHI	756	old placer tailings
Cataract Creek	CATA 18-01	9/2/2010	BEHI	757	old placer tailings
Cataract Creek	CATA 18-01	9/2/2010	BEHI	758	bank 1
Cataract Creek	CATA 18-01	9/2/2010	BEHI	759	bank 1 d/s
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	760	bank 1
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	761	bank 1 d/s
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	762	bank 3
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	763	bank 3 d/s

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	764	bank 4
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	765	bank 4 d/s
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	766	bank 5
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	767	bank 5 d/s
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	768	bank 6
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	769	bank 6 d/s
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	770	bank 7
High Ore Creek	HIOR 15-01	9/2/2010	BEHI	771	bank 7 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	772	bank 1
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	773	bank 1 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	774	bank 2
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	775	bank 3
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	776	bank 3 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	777	bank 4
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	778	bank 4 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	779	bank 5
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	780	bank 5 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	781	bank 6
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	782	bank 6 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	783	bank 7
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	784	bank 7 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	785	bank 8
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	786	bank 8 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	787	bank 9
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	788	bank 9 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	789	bank 10
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	790	bank 10 d/s
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	791	bank 11
Little Boulder River	LBLR 32-01	9/3/2010	BEHI	792	bank 11 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	793	bank 1
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	794	bank 1 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	795	bank 2
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	796	bank 2 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	797	bank 3
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	798	bank 3 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	799	bank 4
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	800	bank 4 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	801	bank 5
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	802	bank 5 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	803	bank 6
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	804	bank 6 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	805	bank 7
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	806	bank 7 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	807	bank 8
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	808	bank 8 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	809	bank 9

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Stream	Reach ID	Date	Camera	Photo	Description
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	810	bank 9 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	811	bank 10
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	812	bank 10 d/s
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	813	bank 11
North Fork Little Boulder River	NFLB 42-01	9/3/2010	BEHI	814	bank 11 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	815	bank 1
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	816	bank 1 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	817	bank 2
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	818	bank 2 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	819	bank 3
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	820	bank 3 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	821	bank 4
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	822	bank 4 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	823	bank 5
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	824	bank 5 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	825	bank 6
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	826	bank 6 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	827	bank 7
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	828	bank 7 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	829	bank 8
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	830	bank 8 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	831	bank 9
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	832	bank 9 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	833	bank 10
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	834	bank 10 d/s
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	835	bank 11
Little Boulder River	LBLR 37-01	9/3/2010	BEHI	836	bank 11 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	837	bank 1
Boulder River	BLDR 13-04	9/7/2010	BEHI	838	bank 1 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	839	bank 2
Boulder River	BLDR 13-04	9/7/2010	BEHI	840	bank 2 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	841	bank 3
Boulder River	BLDR 13-04	9/7/2010	BEHI	842	bank 3 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	843	bank 4
Boulder River	BLDR 13-04	9/7/2010	BEHI	844	bank 4 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	845	bank 5
Boulder River	BLDR 13-04	9/7/2010	BEHI	846	bank 5 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	847	bank 6
Boulder River	BLDR 13-04	9/7/2010	BEHI	848	bank 6 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	849	bank 7
Boulder River	BLDR 13-04	9/7/2010	BEHI	850	bank 7 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	851	bank 8
Boulder River	BLDR 13-04	9/7/2010	BEHI	852	bank 8 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	853	bank 9
Boulder River	BLDR 13-04	9/7/2010	BEHI	854	bank 9 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	855	bank 10

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Stream	Reach ID	Date	Camera	Photo	Description
Boulder River	BLDR 13-04	9/7/2010	BEHI	856	bank 10 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	857	bank 11
Boulder River	BLDR 13-04	9/7/2010	BEHI	858	bank 11 d/s
Boulder River	BLDR 13-04	9/7/2010	BEHI	859	bank 12
Boulder River	BLDR 13-04	9/7/2010	BEHI	860	bank 12 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	861	bank 1
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	862	bank 1 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	863	bank 2
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	864	bank 2 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	865	bank 3
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	866	discard
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	867	bank 3 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	868	bank 4
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	869	bank 4 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	870	bank 5
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	871	bank 5 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	872	bank 7
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	873	bank 7 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	874	bank 9
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	875	discard
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	876	bank 9 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	877	bank 10
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	878	bank 10 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	879	bank 11
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	880	bank 11 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	881	bank 13
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	882	bank 13 d/s
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	883	bank 18
McCarty Creek	MCCA 22-01	9/7/2010	BEHI	884	bank 18 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	885	bank 1
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	886	bank 1 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	887	bank 3
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	888	bank 3 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	889	bank 6
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	890	bank 6 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	891	bank 9
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	892	bank 9 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	893	bank 10
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	894	bank 10 d/s
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	895	bank 11
Muskrat Creek	MUSK 22-08	9/7/2010	BEHI	896	bank 11 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	897	bank 1
Nursery Creek	NURS 07-01	9/8/2010	BEHI	898	bank 1 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	899	bank 2
Nursery Creek	NURS 07-01	9/8/2010	BEHI	900	bank 2 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	901	bank 3

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Stream	Reach ID	Date	Camera	Photo	Description
Nursery Creek	NURS 07-01	9/8/2010	BEHI	902	bank 3 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	903	bank 5
Nursery Creek	NURS 07-01	9/8/2010	BEHI	904	bank 5 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	905	bank 6
Nursery Creek	NURS 07-01	9/8/2010	BEHI	906	bank 6 d/s
Nursery Creek	NURS 07-01	9/8/2010	BEHI	907	bank 7
Nursery Creek	NURS 07-01	9/8/2010	BEHI	908	bank 7 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	909	bank 1
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	910	bank 1 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	911	bank 2
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	912	bank 2 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	913	river right channel at bank 4
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	914	river left channel at bank 3
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	915	d/s at split, banks 3 and 4
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	916	bank 5
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	917	bank 5 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	918	bank 6
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	919	bank 6 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	920	bank 7
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	921	bank 7 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	922	bank 8
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	923	bank 8 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	924	bank 9
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	925	bank 9 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	926	bank 10
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	927	bank 10 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	928	bank 12
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	929	bank 12 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	930	large eroding bank (not in bf)
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	931	large eroding bank (not in bf)
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	932	bank 13
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	933	bank 13 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	934	bank 14
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	935	bank 14 d/s
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	936	bank 15
Muskrat Creek	MUSK 18-01-02	9/8/2010	BEHI	937	bank 15 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	938	bank 1
Boulder River	BLDR 13-10	9/8/2010	BEHI	939	bank 1 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	940	bank 2
Boulder River	BLDR 13-10	9/8/2010	BEHI	941	bank 3
Boulder River	BLDR 13-10	9/8/2010	BEHI	942	bank 3 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	943	bank 4
Boulder River	BLDR 13-10	9/8/2010	BEHI	944	bank 4 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	945	bank 5
Boulder River	BLDR 13-10	9/8/2010	BEHI	946	bank 5 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	947	bank 6

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Boulder River	BLDR 13-10	9/8/2010	BEHI	948	bank 6 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	949	bank 7
Boulder River	BLDR 13-10	9/8/2010	BEHI	950	bank 7 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	951	bank 8
Boulder River	BLDR 13-10	9/8/2010	BEHI	952	bank 8 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	953	bank 9
Boulder River	BLDR 13-10	9/8/2010	BEHI	954	bank 9 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	955	bank 10
Boulder River	BLDR 13-10	9/8/2010	BEHI	956	bank 10 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	957	bank 11
Boulder River	BLDR 13-10	9/8/2010	BEHI	958	bank 11 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	959	bank 12
Boulder River	BLDR 13-10	9/8/2010	BEHI	960	bank 12 d/s
Boulder River	BLDR 13-10	9/8/2010	BEHI	961	bank 13
Boulder River	BLDR 13-10	9/8/2010	BEHI	962	bank 13 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	963	bank 1
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	964	bank 1 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	965	bank 3
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	966	bank 3 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	967	bank 4
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	968	bank 4 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	969	bank 5
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	970	bank 5 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	971	bank 6
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	972	bank 6 d/s
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	973	hoof shear
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	974	bank 7
Elkhorn Creek	ELKH 23-01	9/9/2010	BEHI	975	bank 7 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	976	mass wasting site
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	977	mass wasting site
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	978	mass wasting site
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	979	mass wasting site
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	980	bank 1
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	981	bank 1 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	982	bank 2
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	983	bank 2 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	984	bank 3
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	985	bank 3 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	986	bank 4
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	987	bank 4 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	988	bank 5
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	989	bank 5 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	990	bank 6
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	991	bank 6 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	992	bank 7
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	993	bank 7 d/s

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Stream	Reach ID	Date	Camera	Photo	Description
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	994	bank 8
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	995	bank 8 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	996	bank 9
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	997	bank 9 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	998	bank 10
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	999	bank 10 d/s
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	1000	bank 11
Elkhorn Creek	ELKH 28-01	9/9/2010	BEHI	1001	bank 11 d/s
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1002	bank 1
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1003	bank 1 d/s
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1004	anthropogenic debris
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1005	cattle trampling
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1006	outhouse
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1007	road cut in hillside
High Ore Creek	HIOR 09-01	9/9/2010	BEHI	1008	logging on hillside
Boulder River	BLDR 13-33	9/10/2010	BEHI	1009	bank 1
Boulder River	BLDR 13-33	9/10/2010	BEHI	1010	bank 1 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1011	bank 2
Boulder River	BLDR 13-33	9/10/2010	BEHI	1012	bank 2 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1013	bank 3
Boulder River	BLDR 13-33	9/10/2010	BEHI	1014	bank 3 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1015	bank 4
Boulder River	BLDR 13-33	9/10/2010	BEHI	1016	bank 4 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1017	bank 5
Boulder River	BLDR 13-33	9/10/2010	BEHI	1018	bank 5 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1019	bank 6
Boulder River	BLDR 13-33	9/10/2010	BEHI	1020	bank 6 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1021	bank 7
Boulder River	BLDR 13-33	9/10/2010	BEHI	1022	bank 7 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1023	bank 8
Boulder River	BLDR 13-33	9/10/2010	BEHI	1024	bank 8 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1025	bank 9
Boulder River	BLDR 13-33	9/10/2010	BEHI	1026	bank 9 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1027	bank 10
Boulder River	BLDR 13-33	9/10/2010	BEHI	1028	bank 10 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1029	bank 11
Boulder River	BLDR 13-33	9/10/2010	BEHI	1030	bank 11 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1031	bank 12
Boulder River	BLDR 13-33	9/10/2010	BEHI	1032	bank 12 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1033	bank 13
Boulder River	BLDR 13-33	9/10/2010	BEHI	1034	bank 13 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1035	bank 14
Boulder River	BLDR 13-33	9/10/2010	BEHI	1036	bank 14 d/s
Boulder River	BLDR 13-33	9/10/2010	BEHI	1037	bank 15
Boulder River	BLDR 13-33	9/10/2010	BEHI	1038	bank 15 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1039	bank 1

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Stream	Reach ID	Date	Camera	Photo	Description
Boulder River	BLDR 13-23	9/10/2010	BEHI	1040	bank 1 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1041	bank 2
Boulder River	BLDR 13-23	9/10/2010	BEHI	1042	bank 2 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1043	bank 3
Boulder River	BLDR 13-23	9/10/2010	BEHI	1044	bank 3 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1045	bank 4
Boulder River	BLDR 13-23	9/10/2010	BEHI	1046	bank 4 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1047	bank 5
Boulder River	BLDR 13-23	9/10/2010	BEHI	1048	bank 5 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1049	bank 6
Boulder River	BLDR 13-23	9/10/2010	BEHI	1050	bank 6 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1051	bank 7
Boulder River	BLDR 13-23	9/10/2010	BEHI	1052	bank 7 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1053	bank 8
Boulder River	BLDR 13-23	9/10/2010	BEHI	1054	bank 8 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1055	bank 9
Boulder River	BLDR 13-23	9/10/2010	BEHI	1056	bank 9 d/s
Boulder River	BLDR 13-23	9/10/2010	BEHI	1057	bank 10
Boulder River	BLDR 13-23	9/10/2010	BEHI	1058	bank 10 d/s
Lowland Creek	LOWL 08-01	8/31/2010	XS	2370	reach bottom, u/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2371	reach bottom, d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2372	xs1 from lb
Lowland Creek	LOWL 08-01	8/31/2010	XS	2373	xs1 d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2374	xs2 from lb
Lowland Creek	LOWL 08-01	8/31/2010	XS	2375	xs2 d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2376	xs3 from lb
Lowland Creek	LOWL 08-01	8/31/2010	XS	2377	xs3 d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2378	xs4 from lb
Lowland Creek	LOWL 08-01	8/31/2010	XS	2379	xs4 d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2380	xs5 from lb
Lowland Creek	LOWL 08-01	8/31/2010	XS	2381	xs5 d/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2382	reach top, u/s view
Lowland Creek	LOWL 08-01	8/31/2010	XS	2383	reach top, d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2384	reach bottom, d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2385	reach bottom, u/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2386	xs1 from lb
Bison Creek	BISO 04-02	8/31/2010	XS	2387	xs1 d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2388	xs2 from lb
Bison Creek	BISO 04-02	8/31/2010	XS	2389	xs2 d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2390	xs3 from lb
Bison Creek	BISO 04-02	8/31/2010	XS	2391	xs3 d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2392	xs4 from lb
Bison Creek	BISO 04-02	8/31/2010	XS	2393	xs4 d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2394	xs5 from lb
Bison Creek	BISO 04-02	8/31/2010	XS	2395	xs5 d/s view
Bison Creek	BISO 04-02	8/31/2010	XS	2396	reach top, u/s view

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Stream	Reach ID	Date	Camera	Photo	Description
Bison Creek	BISO 04-02	8/31/2010	XS	2397	reach top, d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2398	reach bottom, d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2399	reach bottom, u/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2400	xs1 from lb
Bison Creek	BISO 11-01	8/31/2010	XS	2401	xs1 d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2402	xs2 from lb
Bison Creek	BISO 11-01	8/31/2010	XS	2403	xs2 d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2404	xs3 from lb
Bison Creek	BISO 11-01	8/31/2010	XS	2405	xs3 d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2406	xs4 from lb
Bison Creek	BISO 11-01	8/31/2010	XS	2407	xs4 d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2408	xs5 from lb
Bison Creek	BISO 11-01	8/31/2010	XS	2409	xs5 d/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2410	reach top, u/s view
Bison Creek	BISO 11-01	8/31/2010	XS	2411	reach top, d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2412	reach bottom, u/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2413	reach bottom, d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2414	xs1 from lb
Basin Creek	BASI 08-02	9/1/2010	XS	2415	xs1 d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2416	xs2 from lb
Basin Creek	BASI 08-02	9/1/2010	XS	2417	xs2 d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2418	xs3 from lb
Basin Creek	BASI 08-02	9/1/2010	XS	2419	xs3 d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2420	xs3 side channel from lb
Basin Creek	BASI 08-02	9/1/2010	XS	2421	xs3 side channel d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2422	xs4 from lb
Basin Creek	BASI 08-02	9/1/2010	XS	2423	xs4 d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2424	xs5 from rb
Basin Creek	BASI 08-02	9/1/2010	XS	2425	xs5 d/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2426	reach top, u/s view
Basin Creek	BASI 08-02	9/1/2010	XS	2427	reach top, d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2428	reach bottom, u/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2429	reach bottom, d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2430	xs1 from lb
Basin Creek	BASI 15-02	9/1/2010	XS	2431	xs1 d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2432	xs2 from lb
Basin Creek	BASI 15-02	9/1/2010	XS	2433	xs2 d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2434	xs3 from rb
Basin Creek	BASI 15-02	9/1/2010	XS	2435	xs3 d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2436	xs4 from lb
Basin Creek	BASI 15-02	9/1/2010	XS	2437	xs4 d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2438	algae at stn 790
Basin Creek	BASI 15-02	9/1/2010	XS	2439	algae at stn 790
Basin Creek	BASI 15-02	9/1/2010	XS	2440	xs5 from rb
Basin Creek	BASI 15-02	9/1/2010	XS	2441	xs5 d/s view
Basin Creek	BASI 15-02	9/1/2010	XS	2442	reach top, u/s view

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Stream	Reach ID	Date	Camera	Photo	Description
Basin Creek	BASI 15-02	9/1/2010	XS	2443	reach top, d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2444	reach bottom, u/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2445	reach bottom, d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2446	xs1 from rb
Boulder River	BLDR 12-04	9/1/2010	XS	2447	xs1 d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2448	xs2 from rb
Boulder River	BLDR 12-04	9/1/2010	XS	2449	xs2 d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2450	xs3 from rb
Boulder River	BLDR 12-04	9/1/2010	XS	2451	xs3 d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2452	xs4 from rb
Boulder River	BLDR 12-04	9/1/2010	XS	2453	xs4 d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2454	xs5 from rb
Boulder River	BLDR 12-04	9/1/2010	XS	2455	xs5 d/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2456	reach top, u/s view
Boulder River	BLDR 12-04	9/1/2010	XS	2457	reach top, d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2458	reach bottom, u/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2459	reach bottom, d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2460	xs1 from rb
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2461	xs1 d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2462	xs2 from rb
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2463	xs2 d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2464	xs3 from rb
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2465	xs3 d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2466	xs4 from rb
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2467	xs4 d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2468	xs5 from rb
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2469	xs5 d/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2470	reach top, u/s view
Uncle Sam Gulch	USGU 10-01	9/2/2010	XS	2471	reach top, d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2472	reach bottom, d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2473	reach bottom, u/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2474	xs1 from rb
Cataract Creek	CATA 18-01	9/2/2010	XS	2475	xs1 d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2476	xs2 from rb
Cataract Creek	CATA 18-01	9/2/2010	XS	2477	xs2 d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2478	xs3 from lb
Cataract Creek	CATA 18-01	9/2/2010	XS	2479	xs3 d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2480	xs5 from rb
Cataract Creek	CATA 18-01	9/2/2010	XS	2481	xs5 d/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2482	reach top, u/s view
Cataract Creek	CATA 18-01	9/2/2010	XS	2483	reach top, d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2484	reach bottom, u/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2485	reach bottom, d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2486	xs1 from lb
High Ore Creek	HIOR 15-01	9/2/2010	XS	2487	xs1 d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2488	xs2 from lb

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Stream	Reach ID	Date	Camera	Photo	Description
High Ore Creek	HIOR 15-01	9/2/2010	XS	2489	xs2 d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2490	xs3 from rb
High Ore Creek	HIOR 15-01	9/2/2010	XS	2491	xs3 d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2492	xs4 from lb
High Ore Creek	HIOR 15-01	9/2/2010	XS	2493	xs4 d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2494	xs5 from lb
High Ore Creek	HIOR 15-01	9/2/2010	XS	2495	xs5 d/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2496	reach top, u/s view
High Ore Creek	HIOR 15-01	9/2/2010	XS	2497	reach top, d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2498	reach bottom, u/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2499	reach bottom, d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2500	xs1 from lb
Little Boulder River	LBLR 32-01	9/3/2010	XS	2501	xs1 d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2502	xs2 from lb
Little Boulder River	LBLR 32-01	9/3/2010	XS	2503	xs2 d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2504	xs3 from rb
Little Boulder River	LBLR 32-01	9/3/2010	XS	2505	xs3 d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2506	xs4 from lb
Little Boulder River	LBLR 32-01	9/3/2010	XS	2507	xs4 d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2508	xs5 from lb
Little Boulder River	LBLR 32-01	9/3/2010	XS	2509	xs5 d/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2510	reach top, u/s view
Little Boulder River	LBLR 32-01	9/3/2010	XS	2511	reach top, d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2512	reach bottom, u/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2513	reach bottom, d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2514	xs1 from rb
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2515	xs1 d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2516	xs2 from lb
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2517	xs2 d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2518	xs3 from rb
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2519	xs3 d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2520	xs5 from rb
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2521	xs5 d/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2522	reach top, u/s view
North Fork Little Boulder River	NFLB 42-01	9/3/2010	XS	2523	reach top, d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2524	reach bottom, d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2525	reach bottom, u/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2526	xs1 from rb
Little Boulder River	LBLR 37-01	9/3/2010	XS	2527	xs1 d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2528	xs2 from rb
Little Boulder River	LBLR 37-01	9/3/2010	XS	2529	xs2 d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2530	xs3 from lb
Little Boulder River	LBLR 37-01	9/3/2010	XS	2531	xs3 d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2532	xs4 from rb
Little Boulder River	LBLR 37-01	9/3/2010	XS	2533	xs4 d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2534	xs5 from rb

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Little Boulder River	LBLR 37-01	9/3/2010	XS	2535	xs5 d/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2536	reach top, u/s view
Little Boulder River	LBLR 37-01	9/3/2010	XS	2537	reach top, d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2538	reach bottom, u/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2539	reach bottom, d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2540	xs1 from lb
Boulder River	BLDR 13-04	9/7/2010	XS	2541	xs1 d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2542	xs2 from lb
Boulder River	BLDR 13-04	9/7/2010	XS	2543	xs2 d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2544	cell 3 from rb
Boulder River	BLDR 13-04	9/7/2010	XS	2545	cell 3 d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2546	xs4 from lb
Boulder River	BLDR 13-04	9/7/2010	XS	2547	xs4 d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2548	xs5 from lb
Boulder River	BLDR 13-04	9/7/2010	XS	2549	xs5 d/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2550	reach top, u/s view
Boulder River	BLDR 13-04	9/7/2010	XS	2551	reach top, d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2552	old reach bottom, u/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2553	old reach bottom, d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2554	reach bottom, u/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2555	reach bottom, d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2556	xs1 from lb
McCarty Creek	MCCA 22-01	9/7/2010	XS	2557	xs1 d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2558	xs2 from lb
McCarty Creek	MCCA 22-01	9/7/2010	XS	2559	xs2 d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2560	cell 3 from lb
McCarty Creek	MCCA 22-01	9/7/2010	XS	2561	cell 3 d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2562	xs4 u/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2563	xs4 d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2564	xs5 from rb
McCarty Creek	MCCA 22-01	9/7/2010	XS	2565	xs5 d/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2566	reach top, u/s view
McCarty Creek	MCCA 22-01	9/7/2010	XS	2567	reach top, d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2568	reach bottom, u/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2569	reach bottom, d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2570	xs1 from lb
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2571	xs1 d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2572	xs2 from rb
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2573	xs2 d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2574	cell 3 from lb
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2575	cell 3 d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2576	xs4 from lb
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2577	xs4 d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2578	xs5 from rb
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2579	xs5 d/s view
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2580	reach top, u/s view

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Muskrat Creek	MUSK 22-08	9/7/2010	XS	2581	reach top, d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2582	reach bottom, u/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2583	reach bottom, d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2584	xs1 from lb
Nursery Creek	NURS 07-01	9/8/2010	XS	2585	xs1 d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2586	xs2 from lb
Nursery Creek	NURS 07-01	9/8/2010	XS	2587	xs2 d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2588	cell 3 from lb
Nursery Creek	NURS 07-01	9/8/2010	XS	2589	cell 3 d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2590	xs4 from lb
Nursery Creek	NURS 07-01	9/8/2010	XS	2591	xs4 d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2592	xs5 from lb
Nursery Creek	NURS 07-01	9/8/2010	XS	2593	xs5 d/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2594	reach top, u/s view
Nursery Creek	NURS 07-01	9/8/2010	XS	2595	reach top, d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2596	reach bottom, u/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2597	reach bottom, d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2598	xs1 from rb
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2599	xs1 d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2600	xs2 from rb
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2601	xs2 d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2602	cell 3 from lb
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2603	cell 3 d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2604	xs4 from lb
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2605	xs4 d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2606	xs5 from rb
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2607	xs5 d/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2608	reach top, u/s view
Muskrat Creek	MUSK 18-01-02	9/8/2010	XS	2609	reach top, d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2610	reach bottom, d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2611	reach bottom, u/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2612	xs1 from lb
Boulder River	BLDR 13-10	9/8/2010	XS	2613	xs1 d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2614	xs2 from lb
Boulder River	BLDR 13-10	9/8/2010	XS	2615	xs2 d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2616	cell 3 d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2617	cell 3 u/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2618	xs4 from lb
Boulder River	BLDR 13-10	9/8/2010	XS	2619	xs4 d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2620	xs5 from lb
Boulder River	BLDR 13-10	9/8/2010	XS	2621	xs5 d/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2622	reach top, u/s view
Boulder River	BLDR 13-10	9/8/2010	XS	2623	reach top, d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2624	reach bottom, u/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2625	reach bottom, d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2626	xs1 from rb

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2627	xs1 d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2628	xs2 from rb
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2629	xs2 d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2630	xs3 from lb
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2631	xs3 d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2632	xs4 from lb
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2633	xs4 d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2634	xs5 from lb
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2635	xs5 d/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2636	reach top, u/s view
Elkhorn Creek	ELKH 23-01	9/9/2010	XS	2637	reach top, d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2638	reach bottom, u/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2639	reach bottom, d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2640	xs1 from lb
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2641	xs1 d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2642	xs2 from lb
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2643	xs2 d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2644	xs3 from lb
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2645	xs3 d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2646	xs4 from lb
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2647	xs4 d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2648	xs5 from lb
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2649	xs5 d/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2650	reach top, u/s view
Elkhorn Creek	ELKH 28-01	9/9/2010	XS	2651	reach top, d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2652	reach bottom, u/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2653	reach bottom, d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2654	xs1 from rb
High Ore Creek	HIOR 09-01	9/9/2010	XS	2655	xs1 d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2656	xs2 from rb
High Ore Creek	HIOR 09-01	9/9/2010	XS	2657	xs2 d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2658	xs3 from rb
High Ore Creek	HIOR 09-01	9/9/2010	XS	2659	xs3 d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2660	xs4 from rb
High Ore Creek	HIOR 09-01	9/9/2010	XS	2661	xs4 d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2662	xs5 from rb
High Ore Creek	HIOR 09-01	9/9/2010	XS	2663	xs5 d/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2664	reach top, u/s view
High Ore Creek	HIOR 09-01	9/9/2010	XS	2665	reach top, d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2666	reach bottom, u/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2667	reach bottom, d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2668	xs1 from lb
Boulder River	BLDR 13-33	9/10/2010	XS	2669	xs1 d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2670	xs2 from rb
Boulder River	BLDR 13-33	9/10/2010	XS	2671	xs2 d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2672	xs4 from lb

Attachment C - Table C-1. Photo log.

Stream	Reach ID	Date	Camera	Photo	Description
Boulder River	BLDR 13-33	9/10/2010	XS	2673	xs4 d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2674	xs5 from rb
Boulder River	BLDR 13-33	9/10/2010	XS	2675	xs5 d/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2676	reach top, u/s view
Boulder River	BLDR 13-33	9/10/2010	XS	2677	reach top, d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2678	reach bottom, d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2679	reach bottom, u/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2680	xs1 from rb
Boulder River	BLDR 13-23	9/10/2010	XS	2681	xs1 d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2682	xs2 from lb
Boulder River	BLDR 13-23	9/10/2010	XS	2683	xs2 d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2684	xs3 from lb
Boulder River	BLDR 13-23	9/10/2010	XS	2685	xs3 d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2686	xs4 from lb
Boulder River	BLDR 13-23	9/10/2010	XS	2687	xs4 d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2688	xs5 from lb
Boulder River	BLDR 13-23	9/10/2010	XS	2689	xs5 d/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2690	reach top, u/s view
Boulder River	BLDR 13-23	9/10/2010	XS	2691	reach top, d/s view

ATTACHMENT D – Quality Assurance/Quality Control Review

General Description of Field Activities

Sediment and habitat monitoring was conducted in the Boulder-Elkhorn TMDL Planning Area in the summer of 2010. Two separate field visits were conducted as part of this assessment. On July 19-20, 2010, a field reconnaissance crew consisting of Jim Bond (DEQ) and Josh Vincent (Water & Environmental Technologies) conducted site visits of potential field assessment sites which were previously identified using aerial photography and GIS. Sites were inspected for their sampling feasibility and ability to gain access to private property. A preliminary list of primary and secondary (alternate) sampling sites was compiled. On August 31- September 10, 2010, a sediment and habitat field crew consisting of Jim Bond, Eric Sivers, and Kristy Zhinin (DEQ), and Josh Vincent, John Trudnowski, John Babcock, and Jay Slocum (Water & Environmental Technologies) conducted field assessments on 23 stream reaches according to the Sampling and Analysis Plan prepared for this project.

Variance from SAP

All field procedures were followed according to the project sampling and analysis plan (SAP) (DEQ 2010a) and guidance documents (DEQ 2010b, Rosgen 2006) with the exception of riffle pebble counts conducted by the cross-section team. Guidance documentation (DEQ 2010b) recommends performing pebble counts in the first riffle encountered in Cells 1, 3 and 5 for a total of 3 pebble counts; however, during this assessment, 4 total pebble counts were performed per reach, generally in Cells 1, 2, 3 and 5. This aligns the data from this assessment with recommendations from DEQ's Water Quality Monitoring and Assessment Program.

During the field assessments, all primary sites identified during field reconnaissance were evaluated with the following exceptions:

Reach BASI 15-02 was surveyed instead of BASI 15-03, which was identified as a primary site in the SAP, but upon further investigation was found to be influenced by cabin development and a small airstrip. Reach 15-02 provided a continuous 1000' section downstream of a small bridge, and was identified as a secondary site in the SAP.

Reach BLDR 13-02 was identified as a primary site in the SAP, but was not surveyed during field assessment. This site has limited access, and reach BLDR 13-04 is a primary site of the same reach type that was surveyed not far downstream. Because of the proximity of BLDR 13-04, no alternate site was chosen for BLDR 13-02.

Reach BLDR 13-10 was surveyed instead of BLDR 13-12, which was identified as a primary site in the SAP. Reach 13-10 was identified as a secondary site, and provided easier access than BLDR 13-12 while maintaining the same reach type and land use.

Reach CATA 14-02 was not surveyed due to lack of access. Due to sporadic ownership of mining claims in the Cataract Creek watershed, no alternate site was identified.

Reach ELKH 34-03 was identified as a primary site near the mouth of Elkhorn Creek, but this reach was not surveyed during field assessment. Elkhorn Creek near the mouth is intercepted by road fill, culverts, and ditches, and has historically been disconnected from the mainstem of the Boulder River.

Reach HIOR 15-01 was surveyed instead of HIOR 14-01, which was identified as a primary site in the SAP. Reach 15-01 was listed as a secondary site, and provided easier access than 14-01 while maintaining the same land use.

MCCA 22-01 was surveyed instead of reaches 20-01 and 27-01, which were identified as primary sites in the SAP. MCCA 22-01 was not listed in the SAP, but was one of the few accessible sites in the watershed due to small reach lengths and sporadic land ownership.

MUSK 18-01 and 18-02 were surveyed as a single 1000’ reach. MUSK 18-01 was listed as a secondary site, but was not long enough for an entire 1000’ reach. The addition of this reach provides greater spatial coverage in the upper Muskrat Creek watershed, and provides an additional reach of type MR-2-2-U.

MUSK 22-08 was surveyed instead of MUSK 22-02. Reach 22-08 was not listed in the SAP, but provided easier access than the identified primary and secondary sites while maintaining the same reach type.

NFLB 42-01 was a secondary site that was surveyed instead of primary site 43-01, which was near the mouth of the stream and fragmented by a road.

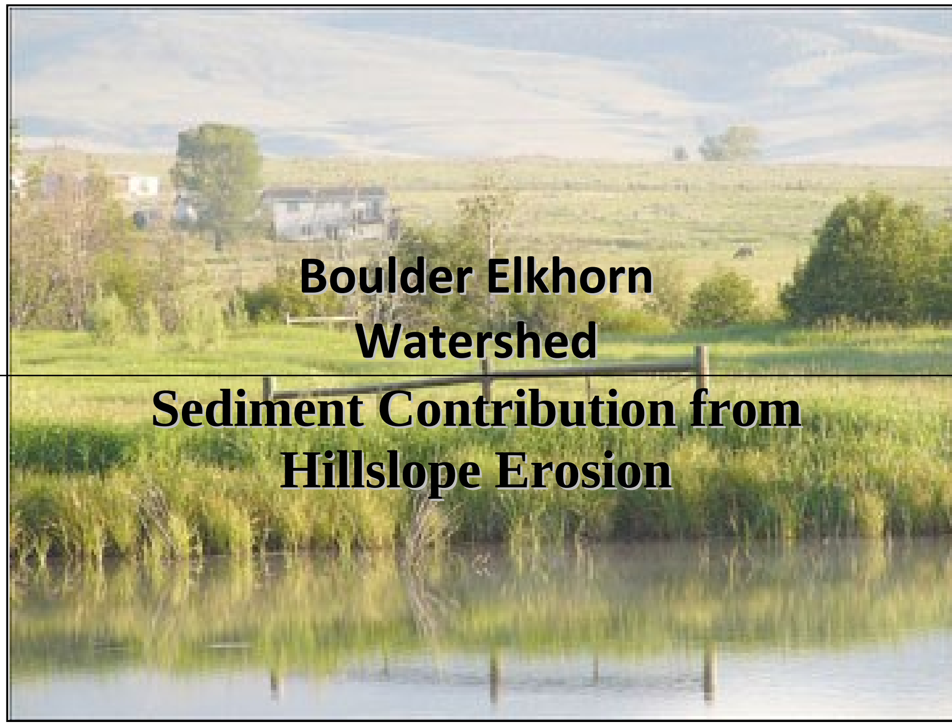
Data Adjustments

The following table provides adjustments made to the field data during data entry and analysis. In reach BISO 04-02, the material adjustment was increased for actively eroding banks to compensate for the exposed sandy material and excessive cattle trampling observed in photos. Bank 10 on reach LBLR 37-01 was changed from “slowly eroding” to “actively eroding” to more accurately reflect erosion conditions after reviewing photographs and bank data.

