Madison Nutrient, *E. coli*, and Metal TMDLs and Water Quality Improvement Plan

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Steve Bullock, Governor
Shaun McGrath, Director DEQ

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Prepared by:
Water Protection Bureau
Watershed Protection Section

Contributors:
Water Protection Bureau
Watershed Protection Section
Lou Volpe, Metals Project Manager
Christina Staten, Project Coordinator
Dean Yashan, Section Supervisor
Jordan Tollefson, Previous *E. coli* and Nutrient Project Manager

Cover Photo:
O'Dell Spring Creek near Ennis, MT
Photo by: Montana Department of Environmental Quality