Table D-1. Data adjustments.

Reach	Location	Parameter	Original Value	Adjusted Value	Rationale
BISO 04-02	Bank 10	material adjustment	0	10	exposed sandy bank with cattle trampling
BISO 04-02	Bank 11	material adjustment	0	10	exposed sandy bank with cattle trampling
BISO 04-02	Bank 15	material adjustment	5	10	exposed sandy bank with cattle trampling
BISO 04-02	Bank 17	material adjustment	5	10	exposed sandy bank with cattle trampling
LBLR 37-01	Bank 10	active vs slow determination	slowly eroding	actively eroding	upon further review, it was determined this bank was erroneously classified in the field as slowly eroding

ATTACHMENT 2 - BOULDER ELKHORN WATERSHED SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION



Boulder Elkhorn Watershed

Sediment Contribution from Hillslope Erosion

Prepared For:

Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901

Attn: Jim Bond

March 22, 2011

Prepared By:

CONFLUENCE incorporated

P.O. Box 1133
Bozeman, MT 59771-1133
406-585-9500
www.confluenceinc.com

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1.0 SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION

1.1 Introduction

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of Best Management Practices (BMPs). The BMPs evaluated assumed modifications in upland management practices as well as improvements within the riparian buffer zone. When reviewing the results of the upland sediment load model, it is important to note that a significant portion of the sediment load is the “natural upland load” and not affected by the application of BMPs to the upland management practices.

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

(1) A = RK(LS)CP (in tons per acre per year)

where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P) (Wischmeier and Smith 1978, Renard et al. 1997). USLE was selected for the Boulder Elkhorn watershed due to its relative simplicity and ease in parameterization and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) the Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe, 1999). A detailed description of the general USLE model parameters is presented below.

The **R-factor** is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons per acre per year) and the maximum 30-minute rainfall intensity (inches per hour). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The **K-factor** or soil erodibility factor indicates the susceptibility of soil to resist erosion. It is a measure of the average soil loss (tons per acre per hundreds of ft-tons per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard SCS erosion plot that is 72.6 ft long with uniform slope of 9%.

The **LS-factor** is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-factor, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen (1998), flow lengths are seldom greater than 400 ft or shorter than 20 ft.

The **C-factor** or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that affect erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks, 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) canopy cover effects, (2) effects of low-growing vegetal cover, mulch, and litter, and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the Boulder Elkhorn setting, Brooks (1997) cautions that more work has been carried out in determining the agriculturally based C-factors than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The **P-factor** or conservation practice factor is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally based conservation practices.

1.2 Modeling Approach

Sediment delivery from hillslope erosion was estimated using a Universal Soil Loss Equation (USLE) based model to predict soil loss along with a distance and riparian health based sediment delivery ratio (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale, grid format, GIS model using ArcView v 9.2 GIS software.

Desired results from the modeling effort include the following: (1) annual sediment load from each of the water quality limited segments on the state's 303(d) list, (2) the mean annual source distribution from each land category type, (3) annual potential sediment load from each of the water quality limited segments on the state's 303(d) list after the application of riparian buffer zone management BMPs, (4) annual potential sediment load from each of the water quality limited segments on the state's 303(d) list after the application of upland management BMPs, and (5) annual potential sediment load from each of the water quality limited segments on the state's 303(d) list after the application of riparian buffer zone management BMPs and upland management BMPs. Based on these considerations, a GIS- modeling approach (USLE) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

1.3 Modeling Scenarios

Four management scenarios were evaluated for the Boulder Elkhorn watershed. They include: (1) an existing conditions scenario that considers the current land cover, management practices, and riparian health in the watershed; (2) an upland BMP conditions scenario that considers improved grazing and cover management; (3) a riparian health BMP conditions scenario that considers improved riparian buffer zones; and (4) a riparian health BMP and upland BMP conditions scenario that considers improved riparian buffer zones and grazing and cover management.

Erosion was differentiated into two source categories for each scenario: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 – Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning. Land cover categories considered to be affected by human-caused activity and therefore affected by BMPs within the Boulder Elkhorn watershed were developed (open space), developed (low intensity), developed (medium intensity), developed (high intensity), pasture/hay, grasslands/herbaceous, shrub/scrub, cultivated crops, and transitional (logging). All other land cover categories were considered to have “natural erosion.”

Well vegetated riparian buffers have been shown to act as filters that help to remove sediment from overland flow. In general, the effectiveness of vegetated riparian buffers is proportional to their width and overall health. A riparian health assessment was completed by the Montana Department of Environmental Quality (DEQ) for the Boulder Elkhorn Watershed. The DEQ riparian health assessment is used here to estimate further reduction in the quantity of eroded sediment that is ultimately delivered to the streams. These riparian areas are also considered to be affected by human-caused activity and are therefore subject to improved riparian health management.

1.4 Data Sources

The USLE model was parameterized using a number of published data sources. These include information from: (1) U.S. Geological Survey (USGS), (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land cover was acquired from the U.S. Forest Service (USFS) and the Natural Resource Conservation Service (NRCS). Specific GIS coverages used in the modeling effort included the following:

Grid data of the **R-factor** was obtained from the NRCS, and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

Polygon data of the **K-factor** were obtained from the NRCS General Soil Map (STATSGO) database and the NRCS Soil Survey Geographic (SSURGO) database. The USLE K factor is a standard component of the STATSGO soil survey, but has not been included for all polygons in the SSURGO soil survey. SSURGO data has higher resolution and is more current than the STATSGO dataset, however, the SSURGO data for the Boulder Elkhorn watershed did not contain the required K-factor for the entire watershed. STATSGO data was used to fill in the blanks. Soils polygon data were summarized and interpolated to grid format.

The **LS-factor** was derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel. This factor is calculated within the model.

The **C-factor** was estimated using the National Land Cover (NLCD) dataset and using C-factor interpretations provided by the NRCS with input from MT DEQ. C-factors are intended to be conservatively representative of conditions in the Boulder Elkhorn watershed.

The **P-factor** was set to one, as per previous communication with the NRCS State Agronomist who suggested that this value is the most appropriate representation of current management practices in the Boulder Elkhorn watershed.

The **sediment delivery ratio** was derived by the model for each grid cell based on the observed relationship between the distance from the delivery point to the stream and the percent of eroded sediment delivered to the stream. This relationship was established by Megehan and Ketcheson (1996).

The **riparian health factor** was derived from a riparian health assessment completed by DEQ. Riparian health ratings of good, moderately good, fair, moderately fair, and poor were assigned according to the professional judgment of the assessment team. The percent of each sub-basin's area falling in each category was reported.

1.5 Modeling Methods

An appropriate grid for each data source was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors was performed as follows:

1.5.1 Sub-basins

The Boulder Elkhorn watershed boundary and the sub-basin boundaries were defined using the USGS 6th code Hydrologic Unit Codes (HUC). High Ore Creek, McCarty Creek, Nursery Creek, and Uncle Sam Gulch are 303(d) listed streams that were not represented in the 6th code HUCs. These sub-basins were cut from the larger HUC sub-basins using USGS topography as a guide to drainage divides. Additionally, the Elkhorn Creek sub-basin was divided into an upper and lower sub-basin, above and below Wood Gulch respectively.

Overall, the Boulder River watershed was divided into 4 sections: headwaters to Basin Creek (Headwaters), Basin Creek to the town of Boulder (Upper), the town of Boulder to Cottonwood Creek (Middle), and Cottonwood Creek to the mouth (Lower). The division between these sections coincided with HUC sub-basin boundaries except between the Upper and Middle sections. This division was made using the USGS topography as a guide.

Figure 1-1. Sub-basin polygons for the Boulder Elkhorn Watershed.

1.5.2 Boulder Elkhorn Watershed DEM

The digital elevation model (DEM) for the Boulder Elkhorn watershed is the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area, and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the Boulder Elkhorn watershed was used for these analyses. The DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Boulder Elkhorn watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m DEM was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

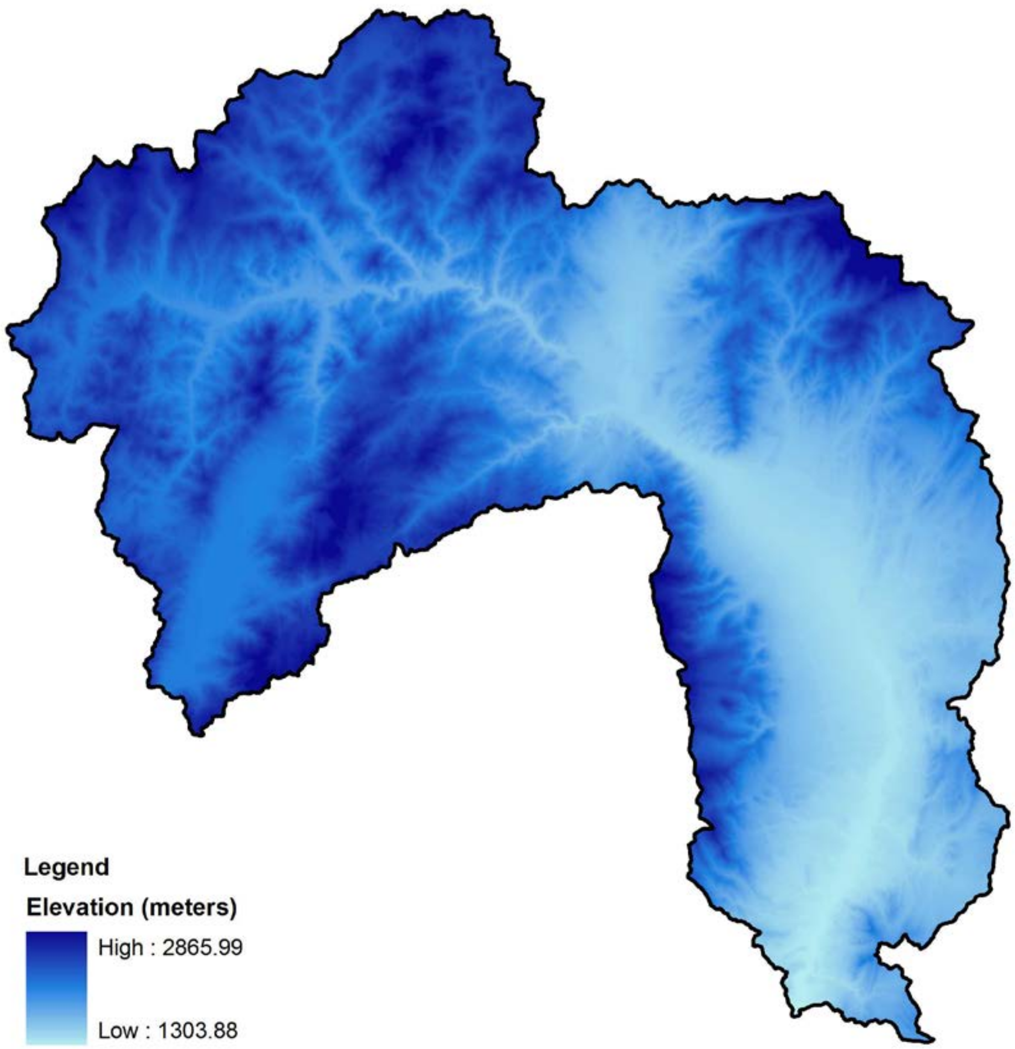

Figure 1-2. Digital Elevation Model (DEM) of the Boulder Elkhorn Watershed Prepared for Hydrologic Analysis.

1.5.3 Boulder Elkhorn Watershed Flow Network

The stream network for the watershed was derived from the 10m DEM, using hydrologic analysis methods developed by the Utah State University Hydrology Research Group, and implemented in the TauDEM (**T**errain **A**nalysis **U**sing **D**igital **E**levation **M**odels) software. These tools prepare a hydrologically correct surface from standard DEM data, filling errant sinks and ensuring positive drainage toward defined pour points. From this surface, a stream network is derived by calculating the watershed area for each pixel in the DEM, and assigning to the stream network those pixels that exceed a specified accumulation area threshold. The threshold is watershed specific, and is chosen in a manner whereby the resulting stream network satisfies the key elevation scaling laws (constant drop property and power law scaling of slope with area) that differentiate concentrated flow processes (channel erosion and transport) from the diffusive processes that characterize hillslope transport of sediment.

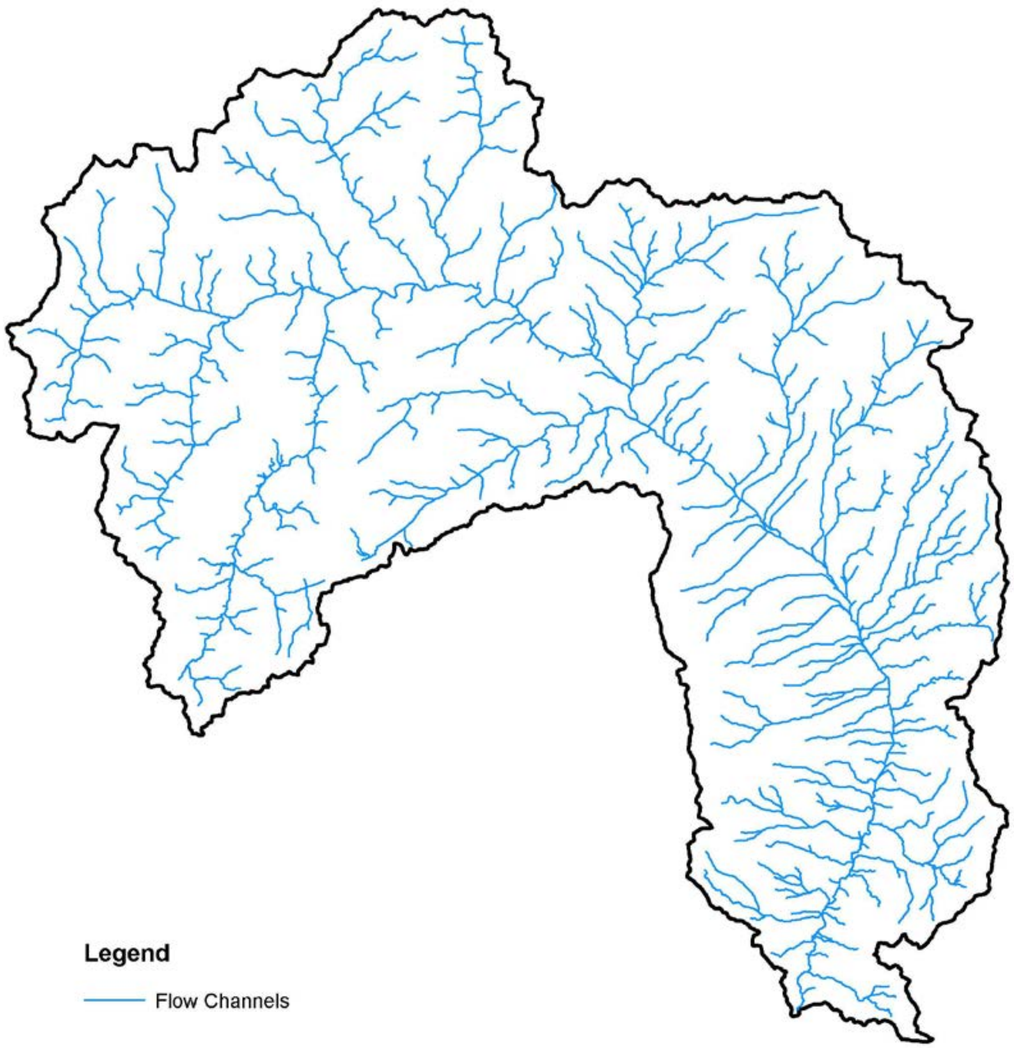

Figure 1-3. Flow network for the Boulder Elkhorn Watershed.

1.5.4 R-Factor

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University, at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the Boulder Elkhorn watershed, to match the project's standard grid definition.

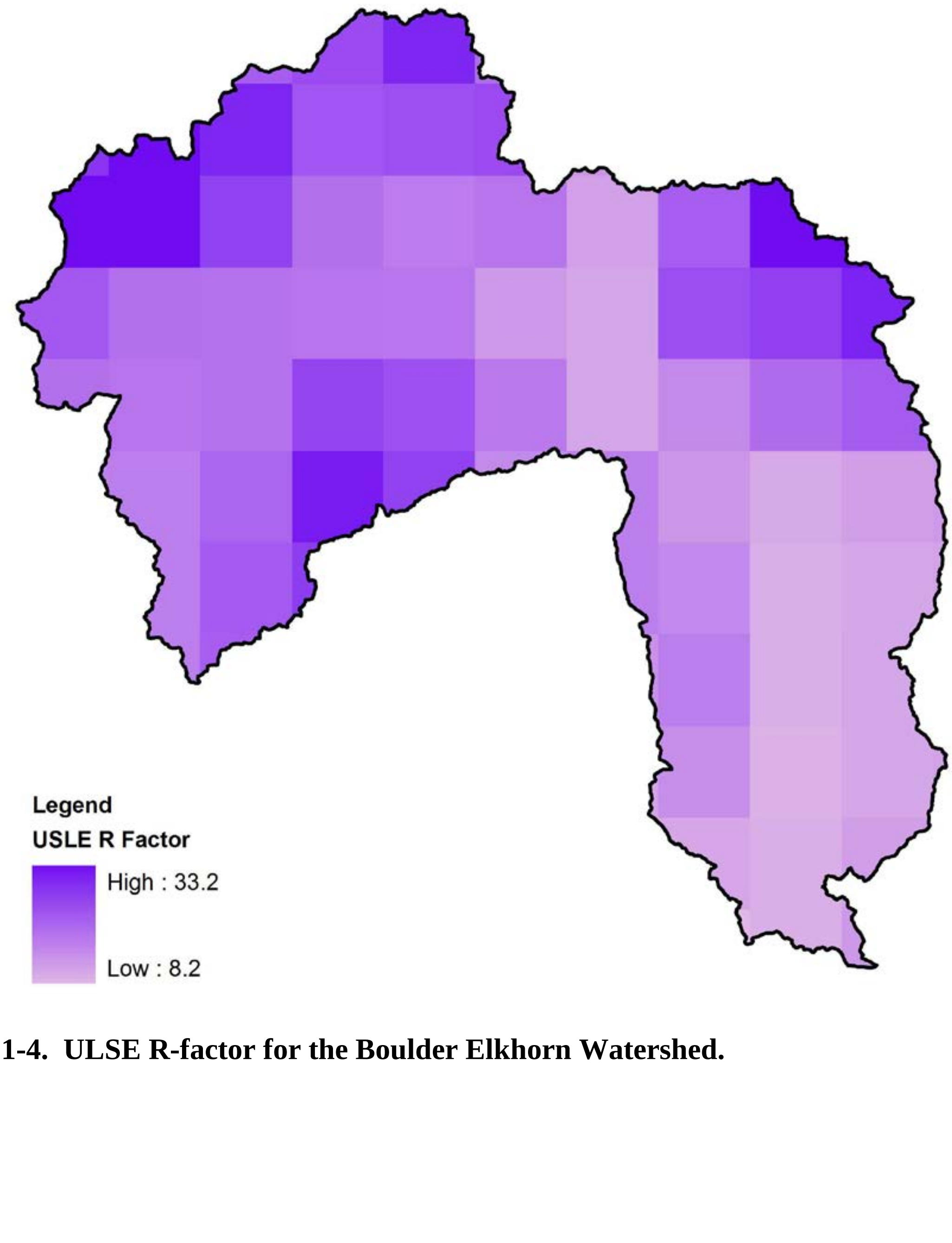

Figure 1-4. ULSE R-factor for the Boulder Elkhorn Watershed.

1.5.5 K-Factor

The soil erodibility factor grid was compiled from the 1:250K STATSGO and SSURGO data, as published by the NRCS. SSURGO data has higher resolution and is more current than the STATSGO dataset, however, the SSURGO data for the Boulder Elkhorn watershed did not contain the required K-factor for the entire watershed. STATSGO data was used to fill in the blanks. STATSGO and SSURGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the map units, and the polygon coverage was converted to a 10m analytic grid for use in the model.

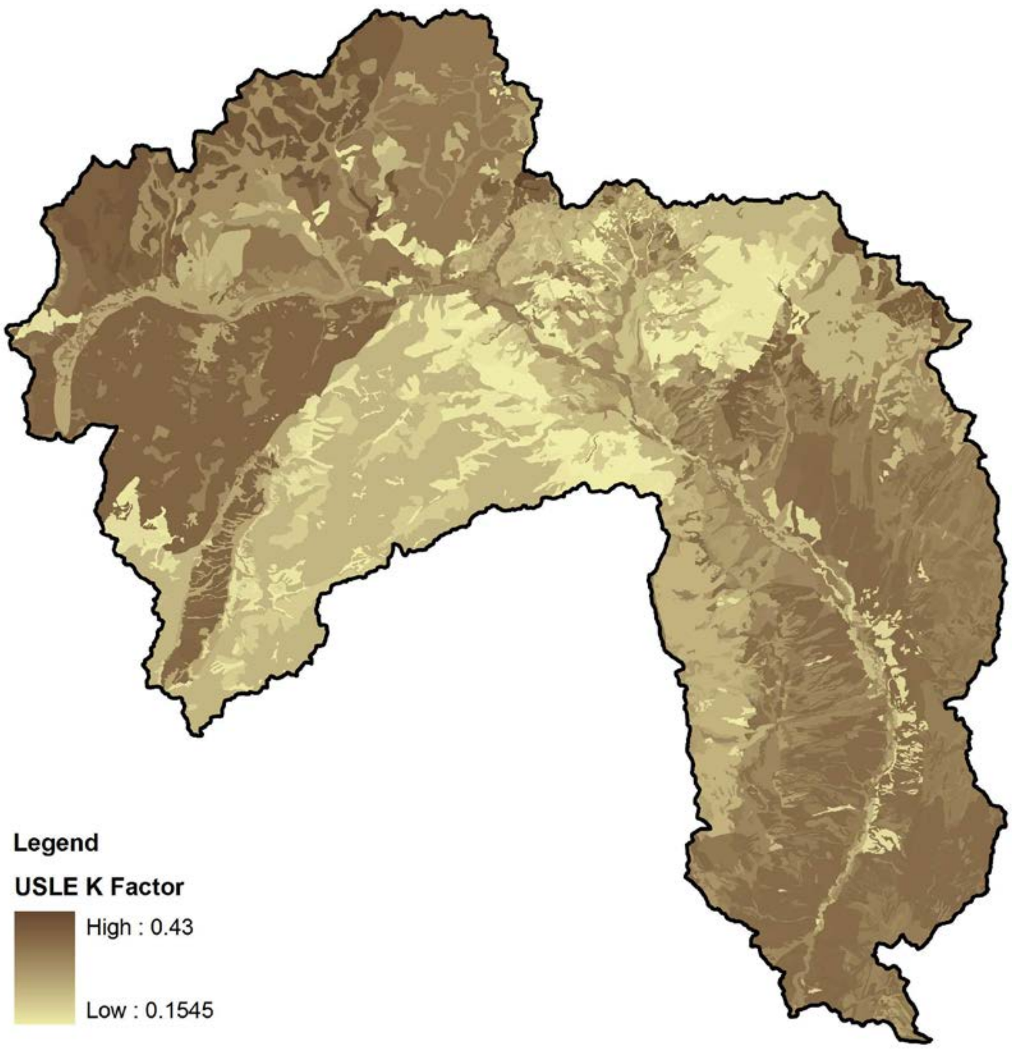

Figure 1-5. ULSE K-factor for the Boulder Elkhorn Watershed

1.5.6 LS-Factor

The equation used for calculating the slope length and slope factor was that given in the updated definition of RUSLE, as published in USDA handbook #703:

$LS = S_i (\lambda_i^{m+1} - \lambda_{i-1}^{m+1}) / (\lambda_I - \lambda_{i-1}) (72.6)^m$

Where:

λ_i = length in feet from top of slope to lower end of ith segment. This value was determined by applying GIS based surface analysis procedures to the Boulder Elkhorn watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, λ was limited to that maximum value.

S_i = slope steepness factor for the ith segment.
$= 10.8 \sin\theta + 0.03$ for $\theta < 9\%$
$= 16.8 \sin\theta - 0.50$ for $\theta \geq 9\%$

m = a variable slope-length exponent.
$= \beta / (1 + \beta)$

and

B = ratio of rill to interrill erosion.
$= (\sin\theta / 0.0896) / [3.0 (\sin\theta)^{0.8} + 0.56]$

θ = slope angle as calculated by GIS based surface analysis procedures from the Boulder Elkhorn watershed DEM.

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

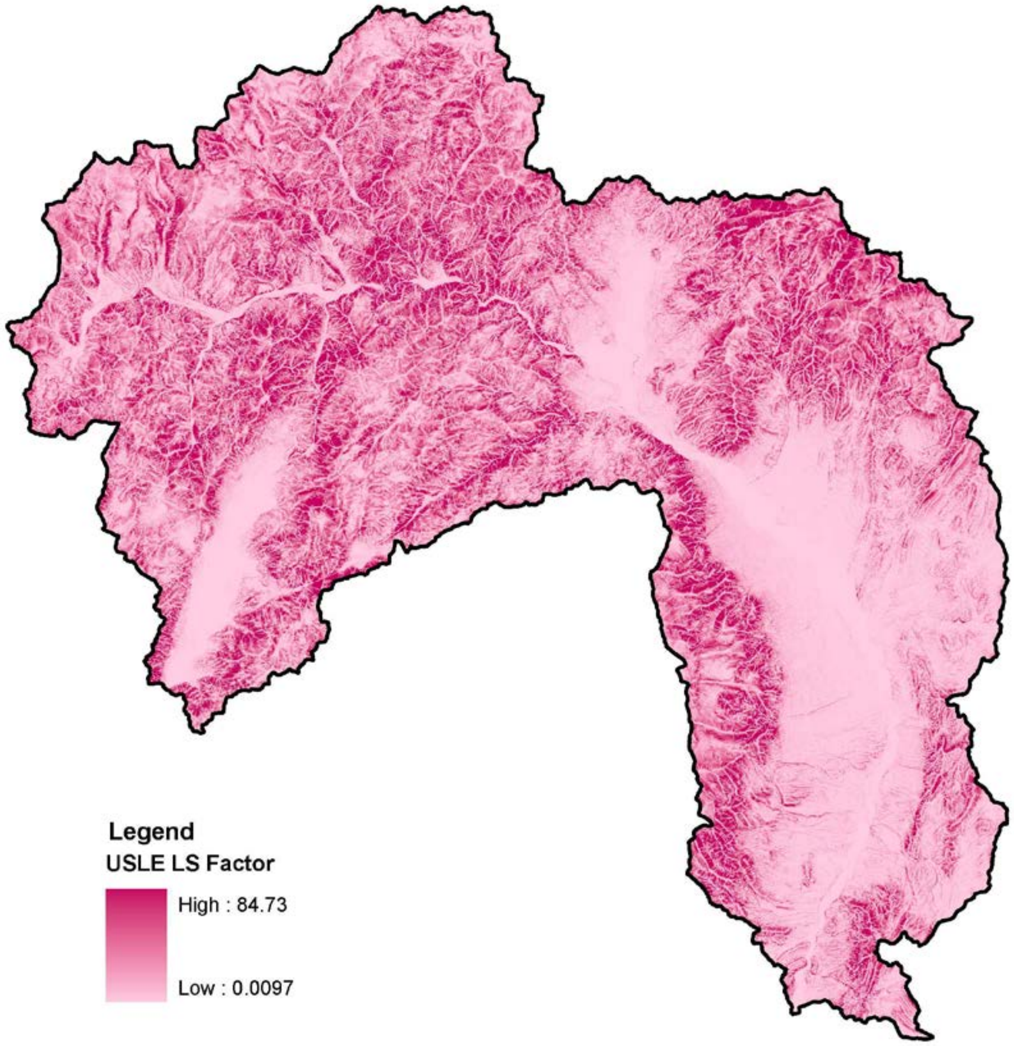

Figure 1-6. ULSE LS-factor for the Boulder Elkhorn Watershed

1.5.7 NLCD

The 2001 National Land Cover Dataset (NLCD) was obtained from USGS for use in establishing USLE C-factors for the Boulder Elkhorn watershed. The 2001 NLCD is the most current NLCD for the project are, and is a categorized 30 meter Landsat Thematic Mapper image shot in 2001. The NLCD image was reprojected to Montana State plane projection/coordinate system, and resampled to the project standard 10m grid. NLCD land cover classification codes for areas present in the Boulder Elkhorn watershed are described as follows:

11. Open Water - areas of open water, generally with less than 25 percent cover of vegetation or soil.

21. Developed, Open Space - Includes areas with a mixture of constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. Developed, High Intensity – Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

31. Barren Land (Rock/Sand/Clay) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. Grasslands/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

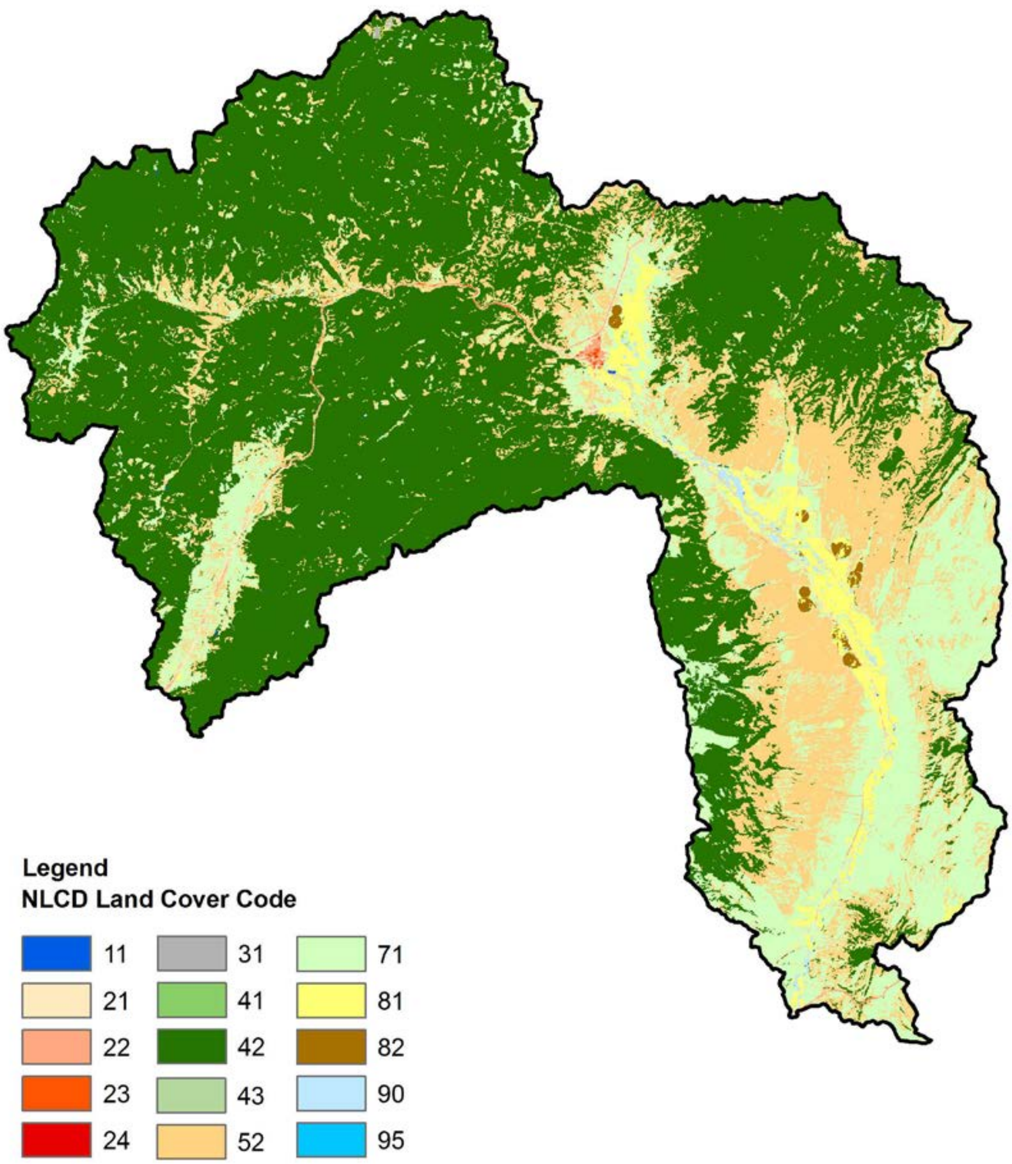

Figure 1-7. NLCD Landcover for the Boulder Elkhorn Watershed.

1.5.8 Logging and Fire Adjustment

In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes that may have occurred since the NLCD image was shot. Given that we are looking for watershed and sub-watershed scale effects, the relative simplicity of the land use mix in the Boulder Elkhorn watershed, and the relative stability of that land use over the 10 years since the Landsat image that the NLCD is based on was taken, this was considered to be a reasonable assumption. One adjustment to the NLCD is necessary and appropriate, however. That is to quantify the amount of logging or fires that has occurred since 2001, and to also identify previously disturbed areas that are reforesting over that same period. As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may affect sediment production.

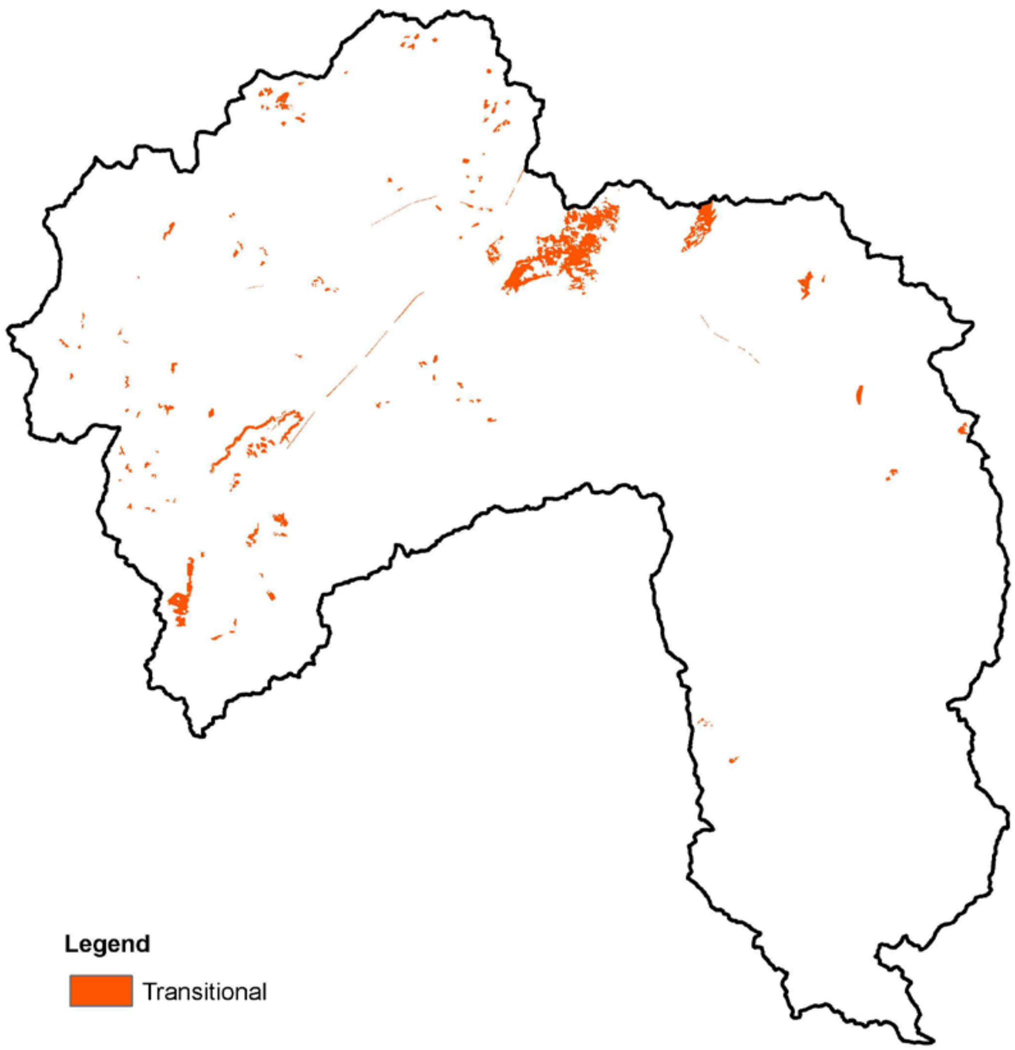

Figure 1-8. Transitional areas for the Boulder Elkhorn Watershed.

Adjustment for logging was accomplished by using fire and harvest record polygons provided by the U.S. Forest Service. Polygons with a harvest or fire date of 2001 or later were selected. There was a large fire north of the town of Boulder in 2000 that was also selected. Additionally, adjustment for logging was accomplished by comparing the 2001 NLCD grid for the Boulder Elkhorn Watershed with the 2009 NAIP aerial photography. Areas which were coded as a forest type (41, 42 or 43) on the NLCD were digitized and coded as Type 1 (logged) if they appeared to be other than forested (typically bare ground, grassland, or shrubland) on the NAIP photos, there were indications of logging activity (proximity to forest or logging roads, appearance of stands, etc), and they were located on non-USFS property. Conversely, areas which were coded something other than forest on the NLCD and appeared to have significant tree coverage on the NAIP photos were digitized and coded as Type 2 (regrowth). These areas were then grouped together into a transitional land cover category.

1.5.9 C-Factor Derivation

For purposes of the base (existing conditions) scenario, the following scheme of reclassification was used to derive annualized USLE C-factors from the NLCD land cover classes present in the Boulder Elkhorn watershed.

This reclassification is based on the NRCS table “C-Factors for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland” and was developed with the assistance and input of local NRCS employees. A narrative description of the professional judgment involved in the selection of these factors and the NRCS table are provided in Attachment A.

To estimate the potential reduction in sediment production that might be accomplished under the desired conditions scenario (application of best management practices), the model was re-run using a different C-factor reclassification scheme. Relative to the existing conditions C-factor scheme, the BMP C-factor for the ‘transitional’ land classification was changed to reflect the forest cover that most such areas are transitioning to in the Boulder Elkhorn watershed. The ‘grasslands/herbaceous’, ‘shrub/scrub’, ‘pasture/hay’, ‘woody wetlands’ BMP C-factors were conservatively changed to reflect a 10 percent increase in ground cover over existing conditions. The ‘cultivated crops’ BMP C-factor was changed to reflect a 20 percent increase in ground cover over existing conditions. No change was applied to the other land use types within the Boulder Elkhorn watershed from the existing conditions scenario.

The C-factors for the two scenarios are presented in **Table 1-1**.

Table 1-1 C-factors in the Boulder Elkhorn watershed.				
NLCD Code	**Description**	**C-Factor Existing Condition**	**C-Factor Desired Condition**	**Percent of Watershed**
42	Evergreen forest	0.003	0.003	58.1%
52	Shrub/scrub	0.020	0.010	19.5%
71	Grassland/herbaceous	0.020	0.010	17.7%
81	Pasture/Hay	0.020	0.010	2.7%
N/A	Transitional	0.006	0.003	1.5%
21	Developed, open space	0.003	0.003	0.8%
90	Woody Wetlands	0.013	0.006	0.5%
82	Cultivated Crops	0.200	0.100	0.3%
22	Developed, low intensity	0.001	0.001	0.3%
23	Developed, medium intensity	0.001	0.001	0.1%
31	Barren land	0.001	0.001	0.03%
43	Mixed forest	0.003	0.003	0.02%
41	Deciduous forest	0.003	0.003	0.01%
24	Developed, high intensity	0.001	0.001	0.001%
95	Emergent Herbaceous Wetlands	0.003	0.003	0.001%

Table 1-2 Changes in percent ground cover for land cover types between existing and improved management conditions.		
Land Cover	**Existing % Ground Cover**	**Improved % Ground Cover**
Shrub/scrub	75	85
Grasslands/Herbaceous	75	85
Pasture/Hay	75	85
Transitional	90	95-100
Woody Wetlands	80	90
Cultivated Crops	20	40

1.5.10 Riparian Health Assessment

Well vegetated riparian buffers have been shown to act as filters that remove sediment from overland flow. Because of this ability, the influence of riparian corridors on water quality is proportionately much greater than the relatively small area in the landscape they occupy. In general, the effectiveness of vegetated riparian buffers is proportional to their width and overall health. Thus, information regarding riparian zone health can be used to refine estimates of sediment delivery to streams from upstream sources. This section describes a riparian corridor quality assessment of the Boulder Elkhorn Watershed.

1.5.10.1 DEQ Riparian assessment

The riparian corridor quality assessment was provided by DEQ. The assessment was based on the results of the DEQ aerial assessment and reach delineation. Reaches were delineated based on a combination of physical attributes (ecoregion, valley slope, valley confinement, and stream order) and the presence and degree of adjacent human activity. For each reach, a riparian corridor condition was estimated using aerial photos, field notes, and best professional judgment. DEQ designated riparian corridor as having poor, moderately poor, fair, moderately good, or good quality. These determinations were made with consideration of adjacent land use, stream-side vegetation, and the presence or absence of human activities. The cumulative length of the reaches within each category was then tallied for each stream, and the percent of the length of stream in each category was calculated.

The results of the riparian corridor quality assessment from DEQ for the sub-basins are shown in **Table 1-3**.

Table 1-3 Percent of stream length in each riparian quality category.

Sub-basin	Existing Conditions					BMP Conditions				
	Good	Moderately Good	Fair	Moderately Fair	Poor	Good	Moderately Good	Fair	Moderately Fair	Poor
Basin Creek	32	66	0	0	2	98	0	2	0	0
Bison Creek	0	0	0	97	3	0	97	3	0	0
Boulder River Headwaters	10	0	90	0	0	100	0	0	0	0
Boulder River Upper	0	0	46.5	46.5	7	0	93	7	0	0
Boulder River Middle	0	0	81	0	19	28.4	52.6	19	0	0
Boulder River Lower	1	0	99	0	0	35.6	64.4	0	0	0
Cataract Creek	27	72	0	0	1	99	0	1	0	0
Elkhorn Creek Upper	24	0	71	0	5	95	0	5	0	0
Elkhorn Creek Lower	0	47	47	0	6	30.6	63.4	6	0	0
High Ore Creek	20	0	71	0	9	91	0	9	0	0
Little Boulder River	44	56	0	0	0	100	0	0	0	0
N.F. Little Boulder River	76	24	0	0	0	100	0	0	0	0
Lowland Creek	5	0	33.5	33.5	28	72	0	28	0	0
McCarty Creek	37	0	61	0	2	58.4	39.6	2	0	0
Muskrat Creek	41	0	0	59	0	41	59	0	0	0
Nursery Creek	0	100	0	0	0	65	35	0	0	0
Uncle Sam Gulch	26	74	0	0	0	100	0	0	0	0

1.5.11 Distance and Riparian Health Based Sediment Delivery Ratio

The USLE model upon which this model is founded is, as its name states, a soil loss (i.e. sediment production) model. Soil lost from one area due to erosive processes is typically redeposited a short distance downslope however, and most sediment produced from a hillslope erosion event does not travel so far as to be delivered to a stream channel. As TMDL questions deal specifically with sediment delivered to the stream, a method of accounting for redeposition and ultimate delivery to streams is required.

With USLE based models, this accounting of sediment redeposition is typically achieved through the application of a *sediment delivery ratio (SDR)*, a factor that estimates the percentage of sediment produced that is ultimately delivered to the stream. We apply a distance based sediment delivery ratio that reflects the relationship between downslope travel distance and ultimate sediment delivery.

Given that riparian zones can be effective sediment filters when wide and well vegetated, that riparian zone health is susceptible to anthropogenic impacts and thus to land management decisions, and that the effectiveness of riparian zones as sediment filters has been quantified in the literature, we incorporate riparian zone health and its effect on sediment delivery into our distance based sediment delivery ratio.

1.5.11.1 Distance based SDR

Megahan and Ketcheson (1996) found that the relationship between the percentage (by volume) of a sediment mass that travels a given percentage of the maximum sediment travel distance of that sediment mass is as shown in **Figure 1-9**.

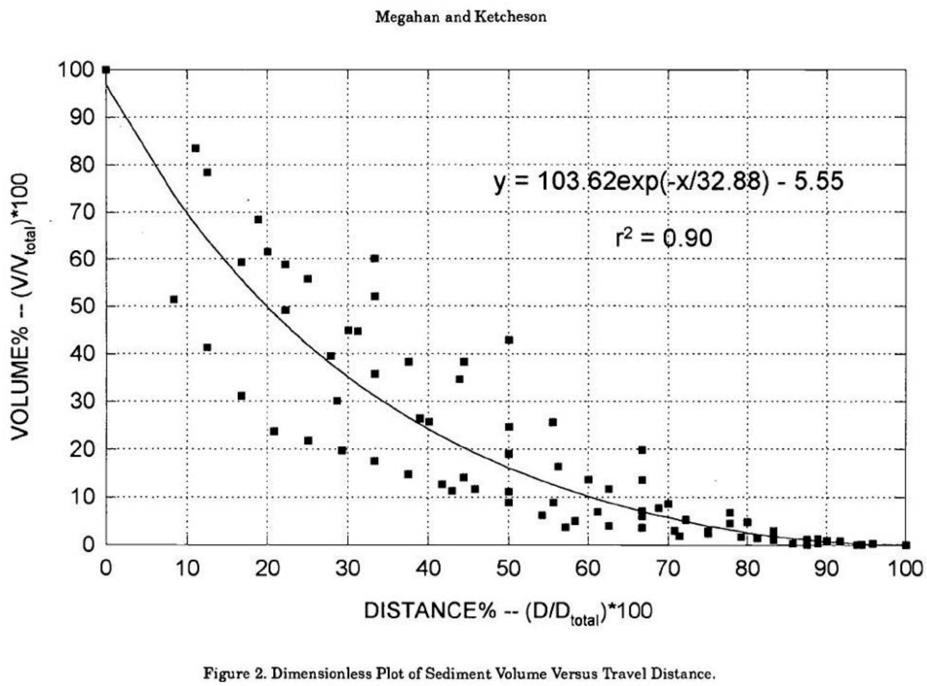

Figure 1-9. Figure 2 from Megahan and Ketcheson (1996), a dimensionless plot of sediment volume vs. travel distance.

This relationship was derived from a dataset of approximately 100 observations of sediment transport downslope from a known source (forest roads) that was not intercepted by a stream. It thus represents the ‘typical’ transport distribution along the maximum transport distance under a variety of field conditions.

Megahan and Ketcheson’s logarithmic regression of the data permits this relationship to be expressed by the equation presented in Figure 1-8, which may be restated as a function of three variables:

*Volume % = 103.62*EXP(-((D/Dtotal)/32.88))-5.55*

where:

Volume% = the percentage of sediment mobilized from a source that travels at least distance D from that source

D = distance from the sediment source, and

Dtotal = the maximum distance that sediment travels from the source

As this equation is dimensionless, to serve as an SDR it must first be scaled to the field conditions of the study area. This is accomplished by evaluating the equation with site specific values for D and Volume% at a single point, and solving for Dtotal. Having established a site specific Dtotal, the M&K equation reduces to two unknowns, the two variables that define a distance based SDR: distance and percent sediment delivered beyond that distance. This SDR may be used to estimate sediment delivery at all points on the sediment delivery path, from streambank to a distance Dtotal.

The derivation of site specific values of D and Volume % for use in scaling Megahan and Ketcheson's dimensionless equation is presented in section 1.5.11.2

1.5.11.2 Sub-basin specific Sediment Delivery Ratio scale factors.

Riparian zone sediment filtering capacity is typically expressed as a given percent reduction in delivery of sediment entering a riparian zone of a given width. This rating of a known percent delivery (Volume%) from a known distance from the stream (D) permits scaling of the Megahan and Ketcheson's dimensionless equation (section 1.5.11.1) for use in predicting percent delivery from other distances.

Literature review (Wegner 1999, Knutson and Naef 1997) indicates that a 100 foot wide, well vegetated riparian buffer zone can be expected to filter 75-90% of incoming sediment from reaching its stream channel. Accordingly, this analysis conservatively assumes that a sediment reduction efficiency of 75% represents the performance of a 100 foot wide, high quality (good) vegetated riparian buffer in the Boulder Elkhorn watershed. Conversely, this analysis conservatively assumes that a 100 foot wide riparian zone without vegetation cover would only filter 10% of incoming sediment from reaching its stream. An approximately equal apportionment of the remaining range in sediment reduction efficiency between the 'poor', 'moderately fair, 'fair', and 'moderately good' riparian assessment categories results in the riparian health/sediment delivery relationship shown in **Figure 1-10**.

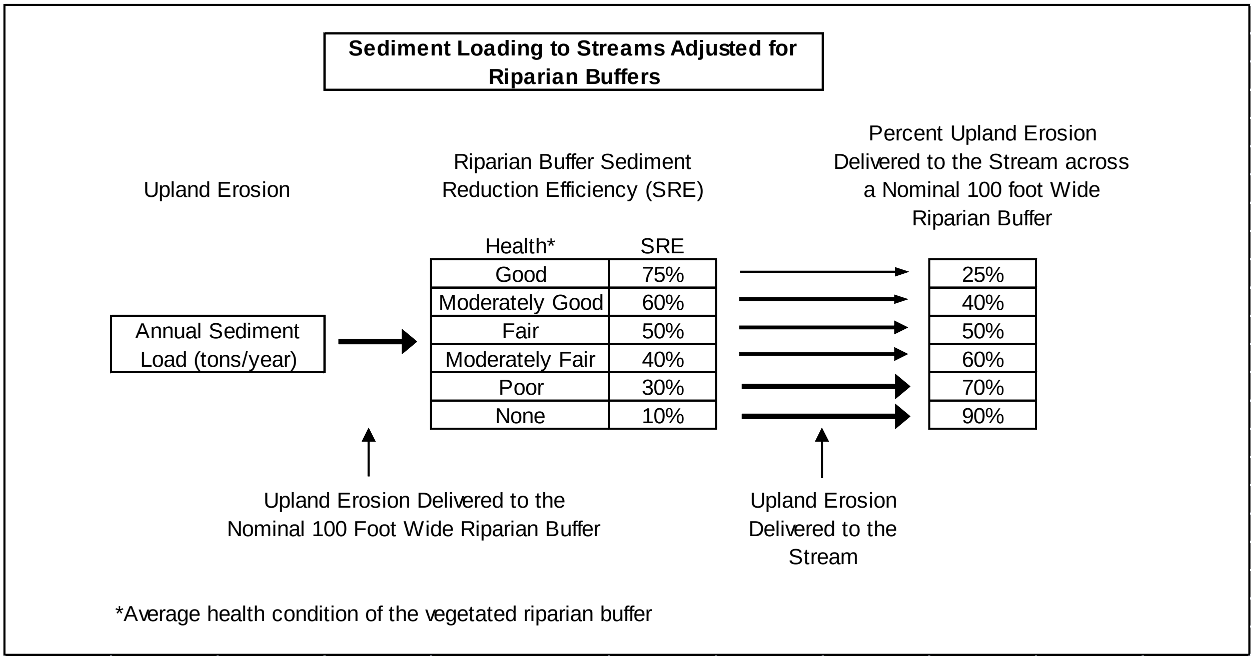

Figure 1-10. USLE Upland Sediment Load Delivery Adjusted for Riparian Buffer Capacity

Applying this relationship to the Boulder Elkhorn riparian assessment, we computed a riparian health score based sediment reduction percentage for each sub-basin of interest. This represents the percent reduction in delivery of sediment from a nominal 100 foot wide riparian zone. This was accomplished by taking the percentage of the stream length in each of the five riparian health classes, multiplying by the assumed sediment delivery efficiency reduction for each class (75% for good quality, 60% for moderately good quality, 50% for fair quality, 40% for moderately fair quality, and 30% for a poor quality) and summing for each stream.

The riparian health assessment based Sediment Reduction Percentage computed for each sub-basin of interest is presented in **Table 1-4.** Values are presented for both the existing conditions scenario and a BMP scenario. Under the BMP scenario, it is assumed that the implementation of BMPs on those activities that affect the overall health of the vegetated riparian buffer will increase an area with poor quality riparian health to fair quality. The increase for areas with an existing riparian health quality of better than poor varies for each sub-basin depending on the potential for improvement as determined by DEQ.

Table 1-4 Sediment reduction percentage based on riparian health assessment.

Sub-Basin	Riparian Quality	Percent of TMDL Stream Length for Existing Conditions	Weighted Sediment Reduction Percentage Existing Conditions	Percent of TMDL Stream Length for BMP Conditions	Weighted Sediment Reduction Percentage BMP Conditions	Change in Sediment Reduction Percentage	BMP Conditions
Bison Creek	Good						-Mod. Fair to Mod. Good -Poor to Fair
	Mod. Good			97	58.2		
	Fair			3	1.5		
	Mod. Fair	97	38.8				
	Poor	3	0.9				
	Total		**39.7**		**59.7**	**20.0**	
Lowland Creek	Good	5	3.8	72	54.0		-Fair to Good -Mod. Fair to Good -Poor to Fair
	Mod. Good						
	Fair	33.5	16.8	28	14.0		
	Mod. Fair	33.5	134				
	Poor	28	8.4				
	Total		**42.3**		**68.0**	**25.7**	
Boulder River Headwaters	Good	10	7.5	100	75.0		-Fair to Good
	Mod. Good						
	Fair	90	45.0				
	Mod. Fair						
	Poor						
	Total		**52.5**		**75.0**	**22.5**	
Basin Creek	Good	32	24.0	98	73.5		-Mod. Good to Good -Poor to Fair
	Mod. Good	66	39.6				
	Fair			2	1.0		
	Mod. Fair						
	Poor	2	0.6				
	Total		**64.2**		**74.5**	**10.3**	
Uncle Sam Gulch	Good	26	19.5	100	75.0		-Mod. Good to Good
	Mod. Good	74	44.4				
	Fair						
	Mod. Fair						
	Poor						
	Total		**63.9**		**75.0**	**11.1**	
Cataract Creek	Good	27	20.3	99	74.3		-Mod. Good to Good -Poor to Fair
	Mod. Good	72	43.2				
	Fair			1	0.5		
	Mod. Fair						
	Poor	1	0.3				
	Total		**63.8**		**74.8**	**11.0**	
High Ore Creek	Good	20	15.0	91	68.3		-Fair to Good -Poor to Fair
	Mod. Good						
	Fair	71	35.5	9	4.5		
	Mod. Fair						
	Poor	9	2.7				
	Total		**53.2**		**72.8**	**19.6**	

Sub-Basin	Riparian Quality	Percent of TMDL Stream Length for Existing Conditions	Weighted Sediment Reduction Percentage Existing Conditions	Percent of TMDL Stream Length for BMP Conditions	Weighted Sediment Reduction Percentage BMP Conditions	Change in Sediment Reduction Percentage	BMP Conditions
Boulder River Upper	Good			93	55.8		-Fair to Mod. Good -Mod. Fair to Mod. Good -Poor to Fair
	Mod. Good						
	Fair	46.5	23.3	7	3.5		
	Mod. Fair	46.5	18.6				
	Poor	7	2.1				
	Total		**44.0**		**59.3**	**15.4**	
N. F. Little Boulder River	Good	76	57.0	100	75.0		-Mod. Good to Good
	Mod. Good	24	14.4				
	Fair						
	Mod. Fair						
	Poor						
	Total		**71.4**		**75.0**	**3.6**	
Little Boulder River	Good	44	33.0	100	75.0		-Mod. Good to Good
	Mod. Good	56	33.6				
	Fair						
	Mod. Fair						
	Poor						
	Total		**66.6**		**75.0**	**8.4**	
Nursery Creek	Good			65	48.8		-65% Mod. Good to Good
	Mod. Good	100	60.0	35	21.0		
	Fair						
	Mod. Fair						
	Poor						
	Total		**60.0**		**69.8**	**9.8**	
Muskrat Creek	Good	41	30.8	41	30.8		-Mod. Fair to Mod. Good
	Mod. Good			59	35.4		
	Fair						
	Mod. Fair	59	23.6				
	Poor						
	Total		**54.4**		**66.2**	**11.8**	
McCarty Creek	Good	37	27.8	58.4	43.8		-35% Fair to Good -65% Fair to Mod. Good -Poor to Fair
	Mod. Good			39.7	23.8		
	Fair	61	30.5	2	1.0		
	Mod. Fair						
	Poor	2	0.6				
	Total		**58.9**		**68.6**	**9.7**	
Elkhorn Creek Upper	Good	24	18.0	95	71.3		-Fair to Good -Poor to Fair
	Mod. Good						
	Fair	71	35.5	5	2.5		
	Mod. Fair						
	Poor	5	1.5				
	Total		**55.0**		**73.8**	**18.8**	

Table 1-4 Sediment reduction percentage based on riparian health assessment (continued).

Table 1-4 Sediment reduction percentage based on riparian health assessment (continued).

Sub-Basin	Riparian Quality	Percent of TMDL Stream Length for Existing Conditions	Weighted Sediment Reduction Percentage Existing Conditions	Percent of TMDL Stream Length for BMP Conditions	Weighted Sediment Reduction Percentage BMP Conditions	Change in Sediment Reduction Percentage	BMP Conditions
Elkhorn Creek Lower	Good			30.5	22.9		-65% Mod. Good to Good -Fair to Mod. Good -Poor to Fair
	Mod. Good	47	28.2	63.5	38.1		
	Fair	47	23.5	6	3.0		
	Mod. Fair						
	Poor	6	1.8				
	Total		**53.5**		**64.0**	**10.5**	
Boulder River Middle	Good			28.4	21.3		-35% Fair to Good -65% Fair to Mod. Good -Poor to Fair
	Mod. Good			52.6	31.6		
	Fair	81	40.5	19	9.5		
	Mod. Fair						
	Poor	19	5.7				
	Total		**46.2**		**62.4**	**16.2**	
Boulder River Lower	Good	1	0.8	35.6	26.7		-35% Fair to Good -65% Fair to Mod. Good
	Mod. Good			64.4	38.6		
	Fair	99	49.5				
	Mod. Fair						
	Poor						
	Total		**50.3**		**65.3**	**15.0**	

1.5.11.3 Sediment Delivery Ratio - Example Calculation

To create a final, sub-basin specific SDR, Megahan and Ketcheson's dimensionless equation relating percent sediment volume to percent travel distance (**Figure 1-9**) was scaled to each sub-basin by using its riparian health assessment based 100 ft Sediment Reduction Percentage to derive a site specific maximum sediment travel distance. For each sub-basin, the following method was applied:

1 From the sub-basin's Riparian Health Assessment, determine the expected % sediment delivery across a nominal 100 foot wide riparian zone.

Example:
Per Table 1-4, the Bison Creek sub-basin's expected existing sediment delivery across a **100** foot wide riparian zone is (100% - 39.7% reduction) = **60.3%** delivered.

2 Substitute the expected % sediment delivery across a 100 foot wide riparian zone into Megahan and Ketcheson's dimensionless sediment volume vs. travel distance equation.

Example:
Volume% = 103.62exp(-((D/Dtotal)*100)/32.88) - 5.55 =

60.3% = 103.62exp(-((**100**/Dtotal)*100)/32.88) - 5.55

3 Solve the M&K equation for Dtotal to arrive at a representative maximum sediment travel distance for that sub-basin.

Example:
60.3% = 103.62exp(-((**100**/Dtotal)*100)/32.88) - 5.55

Dtotal = **100**/(-0.3288*ln((**60.3** + 5.55)/103.62))

Dtotal = **671** feet

4 Restate the M&K equation using the sub-basin's calculated maximum sediment travel distance (Dtotal) to arrive at an integrated Distance and Riparian Health based Sediment Deliver Ratio (SDR) for that sub-basin.

Example:
Within the Bison Creek sub-basin, the SDR for an analytical pixel with a drainage path to the nearest stream of length **D** would be given by:

Volume% = 103.62exp(-((D/**671**)*100)/32.88) - 5.55

By this method, the Sediment Delivery Ratio for each analytical pixel in a Boulder Elkhorn watershed sub-basin is obtained by evaluating this equation:

***SDR** = 103.62*EXP(-((**D/Dtotal**)/32.88))-5.55*

Where:

SDR = the percentage of sediment generated from the pixel that is delivered to a stream;
D = the downslope distance from the pixel to the nearest stream channel; and
Dtotal = the sub-basin specific Riparian Health derived maximum sediment travel distance.

1.5.12 Model Assumptions

The following assumptions are made, concerning the applicability and accuracy of the model with respect to the intended use of the results:

1. That the USLE model is sufficiently accurate for TMDL purposes. Discussion: The USLE model has been in widespread use for more than thirty years, and has been found to be sufficient for natural resources management decision making at the field scale.
2. That it is appropriate to extend the field scale USLE model to watershed scale. Discussion: Many watershed scale implementations of the USLE model have been developed and presented in the peer reviewed literature. This model is a similar gridded USLE implementation, and it faithfully executes the methodology specified in USDA Agriculture Handbook No. 703. It operates in field scale on a 10 meter

analytic pixel, and achieves watershed scale implementation through aggregation of field scale results.

3. That the data sources used are appropriate for USLE parameterization. Discussion: Data sources for USLE R and K factors were purpose built for that use. The USLE C factor is derived from Landsat thematic mapper imagery, classified by a rigorous process of peer reviewed methods into the NLCD landcover dataset. Specific assignment of C factors to landcover classes was performed under the guidance of natural resource professionals well versed in the application of USLE and USLE based sediment production models at the field scale. The USLE P factor was not used, as the best professional judgement of these same land managers is that the agricultural practices intended to be reflected by the USLE P factor are not in significant use in the Boulder Elkhorn watershed. The USLE L & S factors are mathematical constructs representing landform, and are derived here from Digital Terrain data. This analysis assumes that a 10 meter analytic pixel adequately describes the micro terrain slope and slope length at field scale. To the extent that this assumption is not met, results may deviate.
4. That the Riparian Health Assessment is of sufficient accuracy, resolution and coverage to serve as the basis for a sediment delivery ratio. Discussion: The Riparian Health Assessment only surveyed mainstem reaches. The condition of mainstem reaches is considered here to be broadly representative of overall watershed condition. To the extent that this assumption is not met, results may deviate proportionately.
5. That it is appropriate to use Megehan and Ketcheson's (1996) dimensionless equation relating sediment travel distance and delivered volume as the basis for a sediment delivery ratio. Discussion: Megehan and Ketcheson (1996) establishes that the purpose of the work is to provide an empirical alternative to process based modeling approaches for sediment delivery to streams. A decade later, Megehan and Ketcheson went on to produce the Washington Road Surface Erosion Model (WARSEM, 2004) which uses the Megehan and Ketcheson (1996) dimensionless equation as an SDR to account for delivery across fillslopes to streams. Here, we replicate Megehan and Ketcheson's use of the three variable dimensionless equation for the WARSEM SDR, evaluating that equation for a representative maximum sediment travel distance, and arriving at a scaled distance/sediment delivery relationship.

   A specific concern is that the Megehan and Ketcheson method, because it does not explicitly account for changes in vegetation as might be expected transitioning an upland/riparian zone boundary, may not adequately represent sediment delivery across a riparian zone. We note that whereas Megehan and Ketcheson used a single scaling of the dimensionless equation for all locations in an attempt to render the WARSEM model broadly applicable with minimum data collection needs, we take advantage of the available Boulder Elkhorn Riparian Health Assessment data to derive site-specific scalings of the dimensionless equation for Boulder Elkhorn sub-basins, based on riparian condition.

In this implementation, it is assumed that a significant difference in vegetation density between riparian and upland is unlikely to favor the upland, i.e. if there is a great difference, it is going to be a well vegetated near-stream zone paired with a sparsely vegetated upland. The most extreme instance of that would be reflected in this modeling approach as a 'good' riparian health category. For that category, we evaluate the dimensionless equation using the literature value of 75% sediment reduction at 100 feet, deriving a Dtotal value that may be used to estimate the percent sediment reduction at all distances. If failing to explicitly account for a significant change in vegetation produces a 'bust' in this procedure, it will be that it somewhat underestimates the sediment delivered from the upland portion of the delivery path. Given that:

- the maximum percent delivery for that portion of the path is 25%, declining to 0% at the outer bound, and
- that vegetation is only one component of the obstruction value, and
- that the obstruction value is only one of the factors predictive for sediment delivery,

we may conclude that the maximum effect of such a vegetation difference induced 'bust' is, in the most extreme case, some small fraction of 25%. Working down from that rare, most extreme case - if riparian condition and immediately adjacent upland condition are more similar, the potential magnitude of a 'bust' rooted in their difference becomes smaller as well. This places potential error in sediment due to the riparian transition well within the bounds of this effort.

6. That the uncalibrated watershed scale USLE model and sediment delivery ratio are sufficiently accurate for Boulder Elkhorn TMDL purposes. Discussion: The USLE is an empirical model developed initially for eastern US crop lands, but has been extended via revised C factors and other means to be more broadly applicable. The C factors used for this effort were chosen to be as representative of Boulder Elkhorn conditions as professional judgement allows. The Megehan and Ketcheson dimensionless equation was similarly developed as an empirical method for sediment delivery accounting in watersheds similar to the Boulder Elkhorn. The implementation of that SDR method used here is further fit to the Boulder Elkhorn project area with the use of site specific scaling factors. Both components of the model remain uncalibrated to local conditions however, in the sense that these attempts to better represent the Boulder Elkhorn watershed have not been tested empirically. Use of the results for relative comparison (as between sub-basins or alternative management scenarios) is well supported. Use of the results as predictors of absolute sediment load should be undertaken with care. Though both the USLE and the Megehan and Ketcheson SDR are currently in widespread use for absolute prediction of sediment load, local verification of predictive power is (as here) rarely undertaken.

1.6 Results

1.6.1 Management Scenarios

Figures 1-11 through 1-14 present the USLE based hillslope model's prediction of existing and potential conditions graphically. **Table 1-5** presents the prediction of existing and potential conditions numerically, broken out by 6^{th} code HUC (as modified to represent the 303d listed streams) and existing land cover type. **Table 1-6** presents the delivered sediment load cumulative totals within the watershed. The cumulative totals for a sub-basin are a sum of the results for that sub-basin plus the sub-basins upstream of it. For example, Boulder River Headwaters is a sum of the results for that sub-basin plus the results for Bison Creek and Lowland Creek.

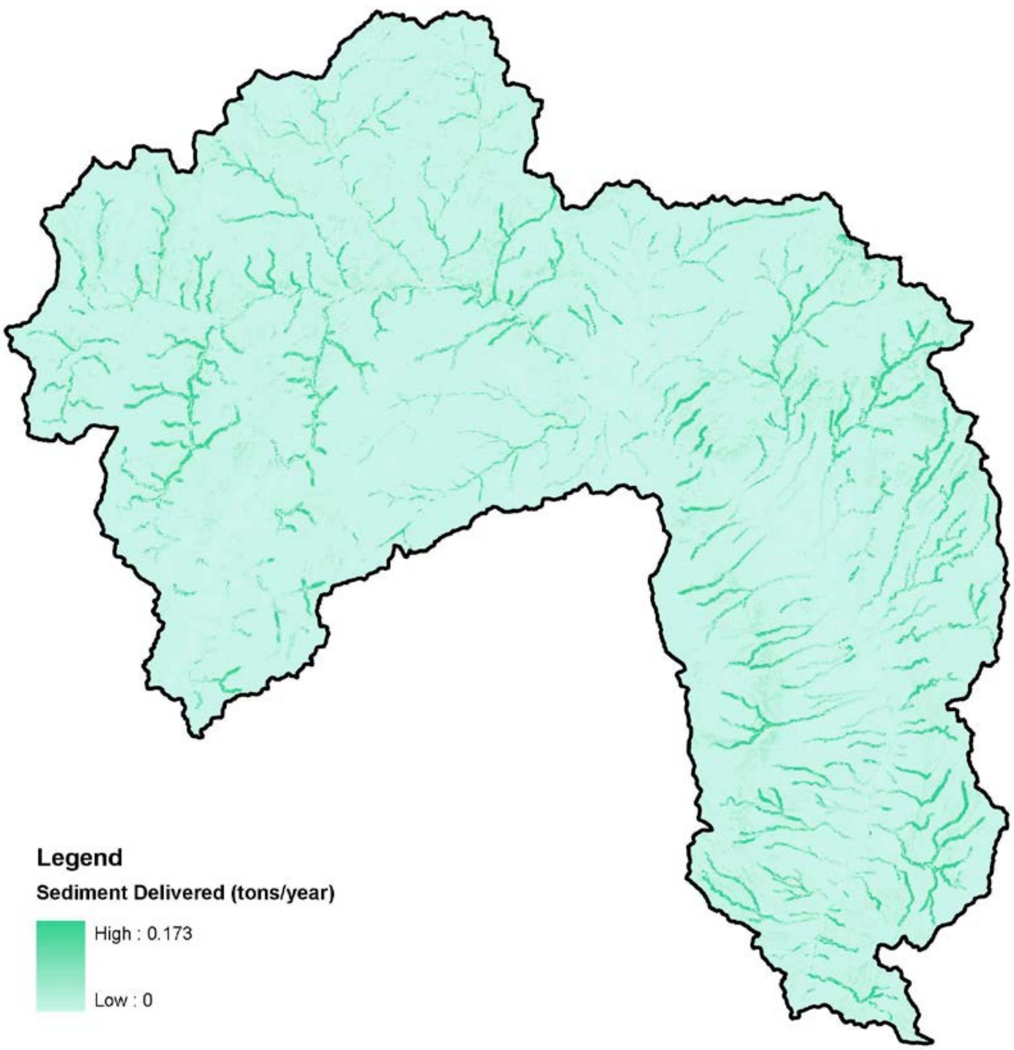

Figure 1-11. Upland Erosion Sediment Load for Existing Upland Conditions and Existing Riparian Health Conditions, Scenario 1.

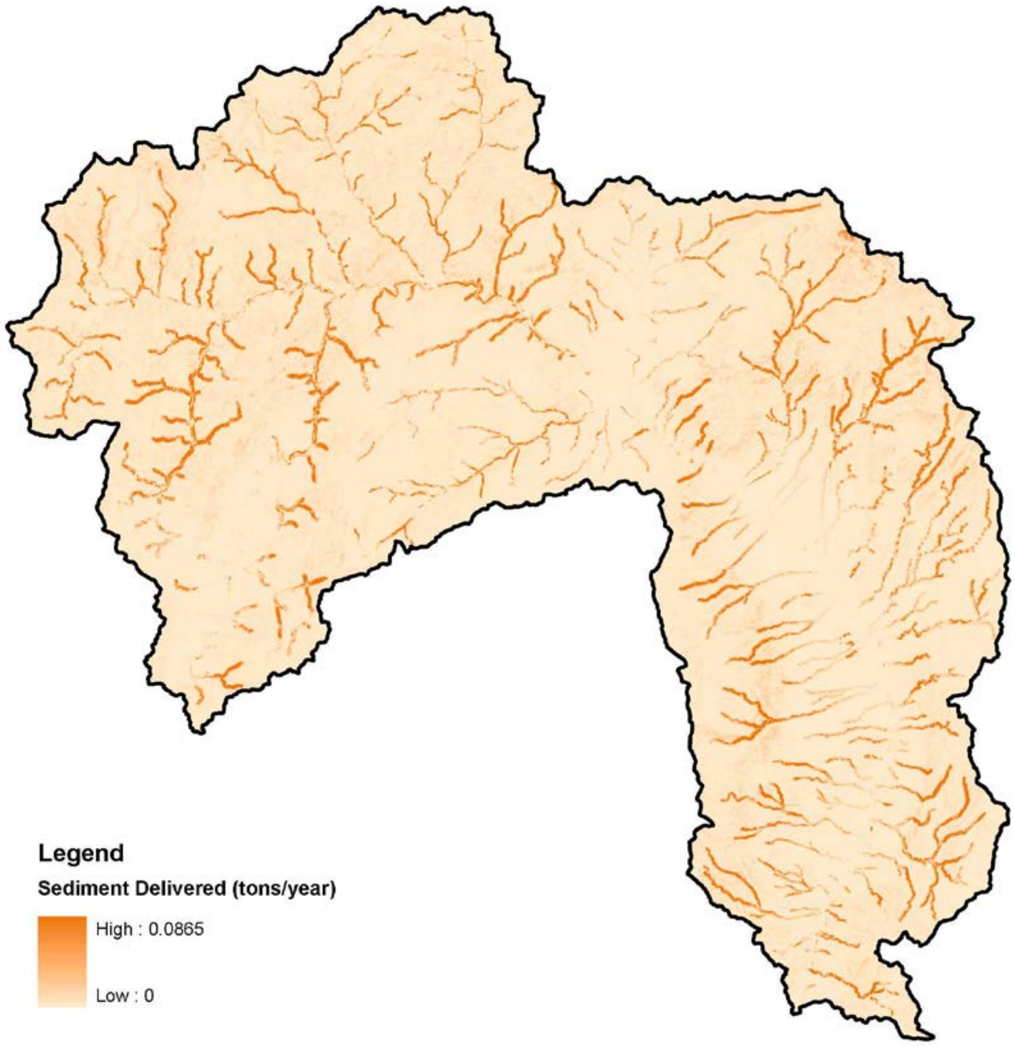

Figure 1-12. Upland Erosion Sediment Load for BMP Upland Conditions and Existing Riparian Health Conditions, Scenario 2.

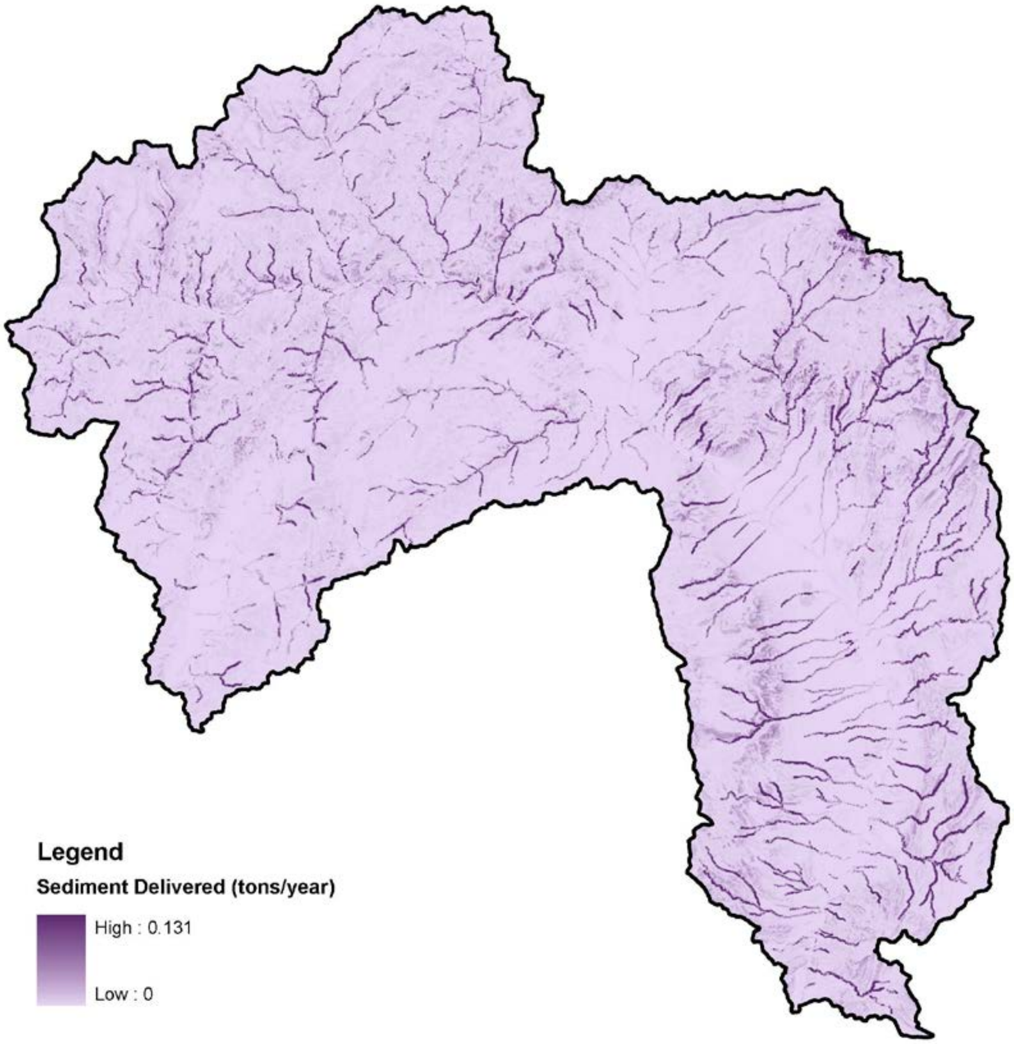

Figure 1-13. Upland Erosion Sediment Load for Existing Upland Conditions and BMP Riparian Health Conditions, Scenario 3.

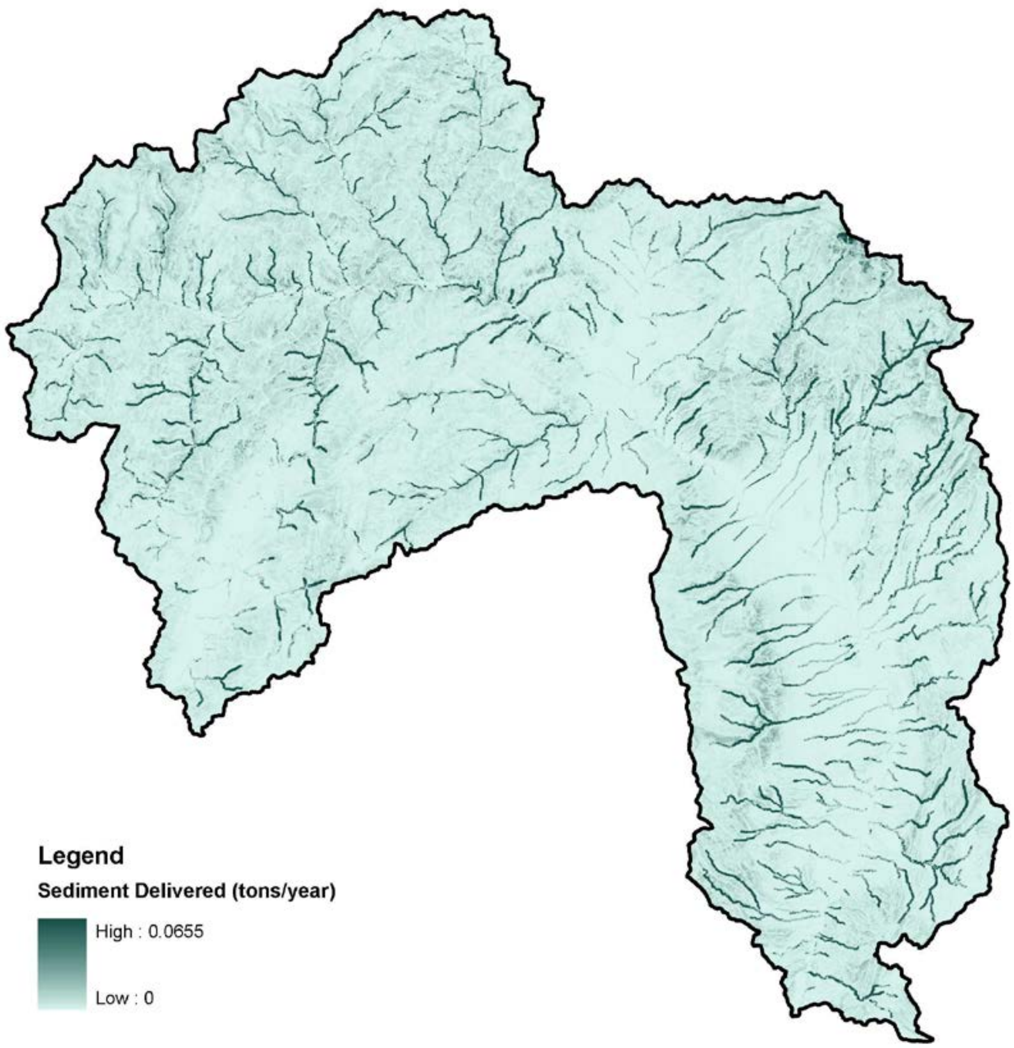

Figure 1-14. Upland Erosion Sediment Load for BMP Upland Conditions and BMP Riparian Health Conditions, Scenario 4.

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed.

			Scenario 1	**Scenario 2**		**Scenario 3**		**Scenario 4**	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Lowland Creek	Evergreen Forest	23,493.4	236.4	236.4	0%	115.1	51%	115.1	51%
	Shrub/Scrub	2,302.7	229.6	114.8	50%	92.3	60%	46.2	80%
	Grassland/Herbaceous	1,137.0	51.3	25.7	50%	20.7	60%	10.3	80%
	Pasture/Hay	0.8	<1	<1	0%	<1	0%	<1	0%
	Transitional	464.8	3.4	1.7	50%	2.0	42%	1.0	71%
	Woody Wetlands	3.6	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	27.1	<1	<1	0%	<1	0%	<1	0%
	Total	**27,429.5**	**521.0**	**378.8**	**27%**	**230.2**	**56%**	**172.7**	**67%**
Bison Creek	Evergreen Forest	34,841.6	298.3	298.3	0%	173.1	42%	173.1	42%
	Shrub/Scrub	4,123.6	76.5	38.3	50%	41.8	45%	20.9	73%
	Grassland/Herbaceous	7,867.5	40.9	20.5	50%	26.1	36%	13.1	68%
	Pasture/Hay	67.9	<1	<1	0%	<1	0%	<1	0%
	Transitional	1,399.8	10.6	5.3	50%	6.3	41%	3.1	70%
	Developed, open space	917.9	9.0	9.0	0%	3.9	57%	3.9	57%
	Woody Wetlands	10.7	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	49.0	2.3	1.1	50%	1.5	36%	0.7	68%
	Developed, low intensity	252.2	1.6	1.6	0%	0.5	66%	0.5	66%
	Developed, medium intensity	44.1	<1	<1	0%	<1	0%	<1	0%
	Barren Land	4.4	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	10.5	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.8	<1	<1	0%	<1	0%	<1	0%
	Total	**49,591.1**	**440.5**	**375.0**	**15%**	**253.8**	**42%**	**215.8**	**51%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Headwaters	Evergreen Forest	53,080.9	431.9	431.8	0%	257.0	40%	257.0	40%
	Shrub/Scrub	6,044.6	227.6	113.8	50%	123.8	46%	61.9	73%
	Grassland/Herbaceous	3,281.5	97.4	48.7	50%	53.2	45%	26.6	73%
	Pasture/Hay	97.8	1.4	0.7	50%	0.7	48%	0.4	74%
	Transitional	309.0	6.7	3.3	50%	3.1	53%	1.6	77%
	Developed, open space	74.9	1.2	1.2	0%	0.5	63%	0.5	63%
	Woody Wetlands	107.5	1.1	0.5	54%	0.6	45%	0.3	74%
	Cultivated Crops	76.9	11.9	6.0	50%	6.5	45%	3.3	73%
	Developed, low intensity	82.6	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	6.9	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	13.5	<1	<1	0%	<1	0%	<1	0%
	Total	**63,176.1**	**779.9**	**606.8**	**22%**	**445.8**	**43%**	**351.7**	**55%**
Basin Creek	Evergreen Forest	24,709.7	143.6	143.6	0%	114.1	20%	114.1	20%
	Shrub/Scrub	1,009.3	39.3	19.6	50%	29.6	25%	14.8	62%
	Grassland/Herbaceous	332.3	9.5	4.7	50%	7.6	20%	3.8	60%
	Pasture/Hay	8.3	<1	<1	0%	<1	0%	<1	0%
	Transitional	359.1	1.6	0.8	50%	1.4	11%	0.7	56%
	Developed, open space	0.5	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	4.0	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	1.3	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	6.4	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	6.2	<1	<1	0%	<1	0%	<1	0%
	Barren Land	135.2	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	2.4	<1	<1	0%	<1	0%	<1	0%
	Total	**26,574.6**	**194.6**	**169.1**	**13%**	**153.3**	**21%**	**133.8**	**31%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Uncle Sam Gulch	Evergreen Forest	1,776.3	11.1	11.1	0%	8.7	21%	8.7	21%
	Shrub/Scrub	102.1	2.4	1.2	50%	2.1	10%	1.1	55%
	Grassland/Herbaceous	41.6	<1	<1	0%	<1	0%	<1	0%
	Transitional	2.0	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	1.1	<1	<1	0%	<1	0%	<1	0%
	Total	**1,923.2**	**14.2**	**12.7**	**11%**	**11.5**	**19%**	**10.1**	**29%**
Cataract Creek	Evergreen Forest	16,577.2	93.9	93.9	0%	74.1	21%	74.1	21%
	Shrub/Scrub	1,393.5	37.5	18.7	50%	29.0	23%	14.5	61%
	Grassland/Herbaceous	1,199.7	17.5	8.7	50%	14.2	19%	7.1	60%
	Pasture/Hay	2.0	<1	<1	0%	<1	0%	<1	0%
	Transitional	297.9	1.9	0.9	50%	1.7	8%	0.9	54%
	Developed, open space	3.0	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	2.4	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	1.2	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	12.8	<1	<1	0%	<1	0%	<1	0%
	Total	**19,489.8**	**150.8**	**122.4**	**19%**	**119.0**	**21%**	**96.6**	**36%**
High Ore Creek	Evergreen Forest	3,845.4	40.1	40.1	0%	22.7	43%	22.7	43%
	Shrub/Scrub	1,227.4	66.3	33.2	50%	39.6	40%	19.8	70%
	Grassland/Herbaceous	297.2	18.4	9.2	50%	10.7	42%	5.4	71%
	Transitional	273.6	1.1	0.6	50%	1.0	10%	0.5	55%
	Barren Land	1.2	<1	<1	0%	<1	0%	<1	0%
	Total	**5,644.9**	**126.0**	**83.0**	**34%**	**74.1**	**41%**	**48.4**	**62%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Upper	Evergreen Forest	10,710.3	93.6	93.6	0%	56.6	40%	56.6	40%
	Shrub/Scrub	4,014.9	127.3	63.6	50%	79.3	38%	39.7	69%
	Grassland/Herbaceous	1,394.9	33.4	16.7	50%	20.6	38%	10.3	69%
	Pasture/Hay	28.2	<1	<1	0%	<1	0%	<1	0%
	Transitional	1,133.6	12.4	6.2	50%	7.8	37%	3.9	69%
	Developed, open space	317.6	3.5	3.5	0%	1.8	47%	1.8	47%
	Woody Wetlands	18.0	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	428.0	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	132.9	<1	<1	0%	<1	0%	<1	0%
	Barren Land	0.1	<1	<1	0%	<1	0%	<1	0%
	Developed, high intensity	1.3	<1	<1	0%	<1	0%	<1	0%
	Total	**18,179.9**	**272.2**	**185.4**	**32%**	**167.3**	**39%**	**113.3**	**58%**
North Fork Little Boulder River	Evergreen Forest	10,863.2	34.8	34.8	0%	31.8	9%	31.8	9%
	Shrub/Scrub	707.3	10.8	5.4	50%	9.7	10%	4.9	55%
	Grassland/Herbaceous	239.4	2.8	1.4	50%	2.6	8%	1.3	54%
	Pasture/Hay	1.0	<1	<1	0%	<1	0%	<1	0%
	Transitional	73.7	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	5.1	<1	<1	0%	<1	0%	<1	0%
	Total	**11,889.7**	**48.8**	**41.8**	**14%**	**44.4**	**9%**	**38.1**	**22%**
Little Boulder River	Evergreen Forest	22,741.2	100.7	100.7	0%	81.3	19%	81.3	19%
	Shrub/Scrub	1,538.0	38.3	19.2	50%	28.9	25%	14.5	62%
	Grassland/Herbaceous	842.3	12.6	6.3	50%	9.4	26%	4.7	63%
	Pasture/Hay	166.6	1.9	1.0	50%	1.7	12%	0.8	56%
	Developed, open space	90.9	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	31.4	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	1.3	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	23.7	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	2.5	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.3	<1	<1	0%	<1	0%	<1	0%
	Total	**25,439.3**	**154.3**	**127.6**	**17%**	**121.8**	**21%**	**101.6**	**34%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Nursery Creek	Evergreen Forest	325.5	1.3	1.3	0%	1.2	14%	1.2	14%
	Shrub/Scrub	25.4	<1	<1	0%	<1	0%	<1	0%
	Grassland/Herbaceous	4.2	<1	<1	0%	<1	0%	<1	0%
	Pasture/Hay	0.9	<1	<1	0%	<1	0%	<1	0%
	Transitional	306.9	3.4	1.7	50%	2.6	21%	1.3	61%
	Total	**662.9**	**5.2**	**3.3**	**37%**	**4.2**	**18%**	**2.7**	**48%**
Muskrat Creek	Evergreen Forest	10,655.4	66.2	66.2	0%	47.8	28%	47.8	28%
	Shrub/Scrub	4,576.7	44.0	22.0	50%	35.1	20%	17.5	60%
	Grassland/Herbaceous	4,438.4	28.3	14.2	50%	21.3	25%	10.7	62%
	Pasture/Hay	2,072.0	5.8	2.9	50%	4.6	21%	2.3	60%
	Transitional	2,016.5	7.4	3.7	50%	6.5	11%	3.3	56%
	Developed, open space	479.3	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	178.7	1.4	0.6	54%	1.2	14%	0.5	61%
	Cultivated Crops	225.0	7.7	3.8	50%	5.7	25%	2.9	63%
	Developed, low intensity	118.1	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	13.0	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	1.1	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	19.0	<1	<1	0%	<1	0%	<1	0%
	Total	**24,793.3**	**161.0**	**113.7**	**29%**	**122.4**	**24%**	**85.1**	**47%**
McCarty Creek	Evergreen Forest	2,950.4	10.8	10.8	0%	8.6	20%	8.6	20%
	Shrub/Scrub	603.2	6.6	3.3	50%	5.2	21%	2.6	61%
	Grassland/Herbaceous	198.3	1.9	0.9	50%	1.4	25%	0.7	62%
	Pasture/Hay	37.4	<1	<1	0%	<1	0%	<1	0%
	Transitional	7.1	<1	<1	0%	<1	0%	<1	0%
	Developed, open space	14.4	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	3.1	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	1.5	<1	<1	0%	<1	0%	<1	0%
	Total	**3,815.6**	**19.5**	**15.2**	**22%**	**15.4**	**21%**	**12.0**	**39%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Elkhorn Creek Upper	Evergreen Forest	16,084.0	141.8	141.8	0%	89.6	37%	89.6	37%
	Shrub/Scrub	2,196.5	131.7	65.9	50%	83.4	37%	41.7	68%
	Grassland/Herbaceous	455.1	16.0	8.0	50%	9.8	39%	4.9	69%
	Pasture/Hay	22.0	<1	<1	0%	<1	0%	<1	0%
	Transitional	185.7	3.0	1.5	50%	1.6	45%	0.8	73%
	Woody Wetlands	9.8	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	13.1	4.1	2.1	50%	2.9	30%	1.5	65%
	Barren Land	1.6	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	3.3	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.1	<1	<1	0%	<1	0%	<1	0%
	Total	**18,972.2**	**297.2**	**219.5**	**26%**	**187.7**	**37%**	**138.7**	**53%**
Elkhorn Creek Lower	Evergreen Forest	1,341.3	10.3	10.3	0%	8.0	22%	8.0	22%
	Shrub/Scrub	1,615.7	45.8	22.9	50%	34.1	26%	17.1	63%
	Grassland/Herbaceous	383.0	14.2	7.1	50%	11.4	20%	5.7	60%
	Pasture/Hay	156.4	1.6	0.8	50%	1.3	21%	0.6	60%
	Developed, open space	50.2	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	90.8	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	2.0	<1	<1	0%	<1	0%	<1	0%
	Total	**3,639.5**	**72.3**	**41.3**	**43%**	**55.1**	**24%**	**31.6**	**56%**

Table 1-5 Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Middle	Evergreen Forest	33,776.8	330.6	330.6	0%	213.1	36%	213.1	36%
	Shrub/Scrub	52,488.6	1,344.2	672.1	50%	841.4	37%	420.7	69%
	Grassland/Herbaceous	46,764.8	727.2	363.6	50%	463.5	36%	231.8	68%
	Pasture/Hay	9,278.4	20.9	10.4	50%	13.3	36%	6.7	68%
	Transitional	223.7	1.1	0.5	50%	1.0	12%	0.5	56%
	Developed, open space	1,490.5	1.1	1.1	0%	0.7	37%	0.7	37%
	Woody Wetlands	1,542.9	1.7	0.8	54%	1.1	38%	0.5	71%
	Cultivated Crops	1,001.9	31.6	15.8	50%	21.1	33%	10.5	67%
	Developed, low intensity	386.8	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	44.5	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	6.0	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	10.7	<1	<1	0%	<1	0%	<1	0%
	Developed, high intensity	3.1	<1	<1	0%	<1	0%	<1	0%
	Emergent Herbaceous Wetlands	4.0	<1	<1	0%	<1	0%	<1	0%
	Total	**147,022.7**	**2,458.4**	**1,395.1**	**43%**	**1,555.3**	**37%**	**884.5**	**64%**
Boulder River Lower	Evergreen Forest	7,215.9	63.3	63.3	0%	43.9	31%	43.9	31%
	Shrub/Scrub	10,111.3	265.8	132.9	50%	173.8	35%	86.9	67%
	Grassland/Herbaceous	16,216.9	255.9	127.9	50%	171.5	33%	85.8	66%
	Pasture/Hay	1,335.7	5.5	2.7	50%	3.3	40%	1.6	70%
	Developed, open space	416.3	1.5	1.5	0%	1.0	37%	1.0	37%
	Woody Wetlands	404.5	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	10.7	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	252.2	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	12.8	<1	<1	0%	<1	0%	<1	0%
	Total	**35,976.2**	**593.7**	**329.3**	**45%**	**394.5**	**34%**	**219.7**	**63%**

Table 1-6 Cumulative Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed.

			Scenario 1	**Scenario 2**		**Scenario 3**		**Scenario 4**	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Headwaters Total (Lowland Ck, Bison Ck, and Boulder River Headwaters)	Evergreen Forest	111,415.9	966.5	966.5	0%	545.1	44%	545.1	44%
	Shrub/Scrub	12,470.9	533.7	266.8	50%	257.9	52%	128.9	76%
	Grassland/Herbaceous	12,286.0	189.7	94.8	50%	100.0	47%	50.0	74%
	Pasture/Hay	166.6	1.8	0.9	50%	0.9	49%	0.5	74%
	Transitional	2,173.6	20.7	10.4	50%	11.4	45%	5.7	73%
	Developed, open space	992.8	10.2	10.2	0%	4.3	58%	4.3	58%
	Woody Wetlands	121.7	1.4	0.7	54%	0.8	42%	0.4	73%
	Cultivated Crops	126.0	14.2	7.1	50%	8.0	44%	4.0	72%
	Developed, low intensity	334.9	2.2	2.2	0%	0.8	64%	0.8	64%
	Developed, medium intensity	51.0	<1	<1	0%	<1	0%	<1	0%
	Barren Land	4.4	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	51.1	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.8	<1	<1	0%	<1	0%	<1	0%
	Total	**140,196.7**	**1,741.3**	**1,360.5**	**22%**	**929.7**	**47%**	**740.2**	**57%**
Cataract Creek Total (Uncle Sam Gulch and Cataract Ck)	Evergreen Forest	18,353.5	105.0	105.0	0%	82.8	21%	82.8	21%
	Shrub/Scrub	1,495.6	39.8	19.9	50%	31.1	22%	15.5	61%
	Grassland/Herbaceous	1,241.4	18.3	9.1	50%	14.9	19%	7.4	59%
	Pasture/Hay	2.0	<1	<1	0%	<1	0%	<1	0%
	Transitional	299.9	1.9	0.9	50%	1.7	8%	0.9	54%
	Developed, open space	3.0	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	2.4	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	1.2	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	14.0	<1	<1	0%	<1	0%	<1	0%
	Total	**21,412.9**	**165.1**	**135.0**	**18%**	**130.5**	**21%**	**106.7**	**35%**

Table 1-6 Cumulative Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Upper Total (Basin Ck, Cataract Ck Total, High Ore Ck, and Boulder River Upper)	Evergreen Forest	57,618.9	382.2	382.2	0%	276.2	28%	276.2	28%
	Shrub/Scrub	7,747.2	272.7	136.4	50%	179.7	34%	89.8	67%
	Grassland/Herbaceous	3,265.8	79.6	39.8	50%	53.8	32%	26.9	66%
	Pasture/Hay	38.5	<1	<1	0%	<1	0%	<1	0%
	Transitional	2,066.2	17.0	8.5	50%	11.9	30%	6.0	65%
	Developed, open space	321.1	3.5	3.5	0%	1.8	47%	1.8	47%
	Woody Wetlands	22.0	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	1.3	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	436.8	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	140.3	<1	<1	0%	<1	0%	<1	0%
	Barren Land	136.5	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	16.4	<1	<1	0%	<1	0%	<1	0%
	Developed, high intensity	1.3	<1	<1	0%	<1	0%	<1	0%
	Total	**71,812.3**	**757.9**	**572.7**	**24%**	**525.2**	**31%**	**402.1**	**47%**
Little Boulder River Total (N.F. Little Boulder River and Little Boulder River)	Evergreen Forest	33,604.4	135.6	135.6	0%	113.0	17%	113.0	17%
	Shrub/Scrub	2,245.4	49.1	24.6	50%	38.7	21%	19.3	61%
	Grassland/Herbaceous	1,081.7	15.4	7.7	50%	11.9	23%	6.0	61%
	Pasture/Hay	167.6	2.0	1.0	50%	1.8	13%	0.9	56%
	Transitional	73.7	<1	<1	0%	<1	0%	<1	0%
	Developed, open space	90.9	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	31.4	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	6.4	<1	<1	0%	<1	0%	<1	0%
	Developed, low intensity	23.7	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	2.5	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.3	<1	<1	0%	<1	0%	<1	0%
	Total	**37,329.0**	**203.2**	**169.5**	**17%**	**166.2**	**18%**	**139.7**	**31%**

Table 1-6 Cumulative Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Muskrat Creek Total (Nursery Ck and Muskrat Ck)	Evergreen Forest	10,980.9	67.5	67.5	0%	48.9	28%	48.9	28%
	Shrub/Scrub	4,602.1	44.2	22.1	50%	35.2	20%	17.6	60%
	Grassland/Herbaceous	4,442.6	28.4	14.2	50%	21.4	25%	10.7	62%
	Pasture/Hay	2,073.0	6.0	3.0	50%	4.8	20%	2.4	60%
	Transitional	2,323.4	10.7	5.4	50%	9.2	15%	4.6	57%
	Developed, open space	479.3	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	178.7	1.4	0.6	54%	1.2	14%	0.5	61%
	Cultivated Crops	225.0	7.7	3.8	50%	5.7	25%	2.9	63%
	Developed, low intensity	118.1	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	13.0	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	1.1	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	19.0	<1	<1	0%	<1	0%	<1	0%
	Total	**25,456.2**	**166.2**	**116.9**	**30%**	**126.6**	**24%**	**87.8**	**47%**
Elkhorn Creek Total (Elkhorn Ck Upper and Elkhorn Ck Lower)	Evergreen Forest	17,425.3	152.0	152.0	0%	97.6	36%	97.6	36%
	Shrub/Scrub	3,812.1	177.5	88.8	50%	117.5	34%	58.8	67%
	Grassland/Herbaceous	838.2	30.2	15.1	50%	21.2	30%	10.6	65%
	Pasture/Hay	178.4	1.9	1.0	50%	1.5	24%	0.7	62%
	Transitional	185.7	3.0	1.5	50%	1.6	45%	0.8	73%
	Developed, open space	50.2	<1	<1	0%	<1	0%	<1	0%
	Woody Wetlands	100.5	<1	<1	0%	<1	0%	<1	0%
	Cultivated Crops	13.1	4.1	2.1	50%	2.9	30%	1.5	65%
	Developed, low intensity	2.0	<1	<1	0%	<1	0%	<1	0%
	Barren Land	1.6	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	3.3	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	1.1	<1	<1	0%	<1	0%	<1	0%
	Total	**22,611.7**	**369.5**	**260.8**	**29%**	**242.8**	**34%**	**170.2**	**54%**

Table 1-6 Cumulative Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Middle Total (Little Boulder River Total, Muskrat Ck Total, McCarty Ck, Elkhorn Ck Total, and Boulder River Middle)	Evergreen Forest	65,133.5	560.9	560.9	0%	368.2	34%	368.2	34%
	Shrub/Scrub	61,506.0	1,572.5	786.2	50%	999.4	36%	499.7	68%
	Grassland/Herbaceous	52,243.9	787.6	393.8	50%	507.5	36%	253.7	68%
	Pasture/Hay	11,567.2	29.0	14.5	50%	19.7	32%	9.9	66%
	Transitional	2,739.9	14.8	7.4	50%	11.8	20%	5.9	60%
	Developed, open space	2,034.3	1.5	1.5	0%	1.0	34%	1.0	34%
	Woody Wetlands	1,825.3	3.7	1.7	54%	2.7	27%	1.2	66%
	Cultivated Crops	1,240.0	43.4	21.7	50%	29.7	31%	14.9	66%
	Developed, low intensity	506.9	<1	<1	0%	<1	0%	<1	0%
	Developed, medium intensity	57.5	<1	<1	0%	<1	0%	<1	0%
	Barren Land	1.6	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	12.0	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	30.8	<1	<1	0%	<1	0%	<1	0%
	Developed, high intensity	3.1	<1	<1	0%	<1	0%	<1	0%
	Emergent Herbaceous Wetlands	4.0	<1	<1	0%	<1	0%	<1	0%
	Total	**198,906.1**	**3,013.6**	**1,787.9**	**41%**	**1,940.1**	**36%**	**1,154.6**	**62%**

Table 1-6 Cumulative Delivered Sediment Load by Land Cover Type for the Boulder Elkhorn Watershed (continued).

			Scenario 1	Scenario 2		Scenario 3		Scenario 4	
Sub-basin	**Land Cover Classification**	**Area (acres)**	Upland Erosion Sediment Load for **Existing** Conditions and **Existing** Riparian Health **(tons/year)**	Upland Erosion Sediment Load for **BMP** Conditions and **Existing** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP** Conditions and **BMP** Riparian Health **(tons/year)**	**Percent Change from Existing**
Boulder River Total (Boulder R Headwaters Total, Boulder R Upper Total, Boulder R Middle Total, and Boulder R Lower)	Evergreen Forest	241,384.2	1,973.0	1,973.0	0%	1,233.5	37%	1,233.5	37%
	Shrub/Scrub	91,835.4	2,644.7	1,322.3	50%	1,610.7	39%	805.3	70%
	Grassland/Herbaceous	84,012.6	1,312.8	656.4	50%	832.8	37%	416.4	68%
	Pasture/Hay	13,108.0	36.7	18.4	50%	24.2	34%	12.1	67%
	Transitional	6,979.7	52.6	26.3	50%	35.1	33%	17.6	67%
	Developed, open space	3,764.6	16.7	16.7	0%	8.1	52%	8.1	52%
	Woody Wetlands	2,373.6	6.2	2.9	54%	4.3	32%	2.0	69%
	Cultivated Crops	1,378.0	58.6	29.3	50%	38.5	34%	19.2	67%
	Developed, low intensity	1,530.8	3.3	3.3	0%	1.4	58%	1.4	58%
	Developed, medium intensity	261.6	1.4	1.4	0%	0.7	49%	0.7	49%
	Barren Land	142.5	<1	<1	0%	<1	0%	<1	0%
	Mixed Forest	79.4	<1	<1	0%	<1	0%	<1	0%
	Deciduous Forest	32.6	<1	<1	0%	<1	0%	<1	0%
	Developed, high intensity	4.5	<1	<1	0%	<1	0%	<1	0%
	Emergent Herbaceous Wetlands	4.0	<1	<1	0%	<1	0%	<1	0%
	Total	**446,891.3**	**6,106.5**	**4,050.4**	**34%**	**3,789.5**	**38%**	**2,516.6**	**59%**

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Attachment A – Assignment of USLE C-factors to NLCD Landcover Values

The NRCS table "C-Factors for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland" (Figure A-1) was used to develop C-factors for the various land use types as defined by the NLCD database within the Boulder Elkhorn watershed. This table uses four sub-factors: the vegetative canopy type and height, the vegetative canopy percent cover, the type of cover that contacts the soil surface, and the percent ground cover to derive a C-factor. The resulting C-factor is very sensitive to the type and percent of ground cover and less sensitive to the type and percent of canopy cover.

The type and percent of canopy cover were determined based on the NLCD land use definition. In some cases the minimum percent canopy cover specified in the land use definition was used and resulted in a conservative C-factor. The type of ground cover was considered to be G (cover is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep) for all of the land uses in the Boulder Elkhorn watershed. The percent ground cover not only includes the basal plant material, but also gravel and plant litter. The percent ground cover for each of the land uses within the Boulder Elkhorn watershed was estimated by Confluence.

Table A-1 provides the C-factors for all land use types within the sub-basins of interest in the Boulder Elkhorn watershed for the existing conditions. The C-factors for the 'barren land', 'developed, low intensity', 'developed, medium intensity', and 'developed, high intensity' land uses are the same C-factors previously recommended by Richard Fasching, the former Montana State Agronomist, for other hillslope USLE modeling efforts.

Table A-2 provides the C-factors for all land use types within the sub-basins of interest in the Boulder Elkhorn watershed for the desired well managed scenario. The percent ground cover was increased by 10% over the existing percentage for the 'shrub/scrub', 'grassland/herbaceous', 'pasture/hay', and 'woody wetlands' land uses to reflect a decrease in grazing. For the 'cultivated crops' land use, the percent ground cover was increased by 20% over the existing percentage to reflect improved agricultural practices. For the 'transitional' land use, the desired scenario assumed a return to a forest land use. The C-factors for the other land use types were not changed. This is similar to the methods used by the DEQ for the Shields River watershed TMDL and by Confluence for other hillslope USLE modeling efforts.

These tables were reviewed and approved by Ronnie Maurer, an NRCS employee familiar with the Boulder Elkhorn watershed.

Exhibit MT510.03

"C" Factors for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland 1/

Vegetal Canopy			Cover that Contacts the Surface (Vegetation, living and dead)					
Type and Height of Raised Canopy 2/	Canopy Cover 3/ %	Type 4/	Percent Ground Cover					
			0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall grass, weeds or brushes with average drop fall height of less than 3 feet 5/	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

1/ All values shown assume: 1) random distribution of mulch or vegetation, and 2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

For grazed woodland with high buildup of organic matter in the topsoil under permanent forest conditions, multiply the table values by 0.7.

2/ Average fall height of waterdrops from canopy to soil surface: m = meters.

3/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

4/ G: Cover at surface is grass, grasslike plants, decaying compacted duff.
W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

5/ The portion of a grass or weed cover that contacts the soil surface during a rainstorm and interferes with water flow over the soil surface is included in "cover at the surface." The remainder is included in canopy cover.

Figure A-1. NRCS C-factor table

Table A-1 C-factors for land cover types in the Boulder Elkhorn watershed for existing conditions.

NLCD #	Name	Type and Height of Raised Canopy	Percent Canopy Cover	Type	Percent Ground Cover	C-factor
21	Developed, open space	no appreciable canopy	-	G	95-100	0.003
22	Developed, low intensity	-	-	-	-	0.001
23	Developed, medium intensity	-	-	-	-	0.001
24	Developed, high intensity	-	-	-	-	0.001
31	Barren land	-	-	-	-	0.001
41	Deciduous forest	trees	75	G	95-100	0.003
42	Evergreen forest	trees	75	G	95-100	0.003
43	Mixed forest	trees	75	G	95-100	0.003
52	Shrub/scrub	appreciable brush	25	G	75	0.020
71	Grassland/herbaceous	no appreciable canopy	-	G	75	0.020
81	Pasture/Hay	no appreciable canopy	-	G	75	0.020
82	Cultivated Crops	no appreciable canopy	-	G	20	0.200
90	Woody Wetlands	trees	25	G	80	0.013
95	Emergent Herbaceous Wetlands	tall grass	75	G	95-100	0.003
99	Transitional	trees	25	G	90	0.006

Notes:

1) Canopy cover percents were selected based on the land cover class definition.
2) Low, medium, and high intensity development land uses are assumed to be the same as barren land.
3) Deciduous and mixed forest land uses are assumed to be the same as evergreen forest.

Table A-2 C-factors for land cover types in the Boulder Elkhorn watershed for BMP conditions.						
NLCD #	**Name**	**Type and Height of Raised Canopy**	**Percent Canopy Cover**	**Type**	**Percent Ground Cover**	**C-factor**
21	Developed, open space	no appreciable canopy	-	G	95-100	0.003
22	Developed, low intensity	-	-	-	-	0.001
23	Developed, medium intensity	-	-	-	-	0.001
24	Developed, high intensity	-	-	-	-	0.001
31	Barren land	-	-	-	-	0.001
41	Deciduous forest	trees	75	G	95-100	0.003
42	Evergreen forest	trees	75	G	95-100	0.003
43	Mixed forest	trees	75	G	95-100	0.003
52	Shrub/scrub	appreciable brush	25	G	85	0.010
71	Grassland/herbaceous	no appreciable canopy	-	G	85	0.010
81	Pasture/Hay	no appreciable canopy	-	G	85	0.010
82	Cultivated Crops	no appreciable canopy	-	G	40	0.100
90	Woody Wetlands	trees	25	G	90	0.006
95	Emergent Herbaceous Wetlands	tall grass	75	G	95-100	0.003
99	Transitional	trees	75	G	95-100	0.003

Notes:

1) Canopy cover percents were selected based on the land cover class definition.
2) Low, medium, and high intensity development land uses are assumed to be the same as barren land.
3) Deciduous and mixed forest land uses are assumed to be the same as evergreen forest.

Attachment 3 – Stream Temperature Assessment for the Boulder River – Boulder-Elkhorn TMDL Planning Area

Addition to Attachment 3 - Discussion of BLDR-T21

Introduction

Figure 2-2 in the Stream Temperature Assessment for the Boulder River (**Attachment 3**) shows a significant drop in temperature at station BLDR-T21. Text in the report does not explain this anomaly in the temperature profile and so this discussion is included to review the temperature data at BLDR-T21, and any potential implications that site may have to analysis.

Discussion

Figure 2-2 presents the maximum, average, and minimum water temperatures of the recorded field data from July 24-26, 2010. The data points were taken from 15 locations along the Boulder River, and represent a longitudinal profile of temperature trends over those three days. The profile shows relatively consistent water temperatures from between data points until around BLDR-T14, when temperatures start increasing. These higher temperatures persist through the remaining sites except at BLDR-T21, where temperatures plummet about 6 degrees C, only to jump right back up at BLDR-T22 to temperatures similar to those observed at BLDR-T20. This very distinctive drop raises questions about why the location at BLDR-T21 is so unique in comparison to the overall temperature profile. Apart from water use, geology plays a role in water availability in the Boulder River valley. Communication with the Montana Bureau of Mines & Geology describes the general trend of surface water/groundwater interaction in that area:

> “We are seeing a shift from generally losing to generally gaining in that area. It appears that there is converging groundwater flow from the East Ridge and Doughty Mtn. in Negro Hollow. There is little if any surface water flow; however all of the southern/northern groundwater flow from these areas must flow to the Boulder River alluvium (or to the east). This combined with the bedrock canyon to the south (essentially a dam forcing groundwater to the river) makes it likely that groundwater is entering the Boulder River in this area. Since there is very little surface water flow in the summer, a small contribution of groundwater would cause more of a change in temperature.”

Figure X-1 below further illustrates the location of BLDR-T21 in the context of geologic maps of the area. **Figure X-2** provides an aerial view of the corridor with data logger locations for BLDR-T21, T22, and T23. Finally, **Figure X-3** is a close up aerial view of BLDR-T21. Of note is the irrigated field immediately adjacent to BLDR-T21 on river right.

Figure 2-3 in **Attachment 3** illustrates the streamflow data profile which follows the general narrative provided by MBMG. From upstream to downstream, flows gradually increase until about BLDR-T12, after which flows steadily decrease until BLDR-T19, where flows again increase.

A review of the actual continuous temperature data also shows the range in diurnal temperature fluctuations at BLDR-T21 to be less than the diurnal temperature fluctuations at BLDR-T20 upstream and BLDR-T22 downstream. For some of the dates reviewed, the difference between maximum and minimum daily temperatures at the BLDR-T21 location is at times as little as 5 degrees F, whereas the temperature ranges at the other two sites were greater than 10 degrees F. This suggests that there may be the influence of coldwater upwelling at BLDR-T21. However, examination of the bihourly data also showed an interesting shift during the time period reviewed. On August 5, at 21:30, the temperature recorded at BLDR-T21 jumped over 8 degrees F. All temperature recordings before and after this point in time never showed a temperature change greater than 1.5 degrees in a 30 minute period. The data logger itself however was in proper working order throughout its deployment and therefore it is unlikely that there were any technical malfunctions. In addition, temperature ranges at BLDR-T21 after that moment followed the trends of the upstream and downstream locations. In other words, the temperatures at BLDR-T21 suddenly became consistent with the temperature observations at the upstream and downstream data collection sites.

While this situation is somewhat perplexing, given what we know of the site and the data logger, there are a few reasonable possibilities. It is possible that data logger BLDR-T21 was coincidentally located directly on top of a coldwater upwelling, and at 21:30 on August 5, it was moved somehow out of the influence of that source, without being removed from the site. The significant jump in temperature could also be the result of a sudden change in irrigation withdrawal or return – whether that was a local or immediate influence from management of the adjacent field, or the delayed effect of water use elsewhere in the valley observed through groundwater flow.

Conclusion

The data recording device and the data collected appear sound, and although the temperature profile is unique, there are reasonable explanations that could account for the anomaly at BLDR-T21. In addition, the modeling that was used to analyze temperature trends in the Boulder River is not affected by this anomaly. All temperature data loggers undergo a quality control check before and after deployment, and the loggers used in this study were found to be functioning properly. The dip in the temperature profile at BLDR-T21 does not invalidate the data recorded at all other locations, and model analysis shows that much of the lower Boulder River exceeds the temperature standard. If the anomaly at BLDR-T21 is taken as is, it shows that groundwater likely influences the temperature for a short distance around BLDR-T21 to levels that would be acceptable under the temperature standard. On the other hand, if it is assumed that the data at BLDR-T21 misrepresents the water temperature conditions through this location because it was coincidentally located within the immediate influence of a source of coldwater, then based on data reviewed post 21:30 on August 5, it can be presumed that the temperature profile at BLDR-T21 would be similar to the upstream and downstream data sites. Under this assumption, the result would indicate that temperature levels are elevated above the limits of the standard throughout this stretch of the river. Therefore, the profile would not contain a noticeable drop in temperature, but rather the line through BLDR-T21 would roughly follow the course of the upstream and downstream data points.

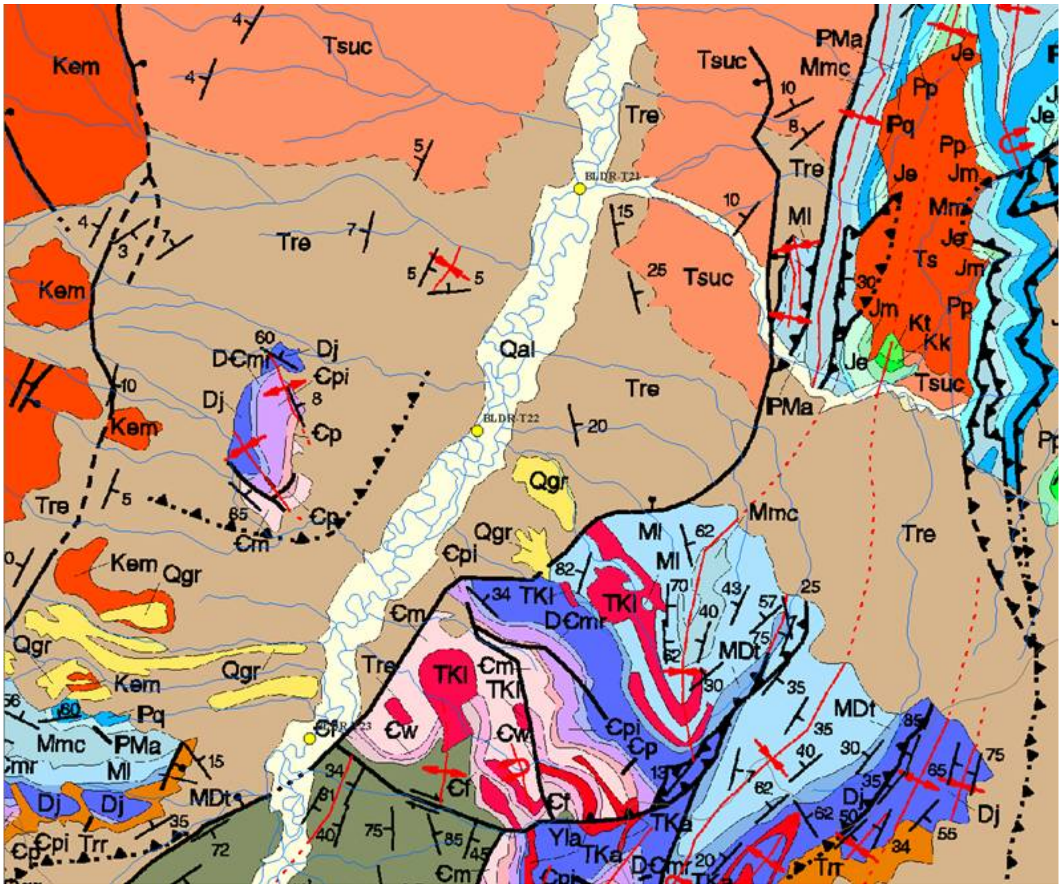


Figure X-1. Geologic Map of the Boulder River valley near BLDR T-20, T-21, and T-22.
(Taken from Geologic map of the Bozeman 30’ X 60’ quadrangle, southwestern Montana, Montana Bureau of Mines and Geology: Open-File Report 469, 39 p., 1 sheet, 1:100,000)

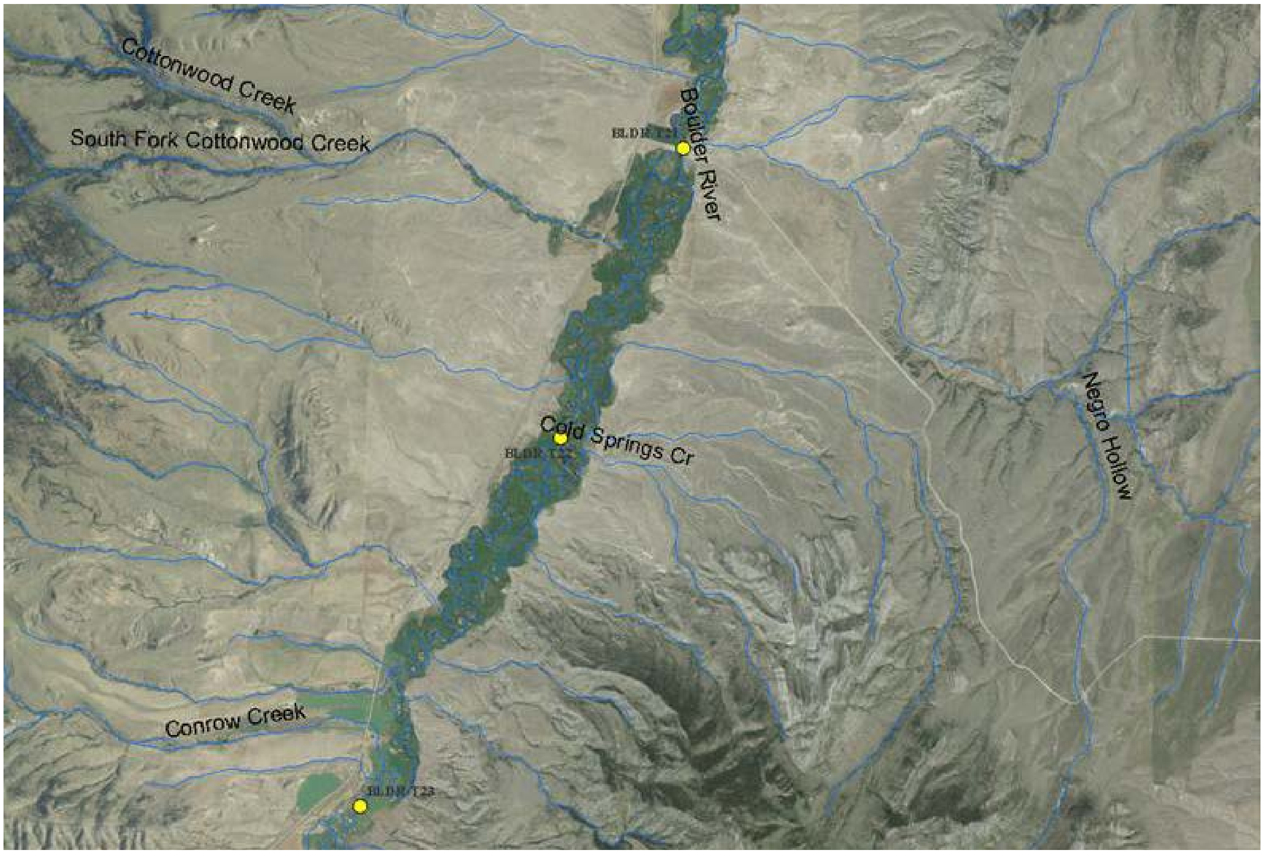
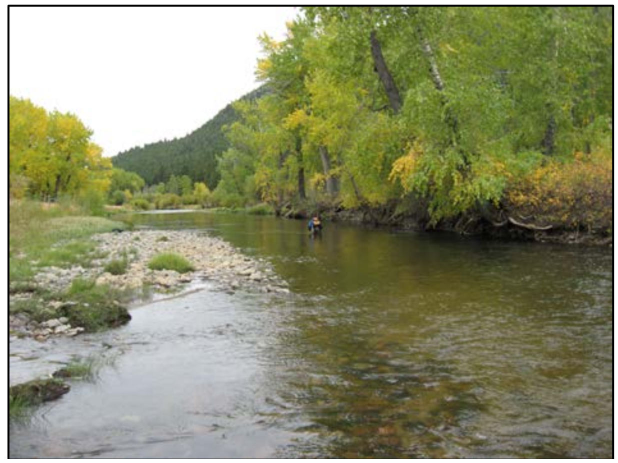


Figure X-2. Aerial view of Boulder River valley near BLDR-T20, T-21, and T-22.

Figure X-3. Aerial view of BLDR T-21.

STREAM TEMPERATURE ASSESSMENT FOR THE BOULDER RIVER

Boulder-Elkhorn TMDL Planning Area



Prepared for:

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
P.O. Box 200901
Helena, MT 59620-0901

Prepared by:

PBS&J
3810 Valley Commons Drive, Suite #4
Bozeman, Montana 59718

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1.0 Introduction

Temperature impairments were assessed within the Boulder River using a combination of in-stream temperature measurements, riparian shading assessments, mid-summer streamflow measurements, and modeling. The Boulder River temperature assessment was conducted to aid in the development of Total Maximum Daily Loads (TMDLs) for temperature impaired stream segments in the Boulder-Elkhorn TMDL Planning Area (TPA) (**Table 1-1**). Data collected during this assessment were used in the QUAL2K model to assess the influence of riparian shading and streamflow on stream temperatures in the Boulder River. The results of this assessment were compared to Montana's water quality standards for temperature to evaluate beneficial use support and potential restoration strategies.

Table 1-1. Temperature Impaired Segments of the Boulder River.

Waterbody ID	Length (Miles)	Use Class	Location	Probable Sources
MT41E001_022	32.9	B-1	Town of Boulder to Cottonwood Creek	Habitat Modification - other than Hydromodification Impacts from Abandoned Mine Lands (Inactive) Impacts from Hydrostructure Flow Regulation/modification Irrigated Crop Production Loss of Riparian Habitat
MT41E001_030	12.7	B-1	Cottonwood Creek to the mouth (Jefferson River)	Impacts from Abandoned Mine Lands (Inactive) Impacts from Hydrostructure Flow Regulation/modification Irrigated Crop Production

1.1 Montana Water Quality Standards

Montana's water quality standard for temperature addresses a maximum allowable increase above the "naturally occurring" temperature to protect the existing thermal regime for fish and aquatic life. Among other uses, the Boulder River is to be maintained suitable for the growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers. For waters classified as B-1, the associated standard specific to temperature is as follows: "A 1ºF maximum increase above naturally occurring water temperature is allowed within the range of 32ºF to 66ºF; within the naturally occurring range of 66ºF to 66.5ºF, no discharge is allowed which will cause the water temperature to exceed 67ºF; and where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF. A 2ºF per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55ºF. A 2ºF maximum decrease below naturally occurring water temperature is allowed within the range of 55ºF to 32ºF." [ARM 17.30.623(2e), ARM 17.30.624(2e) and ARM 17.30.627(2e)]. Temperature monitoring and modeling indicated that naturally occurring stream temperatures in the Boulder River are likely greater than 66.5°F during portions of the summer months (**Table 1-2, Attachment A**). Thus, the maximum allowable increase due to unmitigated human causes in the Boulder River is 0.5°F (0.23°C).

Table 1-2. Measured and Modeled Maximum Temperatures in the Boulder River, 2010.

Site	Measured Seasonal Maximum Temperature		Modeled Naturally Occurring Maximum Temperature	
	Date	Temperature (°F)	Date*	Temperature (°F)
BLDR-T02	08/05/10	71.1	7/24-7/26	68.1
BLDR-T04	07/25/10	71.1	7/24-7/26	66.5
BLDR-T05	07/25/10	71.1	7/24-7/26	66.1
BLDR-T08	07/25/10	71.5	7/24-7/26	65.4
BLDR-T09	07/25/10	71.6	7/24-7/26	65.4
BLDR-T10	07/25/10	71.3	7/24-7/26	66.2
BLDR-T11	07/25/10	71.4	7/24-7/26	66.7
BLDR-T13	07/25/10	71.4	7/24-7/26	66.9
BLDR-T14	07/25/10	71.4	7/24-7/26	68.0
BLDR-T15	07/25/10	73.2	7/24-7/26	71.2
BLDR-T19	07/25/10	76.4	7/24-7/26	71.2
BLDR-T20	07/25/10	75.9	7/24-7/26	70.7
BLDR-T22	07/25/10	76.2	7/24-7/26	73.9
BLDR-T24	07/25/10	74.3	7/24-7/26	69.1

*Modeled maximum temperatures based on average maximum temperature over a three day timeframe from July 24th-26th, 2010.

1.2 Temperature Thresholds

Special temperature considerations are warranted for the westslope cutthroat trout, which are present in the Boulder River watershed and listed by the State of Montana as a species of concern (Carlson 2001). Westslope cutthroat trout are currently found in several Boulder River tributaries, all of which enter the Boulder River upstream of the temperature impaired segments that are the focus of this assessment (R. Spoon, Montana FWP, personal communication, 2/14/11). Recently conducted research by Bear et al. (2005) found that the upper incipient lethal temperature (UILT) for westslope cutthroat trout was 67ºF (19.7ºC), while the UILT for rainbow trout was 76ºF (24.2ºC). The UILT is the temperature that is considered to be survivable indefinitely by 50 percent of the population (Lohr et al. 1996). Although these temperature thresholds are used as a reference that likely causes impact to fish, they are not targeted temperatures for the Boulder River and are not directly related to Montana’s water quality standards.

2.0 Temperature Assessment

The Boulder River temperature assessment was performed in order to identify existing conditions and to determine if human caused disturbances have led to increased stream water temperatures. This assessment utilized field data and computer modeling to assess stream temperatures in relation to Montana's water quality standards.

2.1 Field Data Collection

Field data used in this assessment were collected during the 2010 summer field season and included temperature measurements, streamflow measurements, and an assessment of riparian shading along the Boulder River and selected tributary streams. Field methods are described in *Boulder-Elkhorn TMDL Planning Area Temperature and Instantaneous Flow Monitoring for the Boulder River* (DEQ 2010).

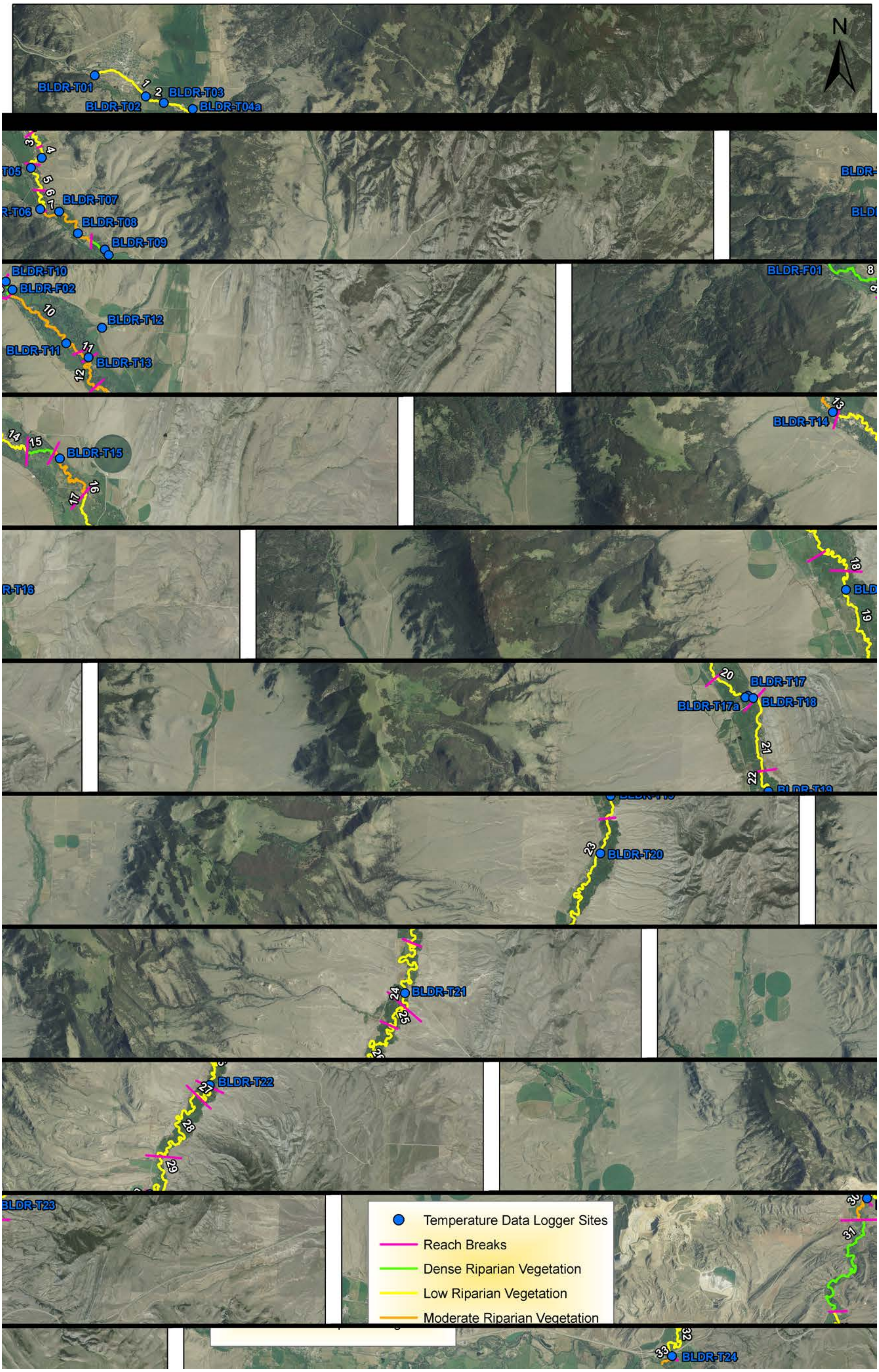
2.1.1 Temperature Measurements

Temperature monitoring was conducted in the Boulder River between late-June and late-September in 2010. The study timeframe examined stream temperatures during the period when streamflows tend to be lowest, water temperatures are warmest, and negative effects to the cold water fishery and aquatic life beneficial uses are likely most pronounced. Temperature monitoring consisted of placing temperature data logging devices at 22 sites in the Boulder River mainstem (**Figure 2-1**). In addition, temperature data logging devices were placed on three tributary streams (Muskrat Creek, Elkhorn Creek, and the Little Boulder River) and at three sites within ditches. Temperature monitoring sites were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width so that the temperature data collected during this assessment could be utilized in the QUAL2K model. A summary of temperature data is presented in **Attachment A**.

2.1.2 Streamflow Measurements

In 2010, streamflow was measured at five sites in the Boulder River watershed in late-June, at 27 sites in early-August, and at 24 sites in late-September. Streamflow data collected during the early-August timeframe were used in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards.

Figure 2-1. Boulder River Temperature Monitoring Sites and Riparian Vegetation Reaches.



2.1.3 Riparian Shading Assessment

Riparian shading was assessed at 14 sites along the Boulder River using a Solar Pathfinder which measures the amount of shade at a site in one-hour intervals between 6 a.m. and 6 p.m. The Solar Pathfinder was utilized to assess riparian shading using the August template for the path of the sun. Shade was measured at three locations over a 200-foot reach at each site. In addition to the Solar Pathfinder readings, the following measurements were performed at each site in which riparian shading was assessed:

- Stream azimuth
- Bankfull width
- Wetted width
- Dominant tree species

Riparian shading data were used to assess existing and potential riparian shading conditions relative to the level of anthropogenic disturbance at a site. Measurements obtained with the Solar Pathfinder were utilized in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards. Solar Pathfinder hourly shade measurements are presented in **Attachment B** and supplemental field data are presented in **Attachment C.**

2.2 QUAL2K Model

The QUAL2K model was used to determine if human caused disturbances within the Boulder River watershed have increased the water temperature above the “naturally occurring” level and, if so, to what degree. QUAL2K is a one dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model utilizes steady state hydraulics that simulate non-uniform steady flow. Within the model, water temperatures are estimated based on climatic data, riparian shading, and channel conditions. For this assessment, the QUAL2K model was used to evaluate maximum summer water temperatures in the Boulder River. The QUAL2K model is available at:
http://www.epa.gov/ATHENS/wwqtsc/html/qual2k.html.

Stream temperature, riparian shading and streamflow data collected in the summer of 2010 were used to calibrate the QUAL2K model for existing conditions. The potential to reduce stream temperatures was then modeled based on seven scenarios, including:

- Baseline scenario (existing conditions)
- Increased shade scenario 1 (reference shade)
- Increased shade scenario 2
- Decreased water consumptive use scenario
- Natural condition scenario (no anthropogenic impacts)
- Naturally occurring scenario (full application of BMPs to present uses)
- Increased shade scenario 1 (reference shade) and increased irrigation efficiency (as applied in the naturally occurring scenario)

The QUAL2K model inputs and outputs are based on the metric system and the plotted results are presented in °C. For comparison, a conversion between °C and °F is included in **Table 2-1**.

Table 2-1. Conversion Table °C to °F.

°C	°F		°C	°F		°C	°F
1	33.8		11	51.8		21	69.8
2	35.6		12	53.6		22	71.6
3	37.4		13	55.4		23	73.4
4	39.2		14	57.2		24	75.2
5	41.0		15	59.0		25	77.0
6	42.8		16	60.8		26	78.8
7	44.6		17	62.6		27	80.6
8	46.4		18	64.4		28	82.4
9	48.2		19	66.2		29	84.2
10	50.0		20	68.0		30	86.0

2.2.1 Data Sources and Model Assumptions

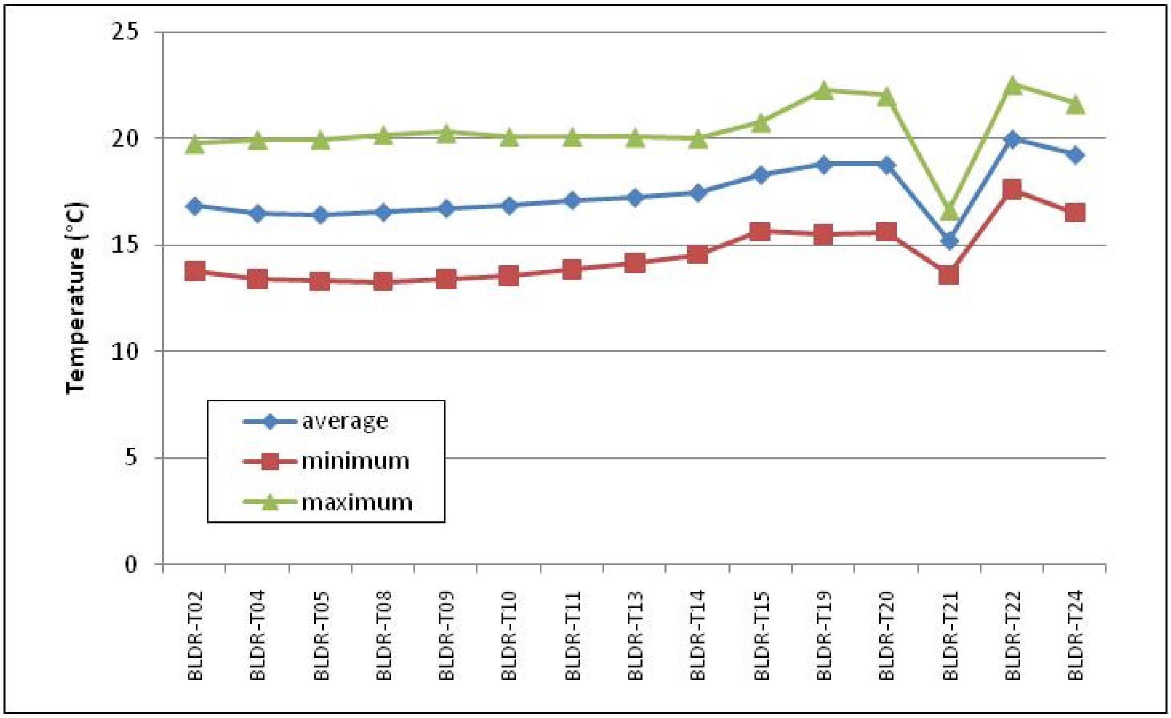
Data sources and model assumptions made during this assessment are described within the following sections. A more detailed discussion of specific model inputs for each data entry tab of the QUAL2K model is presented in **Attachment D**.

2.2.1.1 Temperature Data

Temperature data collected in the Boulder River during the summer of 2010 were applied in the QUAL2K model. Data loggers were deployed between June 27th and 28th and retrieved between September 27th and 30th. Out of the 22 temperature monitoring sites established on the mainstem of the Boulder River in 2010, temperature data loggers were retrieved from 21 sites, while the temperature data logger from site BLDR-T07 was not recovered. Out of the 21 sites on the Boulder River mainstem with temperature data, four sites (BLDR-T01, BLDR-T03, BLDR-T16, and BLDR-T18) have incomplete datasets due to low flows resulting in the data loggers being out of the water for a portion of the monitoring period during the late-July and early-August timeframe. In addition, the data logger at BLDR-T23 was found missing and subsequently replaced in August and one data logger (BLDR-T17a) was added for additional data collection in August. Both of these data loggers also lack data in the late-July and early-August timeframe. Overall, 15 sites have complete temperature datasets for the Boulder River mainstem. Out of these 15 sites, the daily maximum temperature for the period of record was recorded on July 25th, 2010 at 13 sites, while the remaining two sites recorded daily maximum temperatures during August 5th (BLDR-T02) and August 6th (BLDR-T21) (**Attachment A**).

The 7-day average maximum temperature occurred between July 22nd and August 18th at the 15 Boulder River mainstem sites with complete datasets. The 7-day average maximum temperature was reported at five sites on July 22nd, five sites on July 31st, two sites on August 2nd, two sites on August 4th, and one site on August 18th (**Attachment A**). Thus, temperature data recorded in 2010 indicates that the warmest temperatures in the mainstem of the Boulder River occurred between July 22nd and August 18th, with the majority of the high temperatures occurring within the July 22nd to August 6th timeframe. Since nearly all of the daily maximum temperatures occurred on July 25th and this date occurs within the period of greatest 7-day average temperatures, this day was selected for modeling temperature for the Boulder River. In the Boulder River, a three day travel time (the time it takes for water to flow through the study reach) is estimated. Temperature data from July 24th, 25th and 26th were averaged for input into the QUAL2K model, which was run for the July 24th through 26th timeframe (**Figure 2-2**).

Figure 2-2. Boulder River Temperature Data, July 24th-26th, 2010.

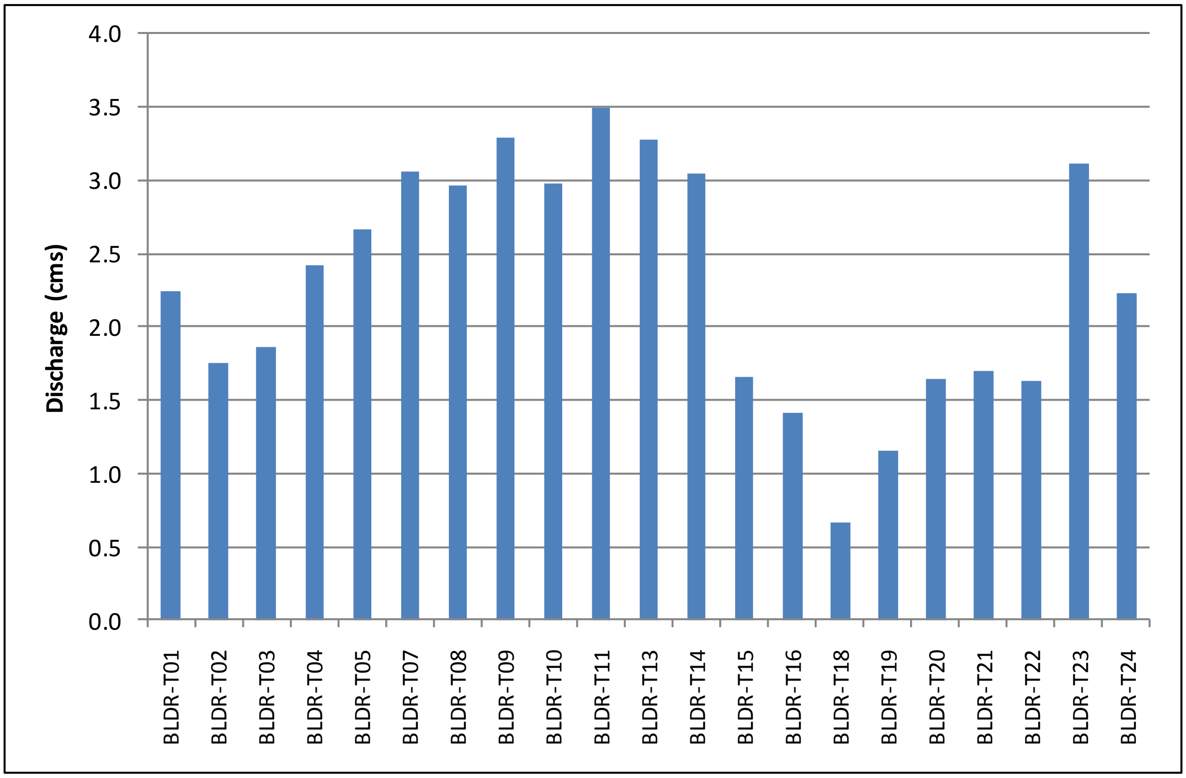


In addition to temperature data collected in the Boulder River, UGSG gaging station data from the Jefferson River near Three Forks (06036650) recorded a maximum temperature of 24.2°C on July 25th, with the 14 days with the highest maximum temperatures occurring between July 21st and August 7th. This information further justifies the use of the July 24th through 26th timeframe to represent the warmest temperature conditions in the Boulder River in 2010.

2.2.1.2 Streamflow Data

Streamflow data collected in the Boulder River during August of 2010 were applied in the QUAL2K model. Streamflow measurements were performed at 21 sites on the mainstem of the Boulder River between August 4th and 6th, 2010 (**Figure 2-3**). Streamflow in three ditches was also measured during this timeframe. Streamflow measurements were performed on the Little Boulder River on August 4th and on Muskrat Creek on August 12th. Elkhorn Creek was dry during the August monitoring event.

Figure 2-3. Boulder River Streamflow Data, August 4th-6th, 2010.



2.2.1.3 Streamside Shading

Streamside shading data collected in the Boulder River during the summer of 2010 were applied in the QUAL2K model. Prior to field data collection, the Boulder River was divided into 33 distinct reaches covering 81.6 kilometers (50.7 miles) using the 1:24:000 NHD stream layer (**Figure 2-1**). Reaches were delineated based on observed riparian conditions using NAIP color aerial imagery from 2009. Reaches were categorized as “dense”, “moderate”, or “low” riparian vegetation density, with 13% of the study reach classified as dense, 18% classified as moderate, and 69% classified as low riparian vegetation density. The predominant riparian vegetation for each reach was evaluated using aerial imagery and the vegetation type was assigned using best professional judgment. Dense riparian vegetation areas had a mix of deciduous trees and shrubs, while moderate riparian vegetation areas contained fewer deciduous trees and generally had an understory comprised of deciduous shrubs and herbaceous vegetation. Areas with low riparian vegetation densities generally lacked overstory vegetation and were comprised of herbaceous vegetation with sparse deciduous shrubs in the understory.

Fourteen shade assessment sites were selected for field data collection, with three sites in the dense riparian category, three sites in the moderate riparian category, and eight sites in the low riparian category. In the QUAL2K model, solar pathfinder hourly data was applied directly to the reaches in which a field monitoring site was located. When no field monitoring site was located within a reach, the average value for the given riparian vegetation category (low, moderate, or dense) at the reach scale was applied. Field data was evaluated based on the following criteria: dense (>30%), moderate (10-30%) and low (<10%) (**Table 2-2**). The complete riparian shading dataset is presented in **Attachment B** and supplemental information for each assessed reach is presented in **Attachment C**. Existing riparian vegetation reach types as determined through GIS analysis of aerial imagery are presented in **Attachment E**.

Table 2-2. Boulder River Riparian Vegetation Reach Type Average Hourly Shade Conditions.

Riparian Vegetation Reach Type	Morning (AM)						Afternoon (PM)						Average Daily Shade
	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	
Dense Riparian	88%	64%	30%	11%	5%	7%	12%	17%	30%	43%	64%	78%	37%
Moderate Riparian	59%	31%	23%	12%	4%	1%	2%	4%	6%	16%	41%	62%	22%
Low Riparian	10%	2%	2%	3%	2%	1%	2%	0%	0%	2%	5%	15%	4%

2.2.1.4 Climatic Data

Climatic data inputs for the QUAL2K model were obtained from the Western Regional Climate Center (http://www.raws.dri.edu/wraws/nidwmtF.html) station in Whitehall, Montana and included air temperature, dew point temperature and wind speed. The dew point temperature was adjusted by increasing the relative humidity by 15% based on local conditions within the stream corridor as measured in a similar assessment in the Big Hole River watershed (Flynn et al. 2008).

2.2.1.5 Hydrologic Balance

To evaluate tributary inflows, waste water treatment plant discharges, and irrigation water withdrawals along the Boulder River, a hydrologic balance was created. Basic assumptions applied when developing the hydrologic balance include:

- Streamflows were balanced between each data logger where streamflow measurements were performed.
- Streamflow measurements from three tributaries (Muskrat Creek, Little Boulder River, Elkhorn Creek) were utilized in the QUAL2K model. Elkhorn Creek was dry during the August monitoring event and all other tributaries besides Muskrat Creek and the Little Boulder River were also assumed to be dry for modeling purposes.
- Wastewater treatment plant discharges were estimated based on August 2010 measurement data obtained from the Montana DEQ Water Protection Bureau.
- Streamflow measurements from two irrigation diversions were utilized in the QUAL2K model. Other irrigation withdrawals were modeled based on the hydrologic balance. If a loss in streamflow was identified between streamflow measurement sites, then it was assumed that all of the lost flow was diverted for irrigation purposes. If multiple diversions were present between streamflow measurement sites and a loss in streamflow was identified, then the flow was divided evenly amongst the diversions.

A detailed hydrologic balance for the Boulder River is presented in **Attachment F**.

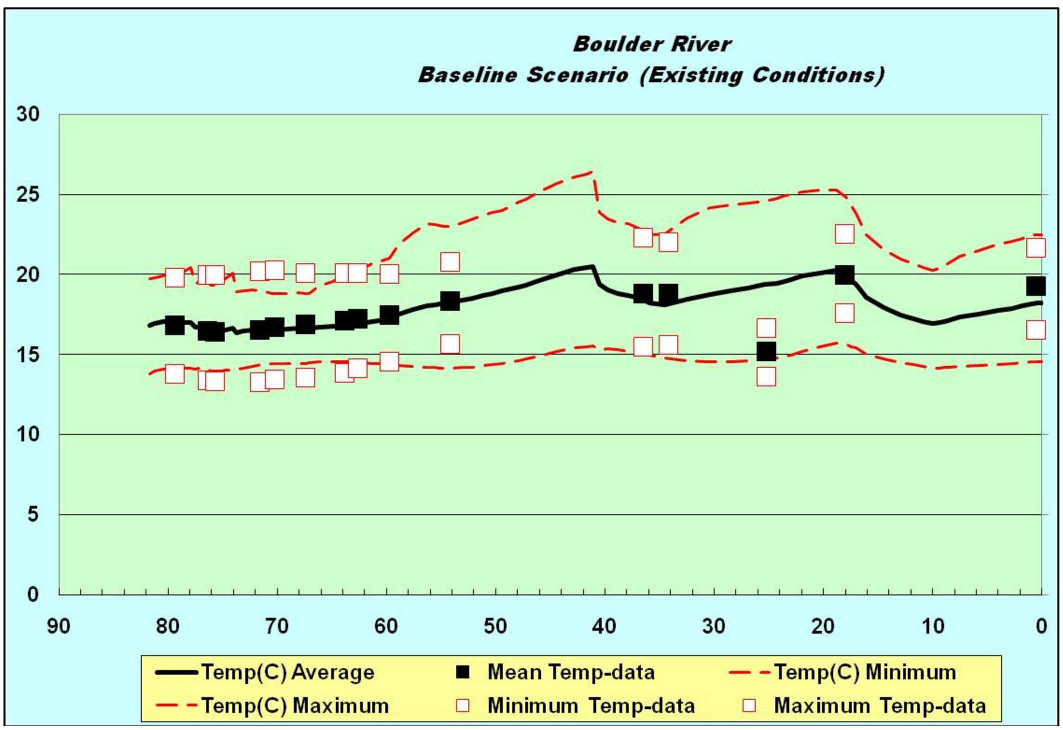
2.2.2 Boulder River Model Scenarios

Several model scenarios were examined for the Boulder River, including the baseline (existing conditions) scenario, two shade scenarios, a water consumptive use scenario, a natural condition scenario, a naturally occurring scenario, and a scenario examining reference shade conditions in combination with increased irrigation efficiency.

2.2.2.1 Baseline Scenario (Existing Conditions)

Once the above calibration steps were performed, the QUAL2K model was run for the baseline scenario, which is intended to represent the existing conditions within the Boulder River. This model run utilized measured field data, with the assumptions described in **Section 2.2.1** and **Attachment D**. Hydraulic output in the model accurately reflected measured conditions, indicating that water routing and channel morphology were adequately calibrated. Subsequent model scenarios were compared to the existing conditions results of the baseline model and not to the field measured values to assure consistency when evaluating the potential to reduce stream temperatures (**Figure 2-4)**.

Figure 2-4. Boulder River QUAL2K Baseline (Existing Conditions) Scenario.



2.2.2.2 Shade Scenario 1 (Reference Shade)

For shade scenario 1, all reaches were assigned the average value for dense riparian vegetation to evaluate reference conditions along the Boulder River. The reference shade scenario assumes the entire length of the Boulder River between the town of Boulder and the confluence with the Jefferson River is capable of supporting a riparian area comprised of large cottonwood trees in the overstory and shrubs in the understory. There is a relatively broad floodplain along the majority of the study reach and the meandering channel is not entrenched, allowing for natural gravel bar formation and the establishment of new cottonwood stands. In this scenario, riparian shade density was increased along a total of 44.1 miles of the Boulder River (**Table 2-3**). Reference shade values for dense riparian vegetation were developed based on riparian vegetation reach type average hourly shade values (see **Table 2-2**). An evaluation of existing shade and potential shade as assigned in shade scenario 1 is presented for each reach in **Attachment F**. The results of shade scenario 1 indicate that an increase in streamside shading along the Boulder River would lead to a decrease in stream water temperature (**Figure 2-5, Table 2-4**).

Table 2-3. Boulder River Existing Conditions and Shade Scenarios for Riparian Vegetation Reach Types.

Riparian Vegetation Reach Type	Baseline (Existing Conditions) Scenario			Shade Scenario 1 (Reference Shade)*			Shade Scenario 2**		
	Number of Reaches	Length (Miles)	Percent	Number of Reaches	Length (Miles)	Percent	Number of Reaches	Length (Miles)	Percent
Dense Riparian	4	6.6	13%	33	50.7	100%	12	15.6	31%
Moderate Riparian	8	9.0	18%	0	0.0	0%	21	35.1	69%
Low Riparian	21	35.1	69%	0	0.0	0%	0	0.0	0%

* Also applied in the Natural Condition Scenario.

** Also applied in the Naturally Occurring Scenario.

Figure 2-5. Boulder River QUAL2K Shade Scenario 1 (Reference Shade).

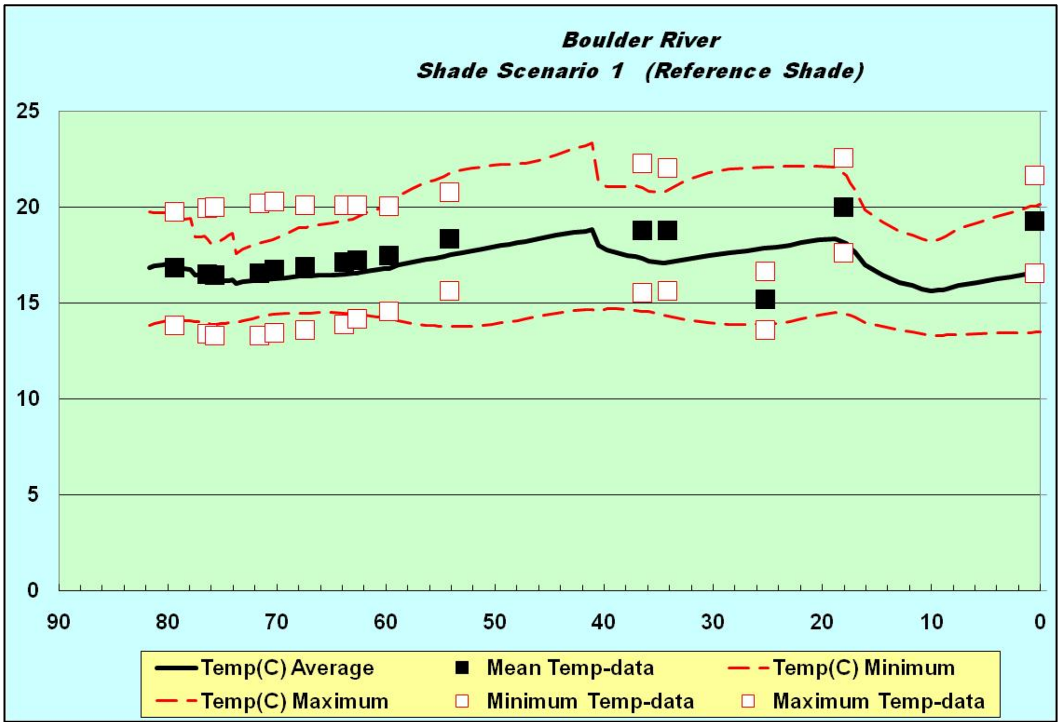


Table 2-4. Boulder River QUAL2K Shade Scenario 1 (Reference Shade).

Data Logger Site	Q2K Existing Conditions			Q2K Shade Scenario 1			Departure from Existing Conditions Model (°C)	Departure from Existing Conditions Model (°F)
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	19.4	66.9	-0.6	-1.1
BLDR-T04	76.3	19.5	67.1	76.3	18.3	65.0	-1.2	-2.2
BLDR-T05	75.6	19.4	66.8	75.6	18.1	64.6	-1.3	-2.3
BLDR-T08	71.4	19.0	66.2	71.4	18.1	64.6	-0.8	-1.5
BLDR-T09	70.4	18.8	65.9	70.4	18.3	64.9	-0.5	-1.0
BLDR-T10	67.4	18.8	65.9	67.4	18.9	66.1	0.1	0.2
BLDR-T11	63.7	20.0	67.9	63.7	19.3	66.8	-0.6	-1.1
BLDR-T13	62.7	20.1	68.3	62.7	19.4	67.0	-0.7	-1.3
BLDR-T14	59.8	21.0	69.9	59.8	20.1	68.2	-0.9	-1.7
BLDR-T15	54.1	23.0	73.4	54.1	21.8	71.2	-1.2	-2.2
BLDR-T19	36.5	22.8	73.0	36.5	21.0	69.8	-1.7	-3.1
BLDR-T20	34.5	22.5	72.6	34.5	20.8	69.4	-1.8	-3.2
BLDR-T22	18.8	25.3	77.5	18.8	22.1	71.7	-3.2	-5.8
BLDR-T24	1.0	22.5	72.5	1.0	20.0	68.0	-2.5	-4.4

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.2.2.3 Shade Scenario 2

For shade scenario 2, reaches categorized as low riparian vegetation (35.1 miles) were assigned the average value for reaches with moderate riparian vegetation, while reaches with moderate riparian vegetation (9.0 miles) were assigned the average value for reaches with dense riparian vegetation. Reaches currently exhibiting dense riparian vegetation were assigned the average value for dense riparian vegetation based on field collected data. This scenario is based on the premise that land-use practices within the watershed have altered the composition of the riparian vegetation along the Boulder River. While the re-establishment of dense cottonwood stands along the entire stream corridor may not be possible, an improvement in riparian vegetation density through the application of Best Management Practices is reasonable. In this scenario, a total of 15.6 miles of stream (31%) were modeled with dense riparian vegetation, while 35.1 miles of stream (69%) were modeled with moderate riparian vegetation (**Table 2-3**). An evaluation of existing shade and potential shade as assigned in shade scenario 2 is presented for each reach in **Attachment F**. The results of shade scenario 2 indicate that an increase in streamside shading along the Boulder River would lead to a decrease in stream water temperature (**Figure 2-6, Table 2-5**).

Figure 2-6. Boulder River QUAL2K Shade Scenario 2.

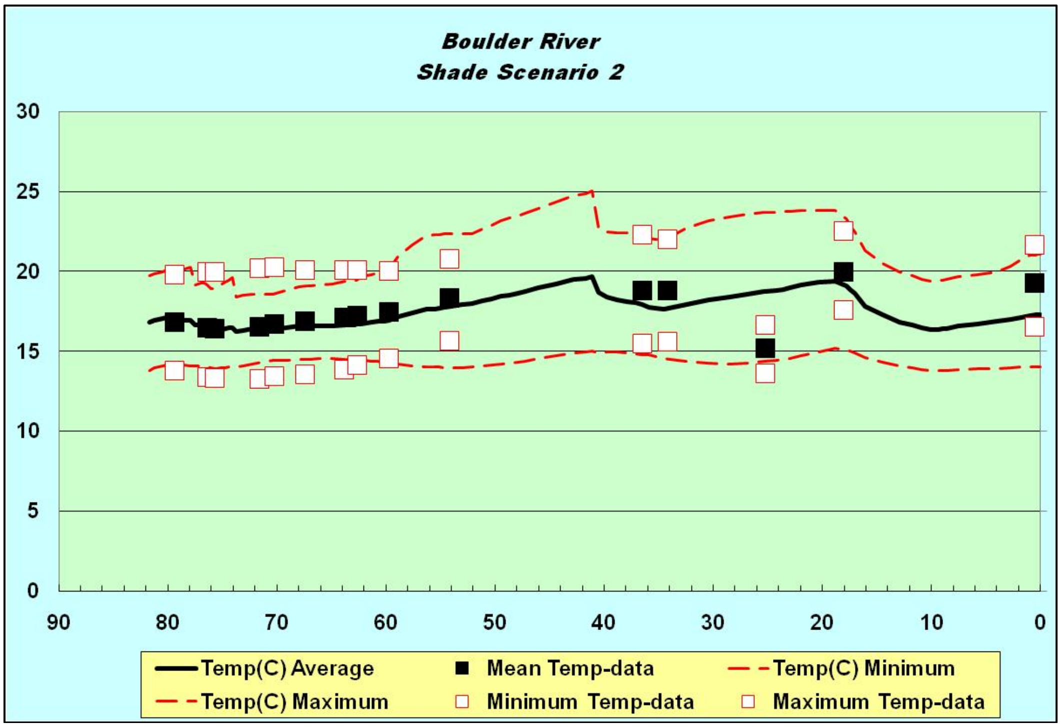


Table 2-5. Boulder River QUAL2K Shade Scenario 2.

Data Logger Site	Q2K Existing Conditions			Q2K Shade Scenario 2			Departure from Existing Conditions Model (°C)	Departure from Existing Conditions Model (°F)
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	20.1	68.1	0.0	0.0
BLDR-T04	76.3	19.5	67.1	76.3	19.1	66.5	-0.4	-0.7
BLDR-T05	75.6	19.4	66.8	75.6	18.9	66.1	-0.4	-0.7
BLDR-T08	71.4	19.0	66.2	71.4	18.5	65.4	-0.4	-0.8
BLDR-T09	70.4	18.8	65.9	70.4	18.6	65.4	-0.3	-0.5
BLDR-T10	67.4	18.8	65.9	67.4	19.1	66.3	0.3	0.5
BLDR-T11	63.7	20.0	67.9	63.7	19.4	66.8	-0.6	-1.1
BLDR-T13	62.7	20.1	68.3	62.7	19.5	67.0	-0.7	-1.2
BLDR-T14	59.8	21.0	69.9	59.8	20.1	68.2	-0.9	-1.6
BLDR-T15	54.1	23.0	73.4	54.1	22.4	72.2	-0.7	-1.2
BLDR-T19	36.5	22.8	73.0	36.5	22.3	72.1	-0.5	-0.8
BLDR-T20	34.5	22.5	72.6	34.5	22.0	71.5	-0.6	-1.1
BLDR-T22	18.8	25.3	77.5	18.8	23.8	74.8	-1.5	-2.7
BLDR-T24	1.0	22.5	72.5	1.0	21.0	69.8	-1.5	-2.6

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.2.2.4 Water Consumptive Use Scenario

The water consumptive use scenario describes the thermal effect of irrigation and domestic water uses on water temperatures in the Boulder River. This scenario was modeled by removing existing water diversions from the study reach as identified in the hydrologic balance (**Attachment F**). This scenario indicated that increased streamflows would lead to a decrease in water temperatures in the Boulder River (**Figure 2-7, Table 2-6**). Due to a lack of measurements of irrigation withdrawals throughout the system, the results of the water consumptive use scenario should be interpreted with caution. If more detailed flow data for the irrigation network becomes available, this scenario may need to be reevaluated.

Figure 2-7. Boulder River QUAL2K Water Consumptive Use Scenario.

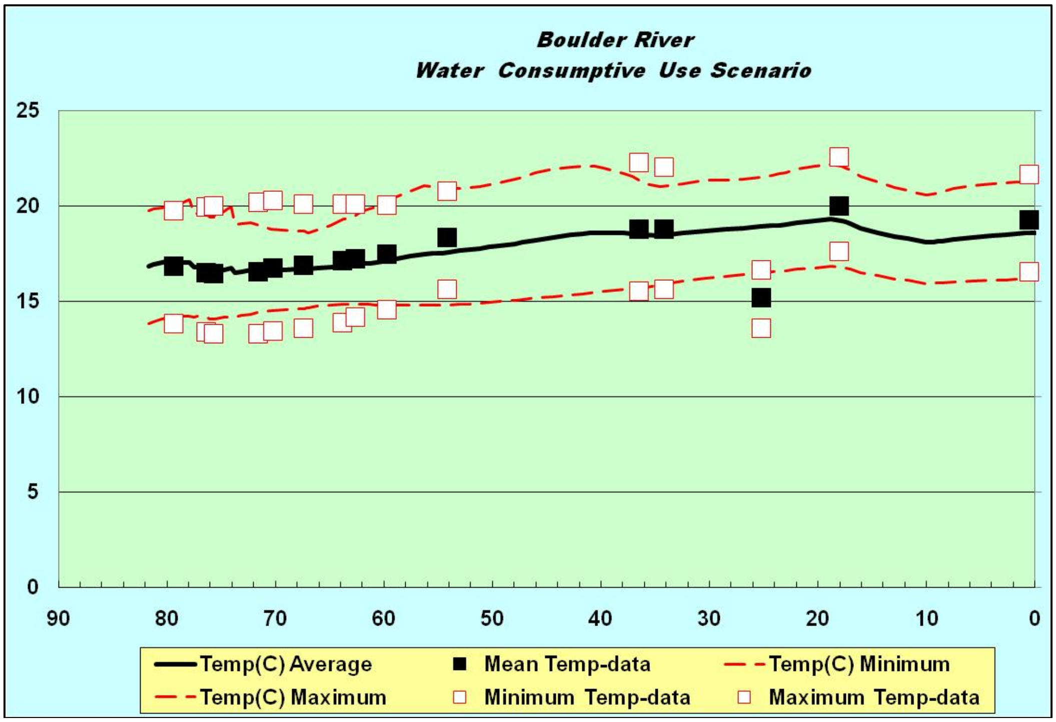


Table 2-6. Boulder River QUAL2K Water Consumptive Use Scenario.

Data Logger Site	Q2K Existing Conditions			Q2K Water Consumptive Use Scenario			Departure from Existing Conditions Model (°C)	Departure from Existing Conditions Model (°F)
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	20.0	68.1	0.0	0.0
BLDR-T04	76.3	19.5	67.1	76.3	19.6	67.3	0.1	0.1
BLDR-T05	75.6	19.4	66.8	75.6	19.4	66.9	0.1	0.1
BLDR-T08	71.4	19.0	66.2	71.4	19.0	66.2	0.0	0.0
BLDR-T09	70.4	18.8	65.9	70.4	18.8	65.8	0.0	0.0
BLDR-T10	67.4	18.8	65.9	67.4	18.7	65.6	-0.1	-0.3
BLDR-T11	63.7	20.0	67.9	63.7	19.3	66.8	-0.6	-1.2
BLDR-T13	62.7	20.1	68.3	62.7	19.5	67.0	-0.7	-1.2
BLDR-T14	59.8	21.0	69.9	59.8	20.1	68.2	-0.9	-1.6
BLDR-T15	54.1	23.0	73.4	54.1	20.9	69.6	-2.1	-3.8
BLDR-T19	36.5	22.8	73.0	36.5	21.3	70.4	-1.4	-2.5
BLDR-T20	34.5	22.5	72.6	34.5	21.0	69.8	-1.6	-2.8
BLDR-T22	18.8	25.3	77.5	18.8	22.2	71.9	-3.1	-5.6
BLDR-T24	1.0	22.5	72.5	1.0	21.3	70.3	-1.2	-2.2

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.2.2.5 Natural Condition Scenario

The natural condition scenario reflects the temperature regime that would be expected in the absence of human influence. This allows for the characterization of the extent of the departure from the natural condition. Factors applied in shade scenario 1 (reference shade) and the water consumptive use scenario (no irrigation withdrawals) were applied to run this scenario. The waste water treatment plant input was also removed from the model. All other parameters from the baseline scenario were retained. The results of the natural condition scenario indicate stream temperatures would naturally be lower than the existing condition along much of the Boulder River (**Figure 2-8, Table 2-7**).

Figure 2-8. Boulder River QUAL2K Natural Condition Scenario.

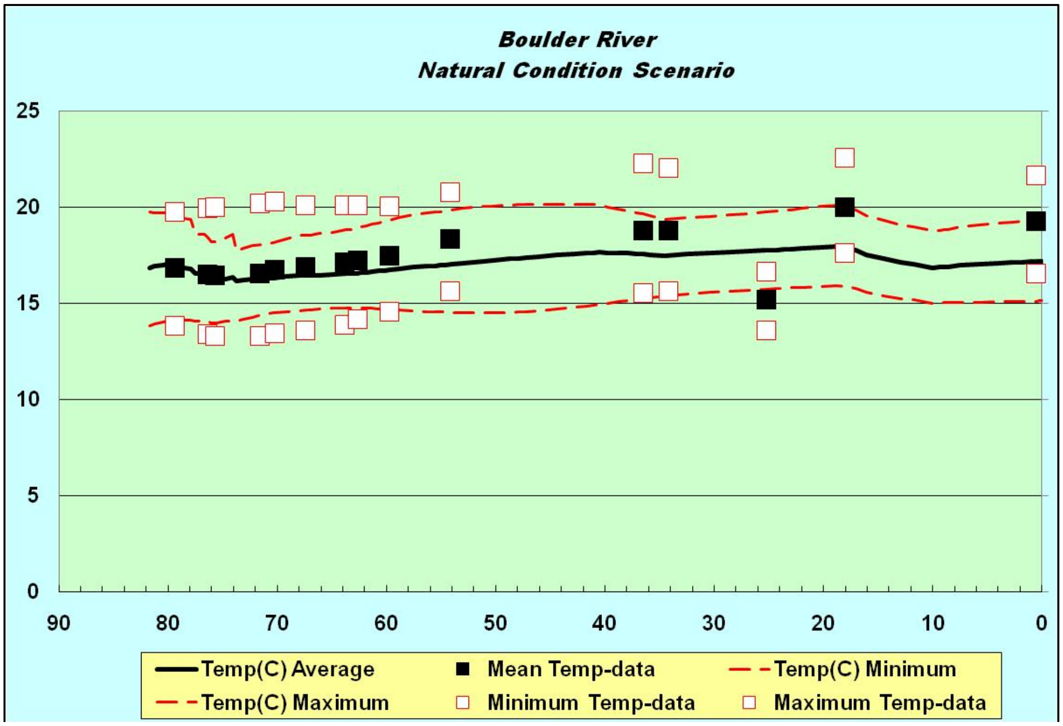


Table 2-7. Boulder River QUAL2K Natural Condition Scenario.

Data Logger Site	Q2K Existing Conditions			Q2K Natural Condition Scenario			Departure from Existing Conditions Model (°C)	Departure from Existing Conditions Model (°F)
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	19.4	67.0	-0.6	-1.1
BLDR-T04	76.3	19.5	67.1	76.3	18.4	65.2	-1.1	-2.0
BLDR-T05	75.6	19.4	66.8	75.6	18.2	64.8	-1.2	-2.1
BLDR-T08	71.4	19.0	66.2	71.4	18.1	64.5	-0.9	-1.7
BLDR-T09	70.4	18.8	65.9	70.4	18.1	64.6	-0.7	-1.2
BLDR-T10	67.4	18.8	65.9	67.4	18.5	65.3	-0.3	-0.5
BLDR-T11	63.7	20.0	67.9	63.7	18.8	65.8	-1.2	-2.1
BLDR-T13	62.7	20.1	68.3	62.7	18.9	66.0	-1.3	-2.3
BLDR-T14	59.8	21.0	69.9	59.8	19.3	66.8	-1.7	-3.1
BLDR-T15	54.1	23.0	73.4	54.1	19.9	67.7	-3.2	-5.7
BLDR-T19	36.5	22.8	73.0	36.5	19.6	67.3	-3.1	-5.6
BLDR-T20	34.5	22.5	72.6	34.5	19.4	66.9	-3.2	-5.7
BLDR-T22	18.8	25.3	77.5	18.8	20.1	68.2	-5.2	-9.3
BLDR-T24	1.0	22.5	72.5	1.0	19.3	66.7	-3.2	-5.7

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.2.2.6 Naturally Occurring Scenario (ARM 17.30.602)

The naturally occurring scenario defines water temperature conditions resulting from the implementation of all reasonable land, soil and water conservation practices as outlined in ARM 17.30.602. This scenario identifies the "naturally occurring" temperature in water bodies of interest and establishes the temperatures to which a 0.5°F (0.23°C) temperature increase is allowable. This, in turn, can be used to identify the impairment status of a water body. The naturally occurring scenario included shade scenario 2 (see **Section 2.2.2.3**) along with a 15% increase in irrigation and domestic water use efficiency. This was estimated by reducing identified irrigation withdrawals by 15%, which is the efficiency improvement estimated by Montana DEQ and Montana DNRC when irrigation best management practices are implemented (Flynn et al. 2008). Based on the results of the naturally occurring scenario, it appears there is the potential for a reduction in in-stream temperatures relative to the existing condition as identified in the baseline scenario (**Figure 2-9, Table 2-8**).

Figure 2-9. Boulder River QUAL2K Naturally Occurring Scenario.

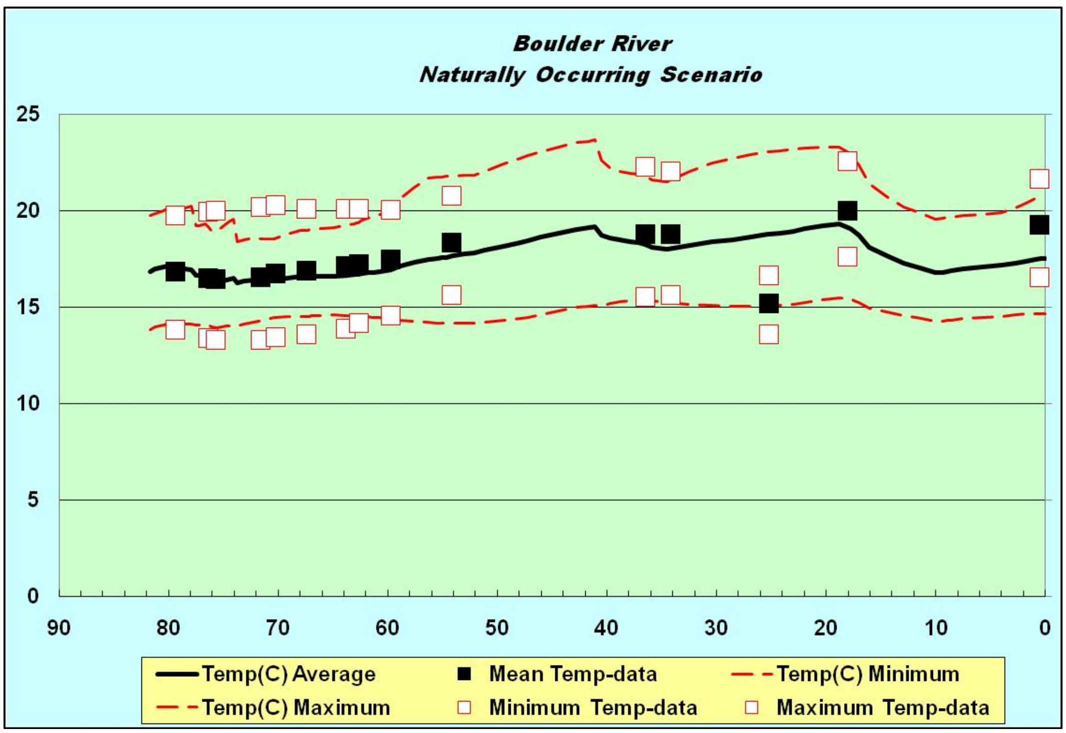


Table 2-8. Boulder River QUAL2K Naturally Occurring Scenario.

Data Logger Site	Q2K Existing Conditions			Q2K Naturally Occurring Scenario			Departure from Existing Conditions	Departure from Existing Conditions
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	20.1	68.1	0.0	0.0
BLDR-T04	76.3	19.5	67.1	76.3	19.2	66.5	-0.4	-0.7
BLDR-T05	75.6	19.4	66.8	75.6	19.0	66.1	-0.4	-0.7
BLDR-T08	71.4	19.0	66.2	71.4	18.6	65.4	-0.4	-0.8
BLDR-T09	70.4	18.8	65.9	70.4	18.5	65.4	-0.3	-0.5
BLDR-T10	67.4	18.8	65.9	67.4	19.0	66.2	0.2	0.3
BLDR-T11	63.7	20.0	67.9	63.7	19.3	66.7	-0.7	-1.2
BLDR-T13	62.7	20.1	68.3	62.7	19.4	66.9	-0.8	-1.4
BLDR-T14	59.8	21.0	69.9	59.8	20.0	68.0	-1.1	-1.9
BLDR-T15	54.1	23.0	73.4	54.1	21.8	71.2	-1.2	-2.2
BLDR-T19	36.5	22.8	73.0	36.5	21.8	71.2	-1.0	-1.8
BLDR-T20	34.5	22.5	72.6	34.5	21.5	70.7	-1.0	-1.9
BLDR-T22	18.8	25.3	77.5	18.8	23.3	73.9	-2.0	-3.6
BLDR-T24	1.0	22.5	72.5	1.0	20.6	69.1	-1.8	-3.3

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.2.2.7 Shade Scenario 1 (Reference Shade) and Increased Irrigation Efficiency

The final scenario assessed combines shade scenario 1 (reference shade) with the potential for increased irrigation efficiency as presented in the naturally occurring scenario. The reference shade scenario assumes the entire length of the Boulder River between the town of Boulder and the confluence with the Jefferson River is capable of supporting a riparian area comprised of large cottonwood trees in the overstory with shrubs in the understory (see **Section 2.2.2.2**). For this scenario, a 15% increase in irrigation and domestic water use efficiency is also applied (see **Section 2.2.2.6)**. Based on the results of this scenario, it appears there is the potential for a reduction in in-stream temperatures relative to the existing condition as identified in the baseline scenario (**Figure 2-10, Table 2-9**).

Figure 2-10. Boulder River QUAL2K Shade Scenario 1 (Reference Shade) and Increased Irrigation Efficiency.

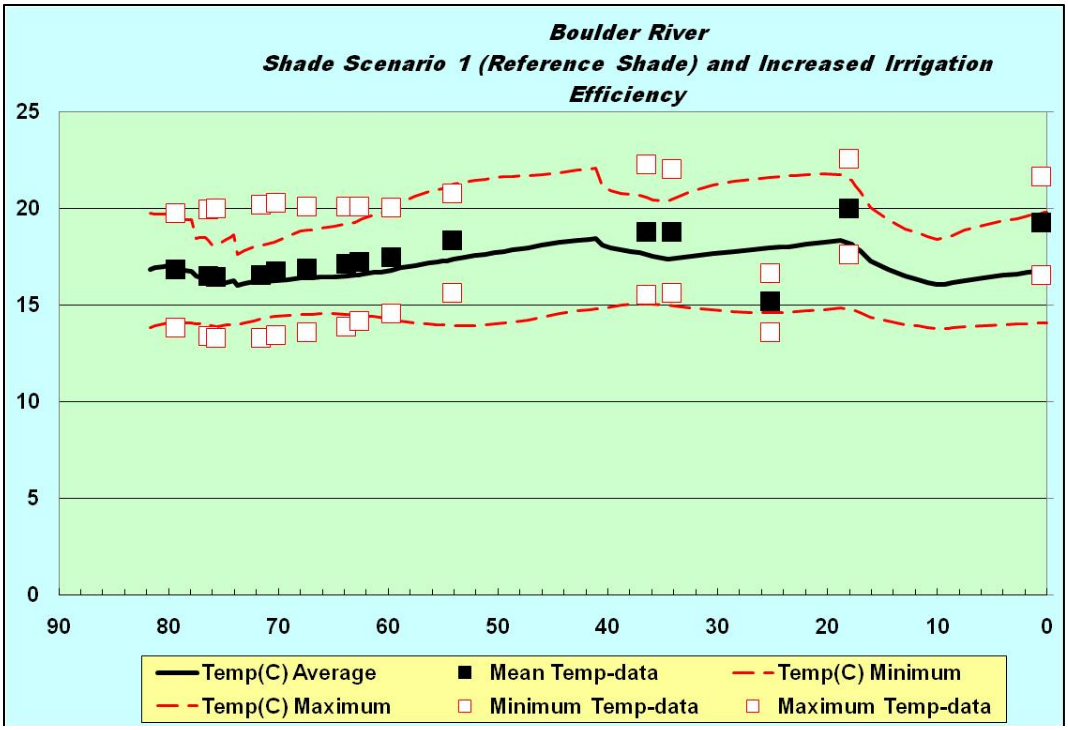


Table 2-9. Boulder River QUAL2K Shade Scenario 1 (Reference Shade) and Increased Irrigation Efficiency.

Data Logger Site	Q2K Existing Conditions			Q2K Shade Scenario 1 (Reference Shade) and Increased Irrigation Efficiency			Departure from Existing Conditions Model (°C)	Departure from Existing Conditions Model (°F)
	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)	Distance (km)	Maximum Temperature (°C)	Maximum Temperature (°F)		
BLDR-T02	79.1	20.1	68.1	79.1	19.4	67.0	-0.6	-1.1
BLDR-T04	76.3	19.5	67.1	76.3	18.3	65.0	-1.2	-2.1
BLDR-T05	75.6	19.4	66.8	75.6	18.1	64.6	-1.2	-2.2
BLDR-T08	71.4	19.0	66.2	71.4	18.1	64.6	-0.9	-1.5
BLDR-T09	70.4	18.8	65.9	70.4	18.3	64.9	-0.6	-1.0
BLDR-T10	67.4	18.8	65.9	67.4	18.9	65.9	0.0	0.1
BLDR-T11	63.7	20.0	67.9	63.7	19.2	66.6	-0.7	-1.3
BLDR-T13	62.7	20.1	68.3	62.7	19.3	66.8	-0.8	-1.5
BLDR-T14	59.8	21.0	69.9	59.8	20.0	67.9	-1.1	-1.9
BLDR-T15	54.1	23.0	73.4	54.1	21.2	70.2	-1.8	-3.2
BLDR-T19	36.5	22.8	73.0	36.5	20.6	69.0	-2.2	-3.9
BLDR-T20	34.5	22.5	72.6	34.5	20.4	68.7	-2.1	-3.9
BLDR-T22	18.8	25.3	77.5	18.8	21.7	71.1	-3.5	-6.4
BLDR-T24	1.0	22.5	72.5	1.0	19.7	67.5	-2.8	-5.0

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

2.3 Modeled Temperatures Relative to Montana Standards

The naturally occurring scenario for the Boulder River indicated that water temperatures greater than 66.5°F can be expected (see **Table 1-2**). Thus, the maximum allowable increase in temperature due to unmitigated human causes is 0.5°F (0.23°C) (see **Section 1.1**). Along the Boulder River in 2010, this standard was exceeded at 11 out of 14 temperature monitoring sites evaluated using the QUAL2K model (**Table 2-10**). Model scenarios indicate that both an increase in shade and an increase in streamflow would help reduce water temperatures in the Boulder River.

Table 2-10. Boulder River Temperatures Relative to Montana's Water Quality Standards.

Data Logger Site	Distance (km)	Field Measured Data	QUAL2K Existing Conditions	Departure from Field Data (ºF)	Naturally Occurring Scenario	Departure from Existing Conditions Model (ºF)
		Maximum Temperature (ºF)	Maximum Temperature (ºF)		Maximum Temperature (ºF)	
BLDR-T02	79.1	67.6	68.1	0.5	68.1	0.0
BLDR-T04	76.3	67.9	67.1	-0.8	66.5	-0.7
BLDR-T05	75.6	67.9	66.8	-1.1	66.1	-0.7
BLDR-T08	71.4	68.3	66.2	-2.2	65.4	-0.8
BLDR-T09	70.4	68.5	65.9	-2.6	65.4	-0.5
BLDR-T10	67.4	68.2	65.9	-2.3	66.2	0.3
BLDR-T11	63.7	68.2	67.9	-0.3	66.7	-1.2
BLDR-T13	62.7	68.1	68.3	0.1	66.9	-1.4
BLDR-T14	59.8	68.0	69.9	1.8	68.0	-1.9
BLDR-T15	54.1	69.4	73.4	4.1	71.2	-2.2
BLDR-T19	36.5	72.1	73.0	0.8	71.2	-1.8
BLDR-T20	34.5	71.6	72.6	0.9	70.7	-1.9
BLDR-T22	18.8	72.6	77.5	4.9	73.9	-3.6
BLDR-T24	1.0	70.9	72.5	1.5	69.1	-3.3

Grey highlighted values indicate that the model scenario predicts a potential decrease in temperature greater than 0.5°F.

3.0 Conclusions

Major findings and restoration recommendations include:

- Temperature data collected in 2010 and the results of this QUAL2K modeling effort suggest that the Boulder River between the town of Boulder and the confluence with the Jefferson River fails to meet Montana's standard for temperature during low flow periods in the middle of summer.

- Modeling indicated that increased shading along 44.1 miles of the Boulder River would lead to a decrease in in-stream temperatures. Improved riparian shading in combination with improved irrigation water management efficiency would lead to additional decreases in water temperatures.

Limitations of this study include a lack of detailed flow measurements for tributary streams and the irrigation network, as well as the reliance on a simplified hydrologic balance based on limited data points. Thus, the results of this assessment may need to be reevaluated as additional information becomes available.

4.0 References

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Attachment A

2010 Temperature Data Summary

Boulder-Elkhorn TMDL Planning Area

Summary Data for Montana Rainbow Trout (deg F)

Site Name	Lat	Long	Start Date	Stop date	Seasonal Maximum		Seasonal Minimum		Seasonal Max ΔT		7-Day averages				Days > 66 F	Days > 75 F	Days > 78 F	Hours > 66 F	Hours > 75 F	Hours > 78 F	Warmest day of 7-day max			Agency
					Date	Value	Date	Value	Date	Value	Date	Maximum	Minimum	Δ T							Date	Maximum	Minimum	
2376167 (BLDR-T12, Elkhorn Creek)	46.1656	111.9907	06/29/10	07/13/10	07/09/10	81.1	07/07/10	47.2	07/08/10	30.6	07/10/10	77.3	50.7	26.6	13	6	2	71.0	16.0	5.5	07/09/10	81.1	51.0	DEQ
2376168 (BLDR-T22, Boulder River)	45.9487	111.9036	06/30/10	09/28/10	07/25/10	76.2	09/23/10	48.9	08/25/10	13.7	08/02/10	75.1	64.3	10.8	50	5	0	591.5	11.0	0.0	07/30/10	75.9	65.1	DEQ
2376170 (BLDR-T06, Little Boulder River)	46.1976	112.0869	06/29/10	09/26/10	07/25/10	67.6	09/07/10	43.3	07/25/10	13.1	08/02/10	65.0	55.4	9.6	3	0	0	6.5	0.0	0.0	07/30/10	66.3	54.9	DEQ
2376171 (BLDR-T08, Boulder River)	46.1908	112.0703	06/29/10	09/27/10	07/25/10	71.5	09/11/10	43.9	08/25/10	15.5	07/22/10	68.6	55.3	13.3	29	0	0	139.5	0.0	0.0	07/25/10	71.5	56.2	DEQ
2376172 (BLDR-T10, Boulder River)	46.1785	112.0328	06/29/10	09/27/10	07/25/10	71.3	09/11/10	44.4	07/24/10	14.9	08/04/10	68.9	56.8	12.1	31	0	0	179.0	0.0	0.0	08/05/10	70.6	56.3	DEQ
2376176 (BLDR-T19, Boulder River)	46.0333	111.8708	06/30/10	09/28/10	07/25/10	76.4	09/23/10	48.3	08/24/10	16.0	07/31/10	72.7	60.1	12.6	48	1	0	408.0	3.5	0.0	07/28/10	73.9	58.8	DEQ
2376177 (BLDR-F02, Boulder Ditch)	46.1761	112.0298	06/29/10	09/19/10	07/25/10	71.3	09/11/10	44.4	07/24/10	14.9	08/04/10	68.8	56.9	11.9	31	0	0	175.5	0.0	0.0	08/05/10	70.5	56.3	DEQ
2376178 (BLDR-T15, Boulder River)	46.1289	111.9392	06/30/10	09/28/10	07/25/10	73.2	09/11/10	46.3	08/25/10	13.3	07/31/10	70.6	60.1	10.6	40	0	0	296.0	0.0	0.0	07/30/10	72.4	60.4	DEQ
2376181 (BLDR-T17, Boulder Ditch)	46.0617	111.8808	06/29/10	09/28/10	08/08/10	72.3	09/11/10	23.3	08/21/10	33.4	08/24/10	67.9	47.8	20.1	10	0	0	51.5	0.0	0.0	08/25/10	69.8	36.8	DEQ
2376182 (BLDR-T13, Boulder River)	46.1566	111.9961	06/29/10	09/27/10	07/25/10	71.4	09/11/10	45.2	07/24/10	13.7	07/22/10	68.6	56.7	11.9	33	0	0	192.0	0.0	0.0	07/25/10	71.4	57.9	DEQ
2376183 (BLDR-T02, Boulder River)	46.2255	112.1108	06/29/10	09/26/10	08/05/10	71.1	09/11/10	43.4	08/25/10	14.6	08/02/10	68.2	57.6	10.6	29	0	0	132.0	0.0	0.0	08/05/10	71.1	57.3	DEQ
2449494 (BLDR-T04, Boulder River)	46.213	112.087	06/29/10	09/29/10	07/25/10	71.1	09/11/10	43.8	08/25/10	15.6	07/22/10	68.5	55.6	13.0	29	0	0	128.0	0.0	0.0	07/25/10	71.1	56.5	DEQ
2449496 (BLDR-T11, Boulder River)	46.1606	112.0059	06/30/10	09/29/10	07/25/10	71.4	09/24/10	45.8	07/24/10	14.5	07/31/10	68.7	57.5	11.2	33	0	0	190.5	0.0	0.0	07/29/10	70.5	58.0	DEQ
2449499 (BLDR-T20, Boulder River)	46.016	111.8744	06/30/10	09/28/10	07/25/10	75.9	09/23/10	48.5	07/28/10	15.4	07/31/10	74.1	60.4	13.7	47	2	0	386.0	4.5	0.0	07/29/10	75.1	60.4	DEQ
2449500 (BLDR-F01, Boulder Ditch)	46.1846	112.0568	06/30/10	09/27/10	07/25/10	71.6	09/07/10	44.2	07/24/10	15.4	08/04/10	68.8	56.6	12.3	31	0	0	162.0	0.0	0.0	08/05/10	70.5	56.0	DEQ
2449501 (BLDR-T14, Boulder River)	46.1418	111.9838	06/30/10	09/27/10	07/25/10	71.4	09/11/10	45.5	07/14/10	13.3	07/22/10	68.9	57.2	11.7	31	0	0	186.5	0.0	0.0	07/25/10	71.4	58.5	DEQ
2449503 (BLDR-T09, Boulder River)	46.1862	112.0585	06/29/10	09/27/10	07/25/10	71.6	09/11/10	44.2	08/25/10	15.6	08/04/10	69.0	56.6	12.5	30	0	0	160.5	0.0	0.0	08/05/10	70.9	56.0	DEQ
2449504 (BLDR-T21, Boulder River)	45.9752	111.8887	06/30/10	09/28/10	08/06/10	73.0	09/25/10	48.5	08/05/10	13.3	08/18/10	70.1	59.9	10.2	26	0	0	193.5	0.0	0.0	08/17/10	71.4	61.2	DEQ
2449505 (BLDR-T24, Boulder River)	45.8693	111.9417	06/30/10	09/28/10	07/25/10	74.3	09/23/10	49.3	07/24/10	12.7	07/31/10	72.4	62.2	10.3	46	0	0	479.5	0.0	0.0	07/29/10	73.7	62.3	DEQ
9760509 (BLDR-T05, Boulder River)	46.2099	112.0915	06/29/10	09/26/10	07/25/10	71.1	09/11/10	43.8	08/25/10	15.6	07/22/10	68.5	55.4	13.1	29	0	0	126.5	0.0	0.0	07/25/10	71.1	56.3	DEQ
9760520 (BLDR-T17a, Boulder River)	46.06121	111.882	08/13/10	09/28/10	08/17/10	71.5	09/23/10	48.0	08/16/10	13.8	08/18/10	69.6	57.3	12.3	11	0	0	65.0	0.0	0.0	08/17/10	71.5	58.1	DEQ
9760522 (BLDR-T23, Boulder River)	45.9155	111.9278	08/07/10	09/28/10	08/18/10	71.1	09/23/10	49.2	08/24/10	13.5	08/18/10	69.2	58.3	10.8	16	0	0	106.0	0.0	0.0	08/18/10	71.1	59.9	DEQ
9774611 (BLDR-T04a, Muskrat Creek)	46.2222	112.0904	08/13/10	09/26/10	08/25/10	64.6	09/07/10	42.4	08/25/10	16.8	08/18/10	63.4	49.4	14.0	0	0	0	0.0	0.0	0.0	08/20/10	64.5	48.2	DEQ
2376173 (BLDR-T18, Boulder River) 6/29/2010-7/15/2010	46.0611	111.8786	06/29/10	07/15/10	07/15/10	78.9	07/07/10	51.5	07/15/10	24.9	07/12/10	69.3	57.1	12.2	8	1	1	46.0	3.0	1.5	07/15/10	78.9	54.0	DEQ
2376173 (BLDR-T18, Boulder River) 8/6/2010-9/28/2010	46.0611	111.8786	08/06/10	09/28/10	08/06/10	74.9	09/23/10	48.0	08/06/10	15.4	08/18/10	71.1	57.6	13.5	20	0	0	121.0	0.0	0.0	08/17/10	72.7	58.3	DEQ
2376174 (BLDR-T16, Boulder River) 7/2/2010-7/14/2010	46.0916	111.9079	07/02/10	07/14/10	07/09/10	68.6	07/07/10	51.0	07/14/10	12.9	07/11/10	66.8	56.8	10.0	6	0	0	23.0	0.0	0.0	07/09/10	68.6	56.8	DEQ
2376174 (BLDR-T16, Boulder River) 8/7/2010-9/28/2010	46.0916	111.9079	08/07/10	09/28/10	08/18/10	72.2	09/11/10	47.4	08/16/10	12.4	08/19/10	70.1	59.4	10.7	17	0	0	123.0	0.0	0.0	08/18/10	72.2	60.5	DEQ
2376175 (BLDR-T01, Boulder River) 6/29/2010-7/23/2010	46.2313	112.1331	06/29/10	07/23/10	07/20/10	71.0	07/07/10	46.6	07/20/10	18.9	07/18/10	67.9	54.3	13.6	7	0	0	15.5	0.0	0.0	07/20/10	71.0	52.1	DEQ
2376175 (BLDR-T01, Boulder River) 8/5/2010-9/27/2010	46.2313	112.1331	08/05/10	09/27/10	08/05/10	70.0	09/11/10	43.2	08/25/10	13.1	08/19/10	65.7	55.1	10.7	6	0	0	17.0	0.0	0.0	08/17/10	67.1	55.1	DEQ
2376184 (BLDR-T03, Boulder River, Duplicate) 6/29/2010-7/24/2010	46.2238	112.1029	06/29/10	07/24/10	07/24/10	69.5	07/07/10	47.1	07/24/10	13.9	07/21/10	67.7	56.1	11.6	9	0	0	39.5	0.0	0.0	07/24/10	69.5	55.6	DEQ
2376184 (BLDR-T03, Boulder River, Duplicate) 8/5/2010-9/26/2010	46.2238	112.1029	08/05/10	09/26/10	08/05/10	71.1	09/11/10	43.4	08/25/10	14.7	08/19/10	66.6	55.3	11.3	12	0	0	45.0	0.0	0.0	08/17/10	68.2	55.4	DEQ
2449498 (BLDR-T03, Boulder River) 6/29/2010-7/24/2010	46.2238	112.1029	06/29/10	07/24/10	07/24/10	69.5	07/07/10	47.2	07/24/10	14.0	07/21/10	67.8	56.1	11.8	9	0	0	41.5	0.0	0.0	07/24/10	69.5	55.6	DEQ
2449498 (BLDR-T03, Boulder River) 8/5/2010-9/26/2010	46.2238	112.1029	08/05/10	09/26/10	08/05/10	71.3	09/11/10	43.6	08/25/10	14.6	08/19/10	66.6	55.4	11.2	12	0	0	45.5	0.0	0.0	08/17/10	68.2	55.5	DEQ
2449495 (BLDR-T16, Boulder River, Duplicate) 7/2/2010-7/14/2010	46.0916	111.9079	07/02/10	07/14/10	07/09/10	68.9	07/07/10	51.2	07/14/10	13.2	07/11/10	67.2	57.1	10.2	6	0	0	29.5	0.0	0.0	07/09/10	68.9	57.0	DEQ
2449495 (BLDR-T16, Boulder River, Duplicate) 8/7/2010-9/28/2010	46.0916	111.9079	08/07/10	09/28/10	08/18/10	72.4	09/11/10	47.5	08/16/10	12.4	08/19/10	70.3	59.6	10.7	17	0	0	127.0	0.0	0.0	08/18/10	72.4	60.6	DEQ

Attachment B

SOLAR PATHFINDER HOURLY SHADE MEASUREMENTS

Boulder-Elkhorn TMDL Planning Area

Reach	Section	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	TOTAL
Reach	Potential	3	5	8	10	12	12	12	12	10	8	5	3	
SP-2-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-1	Transect 1-left	2	1	0	0	0	0	0	0	0	0	0	0	
SP-2-1	Transect 1-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-1	Transect 1 Average	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
SP-2-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-2	Transect 2-left	3	0	0	0	0	0	0	0	0	0	0	0	
SP-2-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-2	Transect 2 Average	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
SP-2-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-3	Transect 3-left	2	0	0	0	0	0	0	0	0	0	0	0	
SP-2-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-2-3	Transect 3 Average	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
SP-2	**Average %**	**26%**	**2%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**2%**
SP-1-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	1	
SP-1-1	Transect 1-left	3	5	5	0	0	0	0	0	0	0	0	0	
SP-1-1	Transect 1-right	1	0	0	0	0	0	0	0	0	0	0	1	
SP-1-1	Transect 1 Average	1.3	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.3
SP-1-2	Transect 2-center	3	4	0	0	0	0	0	0	0	0	1	3	
SP-1-2	Transect 2-left	3	5	8	1	0	0	0	0	0	0	0	0	
SP-1-2	Transect 2-right	3	1	0	0	0	0	1	9	10	8	5	3	
SP-1-2	Transect 2 Average	3.0	3.3	2.7	0.3	0.0	0.0	0.3	3.0	3.3	2.7	2.0	2.0	22.7
SP-1-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	5	3	
SP-1-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	5	3	
SP-1-3	Transect 3-right	0	2	1	2	4	4	6	10	10	7	4	3	
SP-1-3	Transect 3 Average	0.0	0.7	0.3	0.7	1.3	1.3	2.0	3.3	3.3	2.3	4.7	3.0	23.0
SP-1	**Average %**	**48%**	**38%**	**19%**	**3%**	**4%**	**4%**	**6%**	**18%**	**22%**	**21%**	**44%**	**63%**	**24%**
SP-4-1	Transect 1-center	3	5	8	5	0	0	0	0	0	7	3	2	
SP-4-1	Transect 1-left	3	5	8	9	6	1	0	0	0	0	0	1	
SP-4-1	Transect 1-right	3	5	7	0	0	0	0	0	8	3	4	3	
SP-4-1	Transect 1 Average	3.0	5.0	7.7	4.7	2.0	0.3	0.0	0.0	2.7	3.3	2.3	2.0	33.0
SP-4-2	Transect 2-center	3	5	1	0	0	0	0	0	0	0	1	3	
SP-4-2	Transect 2-left	3	5	7	0	0	0	0	0	0	0	1	3	
SP-4-2	Transect 2-right	3	4	0	0	0	0	0	0	7	8	5	3	
SP-4-2	Transect 2 Average	3.0	4.7	2.7	0.0	0.0	0.0	0.0	0.0	2.3	2.7	2.3	3.0	20.7
SP-4-3	Transect 3-center	3	5	1	0	0	1	0	8	10	7	5	3	
SP-4-3	Transect 3-left	3	5	1	0	0	0	0	1	9	8	5	2	
SP-4-3	Transect 3-right	2	2	0	7	10	9	6	12	7	7	5	3	
SP-4-3	Transect 3 Average	2.7	4.0	0.7	2.3	3.3	3.3	2.0	7.0	8.7	7.3	5.0	2.7	49.0
SP-4	**Average %**	**96%**	**91%**	**46%**	**23%**	**15%**	**10%**	**6%**	**19%**	**46%**	**56%**	**64%**	**85%**	**46%**
SP-3-1	Transect 1-center	3	5	1	0	0	0	0	0	0	0	0	3	
SP-3-1	Transect 1-left	3	5	8	4	0	0	0	0	0	0	0	1	
SP-3-1	Transect 1-right	3	4	1	0	0	0	0	0	0	0	1	2	
SP-3-1	Transect 1 Average	3.0	4.7	3.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	14.7
SP-3-2	Transect 2-center	3	0	0	0	0	0	0	0	0	0	3	2	
SP-3-2	Transect 2-left	3	3	0	0	0	0	0	0	0	0	3	3	
SP-3-2	Transect 2-right	2	0	0	0	0	0	0	0	0	0	3	2	
SP-3-2	Transect 2 Average	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.3	9.0
SP-3-3	Transect 3-center	2	0	0	0	0	3	11	11	10	6	4	1	
SP-3-3	Transect 3-left	2	0	0	0	0	0	4	11	8	6	3	2	
SP-3-3	Transect 3-right	1	0	0	0	0	9	10	9	8	6	5	1	
SP-3-3	Transect 3 Average	1.7	0.0	0.0	0.0	0.0	4.0	8.3	10.3	8.7	6.0	4.0	1.3	44.3
SP-3	**Average %**	**81%**	**38%**	**14%**	**4%**	**0%**	**11%**	**23%**	**29%**	**29%**	**25%**	**49%**	**63%**	**31%**
SP-5-1	Transect 1-center	3	5	7	0	0	0	0	0	1	2	4	3	
SP-5-1	Transect 1-left	3	5	8	4	0	0	0	0	1	3	3	3	
SP-5-1	Transect 1-right	2	4	5	0	0	0	0	1	4	5	5	3	
SP-5-1	Transect 1 Average	2.7	4.7	6.7	1.3	0.0	0.0	0.0	0.3	2.0	3.3	4.0	3.0	28.0
SP-5-2	Transect 2-center	3	5	0	0	0	0	0	0	2	3	3	3	
SP-5-2	Transect 2-left	3	5	2	0	0	0	0	0	0	3	3	2	
SP-5-2	Transect 2-right	3	4	0	0	0	0	7	2	5	7	4	2	
SP-5-2	Transect 2 Average	3.0	4.7	0.7	0.0	0.0	0.0	2.3	0.7	2.3	4.3	3.3	2.3	23.7
SP-5-3	Transect 3-center	2	0	0	0	0	0	0	0	0	4	4	3	
SP-5-3	Transect 3-left	2	0	0	0	0	0	0	0	0	2	5	1	
SP-5-3	Transect 3-right	2	0	0	0	0	0	0	0	0	6	5	3	
SP-5-3	Transect 3 Average	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.7	2.3	13.0
SP-5	**Average %**	**85%**	**62%**	**31%**	**4%**	**0%**	**0%**	**6%**	**3%**	**14%**	**49%**	**80%**	**85%**	**35%**
SP-6-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	1	2	
SP-6-1	Transect 1-left	0	0	0	0	0	0	0	0	0	0	0	1	
SP-6-1	Transect 1-right	0	0	0	0	0	0	0	0	0	4	4	2	
SP-6-1	Transect 1 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.7	1.7	4.7
SP-6-2	Transect 2-center	0	0	0	0	0	0	0	0	0	3	4	1	
SP-6-2	Transect 2-left	1	0	0	0	0	0	0	0	0	2	2	2	
SP-6-2	Transect 2-right	0	0	0	0	0	0	0	0	0	7	5	1	
SP-6-2	Transect 2 Average	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	3.7	1.3	9.3
SP-6-3	Transect 3-center	2	0	1	1	0	0	0	0	0	0	0	0	
SP-6-3	Transect 3-left	3	0	0	0	0	0	0	0	0	0	0	0	
SP-6-3	Transect 3-right	2	0	3	6	0	0	0	0	0	0	0	0	
SP-6-3	Transect 3 Average	2.3	0.0	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
SP-6	**Average %**	**30%**	**0%**	**6%**	**8%**	**0%**	**0%**	**0%**	**0%**	**0%**	**22%**	**36%**	**33%**	**11%**
SP-7-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-1	Transect 1-left	0	0	3	8	6	2	0	0	0	0	0	0	
SP-7-1	Transect 1-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-1	Transect 1 Average	0.0	0.0	1.0	2.7	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	6.3
SP-7-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-2	Transect 2-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-2	Transect 2 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP-7-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-7-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	1	3	
SP-7-3	Transect 3 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	1.3
SP-7	**Average %**	**0%**	**0%**	**4%**	**9%**	**6%**	**2%**	**0%**	**0%**	**0%**	**0%**	**2%**	**11%**	**3%**

Reach	Section	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	TOTAL
Reach	Potential	3	5	8	10	12	12	12	12	10	8	5	3	
SP-8-1	Transect 1-center	1	0	0	0	0	0	0	0	0	0	0	2	
SP-8-1	Transect 1-left	2	0	0	0	0	0	0	0	0	0	0	0	
SP-8-1	Transect 1-right	1	0	0	0	0	0	0	0	0	0	0	2	
SP-8-1	Transect 1 Average	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.7
SP-8-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-8-2	Transect 2-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-8-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-8-2	Transect 2 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP-8-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-8-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-8-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	0	1	
SP-8-3	Transect 3 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
SP-8	**Average %**	**15%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**19%**	**3%**
SP-X-1	Transect 1-center	3	2	8	5	0	0	0	0	0	0	4	3	
SP-X-1	Transect 1-left	3	2	3	10	5	0	0	0	0	0	4	3	
SP-X-1	Transect 1-right	3	3	6	0	0	0	0	0	0	1	5	3	
SP-X-1	Transect 1 Average	3.0	2.3	5.7	5.0	1.7	0.0	0.0	0.0	0.0	0.3	4.3	3.0	25.3
SP-X-2	Transect 2-center	3	5	8	7	0	0	0	0	0	0	0	3	
SP-X-2	Transect 2-left	3	5	6	9	8	0	0	0	0	0	0	3	
SP-X-2	Transect 2-right	3	4	8	2	0	0	0	0	0	0	0	1	
SP-X-2	Transect 2 Average	3.0	4.7	7.3	6.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.3	26.0
SP-X-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	2	3	
SP-X-3	Transect 3-left	1	0	0	0	0	0	0	0	0	0	0	2	
SP-X-3	Transect 3-right	0	0	0	0	0	0	0	0	0	6	5	3	
SP-X-3	Transect 3 Average	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.3	2.7	7.3
SP-X	**Average %**	**70%**	**47%**	**54%**	**37%**	**12%**	**0%**	**0%**	**0%**	**0%**	**10%**	**44%**	**89%**	**30%**
SP-9-1	Transect 1-center	3	5	2	0	0	0	0	0	0	2	5	3	
SP-9-1	Transect 1-left	3	5	6	0	0	0	0	0	0	0	2	3	
SP-9-1	Transect 1-right	3	4	0	0	0	0	0	0	0	7	5	3	
SP-9-1	Transect 1 Average	3.0	4.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	3.0	4.0	3.0	20.3
SP-9-2	Transect 2-center	3	1	0	0	0	0	0	0	0	0	0	1	
SP-9-2	Transect 2-left	3	1	1	1	0	0	0	0	0	0	0	0	
SP-9-2	Transect 2-right	3	1	0	0	0	0	0	0	0	0	1	3	
SP-9-2	Transect 2 Average	3.0	1.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.3	6.3
SP-9-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	2	
SP-9-3	Transect 3-left	3	1	0	0	0	0	0	0	0	0	0	1	
SP-9-3	Transect 3-right	3	0	0	0	0	0	0	0	0	0	4	1	
SP-9-3	Transect 3 Average	2.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	5.0
SP-9	**Average %**	**89%**	**40%**	**13%**	**1%**	**0%**	**0%**	**0%**	**0%**	**0%**	**13%**	**38%**	**63%**	**21%**
SP-10-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-10-1	Transect 1-left	1	0	0	0	0	0	0	0	0	0	0	0	
SP-10-1	Transect 1-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-10-1	Transect 1 Average	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
SP-10-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	3	
SP-10-2	Transect 2-left	0	0	0	0	0	0	0	0	0	0	0	1	
SP-10-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	5	3	
SP-10-2	Transect 2 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.3	4.0
SP-10-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	2	
SP-10-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	0	1	
SP-10-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	5	3	
SP-10-3	Transect 3 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.0	3.7
SP-10	**Average %**	**4%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**22%**	**48%**	**6%**
SP-11-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-11-1	Transect 1-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-11-1	Transect 1-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-11-1	Transect 1 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP-11-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	1	
SP-11-2	Transect 2-left	1	0	0	0	0	0	0	0	0	0	0	1	
SP-11-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	0	2	
SP-11-2	Transect 2 Average	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.7
SP-11-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-11-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-11-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	0	1	
SP-11-3	Transect 3 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
SP-11	**Average %**	**4%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**19%**	**2%**
SP-12-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-1	Transect 1-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-1	Transect 1-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-1	Transect 1 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP-12-2	Transect 2-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-2	Transect 2-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-2	Transect 2-right	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-2	Transect 2 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SP-12-3	Transect 3-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-3	Transect 3-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-12-3	Transect 3-right	0	0	0	0	0	0	0	0	0	0	0	3	
SP-12-3	Transect 3 Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
SP-12	**Average %**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**11%**	**1%**
SP-13-1	Transect 1-center	0	0	0	0	0	0	0	0	0	0	0	0	
SP-13-1	Transect 1-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-13-1	Transect 1-right	0	0	1	0	0	0	0	0	0	0	0	0	
SP-13-1	Transect 1 Average	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
SP-13-2	Transect 2-center	0	0	0	0	0	2	6	0	0	0	0	0	
SP-13-2	Transect 2-left	0	0	0	0	0	0	0	0	0	0	0	0	
SP-13-2	Transect 2-right	0	0	0	7	12	0	8	0	0	0	0	0	
SP-13-2	Transect 2 Average	0.0	0.0	0.0	2.3	4.0	0.7	4.7	0.0	0.0	0.0	0.0	0.0	11.7
SP-13-3	Transect 3-center	1	0	0	0	0	0	0	0	0	2	2	0	
SP-13-3	Transect 3-left	3	5	8	6	0	0	0	0	0	0	0	0	
SP-13-3	Transect 3-right	1	0	0	0	0	0	0	0	2	8	2	0	
SP-13-3	Transect 3 Average	1.7	1.7	2.7	2.0	0.0	0.0	0.0	0.0	0.7	3.3	1.3	0.0	13.3
SP-13	**Average %**	**19%**	**11%**	**13%**	**14%**	**11%**	**2%**	**13%**	**0%**	**2%**	**14%**	**9%**	**0%**	**9%**

Attachment C

SOLAR PATHFINDER SUPPLEMENTAL FIELD DATA

Boulder-Elkhorn TMDL Planning Area

Solar Pathfinder Site	Reach	GIS Riparian Vegetation Reach Type	Site Description	Average Daily Shade (%)	GIS Reach Scale Aspect	Azimuth			Bankfull Width (Feet)			Average Bankfull Width (Feet)	Wetted Width (Feet)			Average Wetted Width (Feet)	Potential Riparian Conditions
						1	2	3	1	2	3		1	2	3		
SP-1	BLDR-01	low	Young cottonwoods and willows along channel margin, with urban/industrial clearing on floodplain along both sides of channel. Gravel berms limit lateral channel migration.	24	-45	-45	-45	90	93	102	115	103	40	62	41	48	cottonwoods
SP-2	BLDR-04	low	Sparse willows with grassy streambanks. Riparian clearing along river right for agriculture.	2	45	0	0	0	66	66	75	69	47	51	53	50	cottonwoods
SP-3	BLDR-07	moderate	Willows and cottonwoods. Mature cottonwood stands lack understory shrubs. Cottonwood regeneration occurring on point bars.	31	0	0	0	-45	82	78	80	80	44	39	37	40	cottonwoods
SP-4	BLDR-08	high	Mature cottonwoods and aspen with shrubs in understory. Site at potential conditions.	46	0	0	0	-45	81	72	75	76	45	54	40	46	cottonwoods
SP-5	BLDR-10	high	Mature cottonwoods. Site approaching potential conditions.	35	0	0	0		80	88	115	94	52	45	39	45	cottonwoods
SP-X	BLDR-16	moderate	Mature cottonwoods with herbacous understory and sparse willows.	30	0	0	0	-45	90	80	78	83	56	49	29	45	cottonwoods
SP-6	BLDR-17	low	Sparse willows with grassy streambanks, some decadent cottonwoods.	11	0	0	-45	90	95	108	82	95	40	50	39	43	cottonwoods
SP-7	BLDR-19	low	Sparse willows with grassy streambanks. Riparian clearing along river right for agriculture.	3	90	90	90	45	70	64	85	73	65	55	66	62	cottonwoods
SP-8	BLDR-20	low	Grassy streambanks with a few young willows.	3	-45	90	90	90	55	43	69	56	51	38	51	47	cottonwoods
SP-9	BLDR-22	low	Mature cottonwoods and willows.	21	0	0	0	0	62	64	81	69	57	40	48	48	cottonwoods
SP-10	BLDR-24	low	Willows, wetland vegetation and grass.	6	0	0	0	0	97	66	84	82	47	53	57	52	cottonwoods
SP-11	BLDR-26	low	Willows lining both banks with sparse cottonwoods on the floodplain.	2	45	0	45	0	58	56	55	56	54	38	37	43	cottonwoods
SP-12	BLDR-30	moderate	Willows lining both banks. Channel somewhat incised at site limiting floodplain access.	1	90	45	45	45	52	56	56	55	45	52	52	50	cottonwoods
SP-13	BLDR-31	high	Cottonwoods, junipers, and willows. Powerlines along river left bank.	9	90	90	90	90	53	66	51	57	44	62	45	50	cottonwoods

Attachment D

QUAL2K Model Calibration Inputs

Boulder-Elkhorn TMDL Planning Area

1. **QUAL2K**
    a. Model timeframe covers 3 days: July 24, 25, 26

2. **Headwater**
    a. Flow rate taken from BLDR-T01
    b. Temperature data taken from BLDR-T02
    c. Elevation based on the top of the impaired segment just upstream of Boulder
    d. Rating curve coefficients calculated using mean velocity and mean depth from August streamflow measurements at 21 sites and exponents based on typical values as presented in the QUAL2K guidance manual

3. **Downstream**
    a. No prescribed downstream boundary

4. **Reach**
    a. 33 reaches based on vegetation and aspect derived from GIS analysis of aerial imagery from 2009
    b. Reach stationing developed from the 1:24,000 NHD layer, with station 81.632km at the upper end of the study area and station 0.000km at the mouth
    c. Rating curve coefficients calculated using mean velocity and mean depth from August streamflow measurements at 21 sites and exponents based on typical values as presented in the QUAL2K guidance manual

5. **Reach Rates**
    a. N/A

6. **Air Temperature**
    a. Western Regional Climate Center, Whitehall, MT, averaged over 3 days (July 24-26)

7. **Due Point Temperature**
    a. Averaged over 3 days (July 24-26)
    b. Increased relative humidity data by 15% based on Big Hole assessment

8. **Wind Speed**
    a. Averaged over 3 days (July 24-26)

9. **Cloud Cover**
    a. Assumed to be 0%

10. **Shade**
    a. Solar pathfinder measurements were assigned to the reach in which they were located
    b. Riparian vegetation reach type average solar pathfinder values were assigned to reaches in which no measurement was performed
    c. Riparian vegetation reach types assessed in GIS using 2009 NAIP color aerial imagery (dense, moderate, and low riparian categories)
    d. Riparian vegetation reach type averages derived from field data based on the following criteria: dense (>30%), moderate (10-30%), and low (<10%)
    e. For shade scenario 1, all reaches assigned the average value for dense riparian vegetation (also applied in the natural conditions scenario)
    f. For shade scenario 2, low riparian reaches were assigned the average value for moderate riparian vegetation, while moderate riparian and dense riparian reaches were assigned the average value for dense riparian vegetation (also applied in the naturally occurring scenario)

11. **Rates**
    a. No adjustment to standard model assumptions

12. **Light and Heat**
    a. Utilized sediment thermal thickness of 10 cm and sediment thermal diffusivity of 0.005 cm^2/s

13. Diffuse Sources

a. Hydrologic balance performed between each streamflow measurement site
b. Irrigation loss assumed in five reaches, though actual diversions not observed in aerial imagery
c. Gains in streamflow documented in 10 reaches, with six assumed to be due to groundwater upwelling and spring flows, while the remaining four reaches were assumed to be surface water inputs
d. Groundwater inputs modeled at 11°C
e. Surface water inputs modeled at 15.19°C based on the temperature measured at BLDR-T06 (Little Boulder River)
f. Based on communication with MFWP Fisheries Biologist Ron Spoon (2/14/11), inflows in reaches BLDR27 through BLDR29 were primarily attributed to contributions from "Cold Springs" within reach BLDR27 and were modeled at 11°C
g. For the water consumptive use scenario and the natural condition scenario, diffuse abstractions were assumed to be zero
h. For the naturally occurring scenario, diffuse abstractions were reduced by 15%

14. Point Sources

a. 13 identified tributaries based on 1:100,000 NHD layer
b. two tributary streamflow measurements (Muskrat Creek/BLDR-T04a, Little Boulder River/BLDR-T06)
c. Elkhorn Creek (BLDR-T12) dry during August monitoring
d. all other tributaries assumed to be dry or intercepted by ditches
e. Temperature data from BLDR-T06 on the Little Boulder River applied to Muskrat Creek since the Muskrat Creek data logger lacked data from the July 24-26 timeframe
f. WWTP discharge based on flow/temperature data for August 2010
g. Inflow from point source with data logger BLDR-T17 modeled at temperature measured at BLDR-T06 since the BLDR-T17 data logger indicated groundwater influences
h. 20 identified diversions based on review of 2009 NAIP color aerial imagery
i. Measured abstractions from two diversions (BLDR-F01, BLDR-F02)
j. Hydrologic balance performed between each streamflow measurement site
k. If a loss in streamflow was identified in the hydrologic balance, then it was assumed that all of the lost flow was diverted for irrigation
l. If multiple diversions were present between streamflow measurement sites and a loss in streamflow was identified in the hydrologic balance, then the flow was divided evenly amongst the diversions
m. Modeled abstractions from 10 diversions based the on hydrologic balance
n. Irrigation withdrawals for the remaining diversions were modeled to be zero since no loss in streamflow was identified based on the hydrologic balance
o. For the water consumptive use scenario and the natural condition scenario, abstractions were assumed to be zero
p. For the water consumptive use scenario and the natural condition scenario, the inflow at station 40.355km was assumed to be zero since this is a potential irrigation return flow (BLDR-T17)
q. For the natural condition scenario, the WWTP input was removed
r. For the naturally occurring scenario, point source abstractions were reduced by 15%

15. Hydraulics Data

a. 21 streamflow measurements recorded between August 4-6
b. discarded flow measurement from BLDR-T17a since recorded on August 12

16. Temperature Data

a. 15 temperature measurements, averaged over 3 days (July 24-26)
b. Model not calibrated to BLDR-T21, appears site measures groundwater upwelling
c. BLDR-T21 was not included when evaluating model scenarios

Attachment E

RIPARIAN VEGETATION REACH TYPES

Boulder-Elkhorn TMDL Planning Area

Reach	Length (Kilometers)	Length (Miles)	Existing Shade	Shade Scenario 1	Shade Scenario 2
BLDR-01	2.2	1.4	low	dense	moderate
BLDR-02	1.8	1.1	low	dense	moderate
BLDR-03	0.8	0.5	low	dense	moderate
BLDR-04	0.9	0.6	low	dense	moderate
BLDR-05	1.3	0.8	low	dense	moderate
BLDR-06	1.0	0.6	low	dense	moderate
BLDR-07	2.6	1.6	moderate	dense	dense
BLDR-08	3.5	2.2	dense	dense	dense
BLDR-09	0.6	0.4	dense	dense	dense
BLDR-10	3.7	2.3	moderate	dense	dense
BLDR-11	0.5	0.3	moderate	dense	dense
BLDR-12	1.6	1.0	moderate	dense	dense
BLDR-13	1.5	1.0	moderate	dense	dense
BLDR-14	3.8	2.4	low	dense	moderate
BLDR-15	1.2	0.7	dense	dense	dense
BLDR-16	2.9	1.8	moderate	dense	dense
BLDR-17	2.6	1.6	low	dense	moderate
BLDR-18	2.1	1.3	low	dense	moderate
BLDR-19	4.9	3.0	low	dense	moderate
BLDR-20	1.8	1.1	low	dense	moderate
BLDR-21	2.8	1.7	low	dense	moderate
BLDR-22	1.9	1.2	low	dense	moderate
BLDR-23	6.2	3.8	low	dense	moderate
BLDR-24	4.8	3.0	low	dense	moderate
BLDR-25	1.8	1.1	low	dense	moderate
BLDR-26	4.7	2.9	low	dense	moderate
BLDR-27	1.2	0.7	low	dense	moderate
BLDR-28	4.7	2.9	low	dense	moderate
BLDR-29	2.5	1.6	low	dense	moderate
BLDR-30	1.2	0.7	moderate	dense	dense
BLDR-31	5.2	3.3	dense	dense	dense
BLDR-32	2.7	1.6	low	dense	moderate
BLDR-33	0.5	0.3	moderate	dense	dense

Attachment F

HYDROLOGIC BALANCE

Boulder-Elkhorn TMDL Planning Area

Reach	Temperature Data Logger Site	Measurement Date	Measured Discharge (cfs)	Modeled Discharge (cms)	Modeled Discharge (cfs)	Notes
1	BLDR-T01	8/4/2010	79.2	2.242	79.2	BLDR-T01
				0.491	17.3	Diversion 1 - irrigation loss (both sides of channel)
				1.751	61.8	flow at outlet of 1
2	BLDR-T02	8/4/2010	61.8	1.751	61.8	BLDR-T02
				0.004	0.1	WWTP discharge - gain
				0.105	3.7	gain
						Diversion 2 - irrigation loss
	BLDR-T03	8/4/2010	65.7	1.860	65.7	BLDR-T03
				1.860	65.7	flow at outlet of 2
				0.405	14.3	trib 1 - Muskrat Creek (BLDR-T04a on 8/12/10)
3				2.265	80.0	flow at outlet of 3
				0.156	5.5	gain
4	BLDR-T04	8/4/2010	85.5	2.421	85.5	BLDR-T04
				2.421	85.5	flow at outlet of 4
				0.238	8.4	gain
5	BLDR-T05	8/4/2010	93.9	2.659	93.9	BLDR-T05
				2.659	93.9	flow at outlet of 5
6				2.659	93.9	flow at outlet of 6
				0.742	26.2	trib 2 - Little Boulder River (BLDR-T06)
				0.347	12.3	loss
7	BLDR-T07	8/5/2010	107.8	3.053	107.8	BLDR-T07
						trib 3 - Farnham Creek
				0.097	3.4	loss
	BLDR-T08	8/5/2010	104.4	2.957	104.4	BLDR-T08
				2.957	104.4	flow at outlet of 7
						Diversion 3 - irrigation loss
				0.327	11.5	gain
8	BLDR-T09	8/5/2010	116.0	3.284	116.0	BLDR-T09
				0.357	12.6	Diversion 4 - irrigation loss (BLDR-F01)
				2.927	103.4	flow at outlet of 8
				0.048	1.7	gain
9	BLDR-T10	8/5/2010	105.1	2.975	105.1	BLDR-T10
				0.100	3.5	Diversion 5 (BLDR-F02)
				2.875	101.5	flow at outlet of 9
						Diversion 6 - irrigation loss
						Diversion 7 - irrigation loss
				0.613	21.6	gain
10	BLDR-T11	8/6/2010	123.2	3.488	123.2	BLDR-T11
				3.488	123.2	flow at outlet of 10
				0.000	0.0	trib 4 - Elkhorn Creek (BLDR-T12)
				0.213	7.5	loss
11	BLDR-T13	8/6/2010	115.6	3.274	115.6	BLDR-T13
				3.274	115.6	flow at outlet of 11
12				3.274	115.6	flow at outlet of 12
				0.224	7.9	loss
13	BLDR-T14	8/6/2010	107.7	3.050	107.7	BLDR-T14
				1.387	49.0	Diversion 8 - irrigation loss
				1.663	58.7	flow at outlet of 13
						trib 5 - Jack Creek
14				1.663	58.7	flow at outlet of 14
15				1.663	58.7	flow at outlet of 15
16	BLDR-T15	8/5/2010	58.7	1.663	58.7	BLDR-T15
				0.081	2.9	Diversion 9 - irrigation loss
						trib 6 - Dry Creek
						trib 7 - Quinn Creek
				1.582	55.9	flow at outlet of 16
				0.081	2.9	Diversion 10 - irrigation loss
17				1.501	53.0	flow at outlet of 17
				0.081	2.9	Diversion 11 - irrigation loss
18				1.419	50.1	flow at outlet of 18
19	BLDR-T16	8/6/2010	50.1	1.419	50.1	BLDR-T16
				0.460	16.2	Diversion 12 - irrigation loss
						trib 8 - Brady Creek
				0.960	33.9	flow at outlet of 19
				0.460	16.2	Diversion 13 - irrigation loss
				0.500	17.6	flow downstream of Diversion 13
	BLDR-T17a	8/12/2010	66.4	1.880	66.4	BLDR-T17a
				0.164	5.8	gain (BLDR-T17)
20	BLDR-T18	8/5/2010	23.4	0.664	23.4	BLDR-T18
				0.664	23.4	flow at outlet of 20
						Diversion 14 - irrigation loss
						trib 9 - Dunn Creek
21				0.664	23.4	flow at outlet of 21
						Diversion 15 - irrigation loss
				0.494	17.4	gain
22	BLDR-T19	8/5/2010	40.9	1.157	40.9	BLDR-T19
						Diversion 16 - irrigation loss
						Diversion 17 - irrigation loss
						trib 10 - Dry Cottonwood Creek
				1.157	40.9	flow at outlet of 22
				0.482	17.0	gain
23	BLDR-T20	8/6/2010	57.9	1.639	57.9	BLDR-T20
						trib 11 - McKanna Spring Creek
				1.639	57.9	flow at outlet of 23
				0.055	1.9	gain
24	BLDR-T21	8/6/2010	59.8	1.694	59.8	BLDR-T21
				1.694	59.8	flow at outlet of 24
						trib 12 - Cottonwood Creek
25				1.694	59.8	flow at outlet of 25
				0.061	2.2	loss
26	BLDR-T22	8/6/2010	57.7	1.633	57.7	BLDR-T22
				1.633	57.7	flow at outlet of 26
27				1.633	57.7	flow at outlet of 27
28				1.633	57.7	flow at outlet of 28
						trib 13 - Conrow Creek
				1.475	52.1	gain
29	BLDR-T23	8/6/2010	109.8	3.108	109.8	BLDR-T23
				3.108	109.8	flow at outlet of 29
30				3.108	109.8	flow at outlet of 30
				0.291	10.3	Diversion 18 - irrigation loss
				0.291	10.3	Diversion 19 - irrigation loss
				0.291	10.3	Diversion 20 - irrigation loss
31				2.234	78.9	flow at outlet of 31
32	BLDR-T24	8/5/2010	78.9	2.234	78.9	BLDR-T24
32				2.234	78.9	flow at outlet of 32
33				2.234	78.9	flow at outlet of 32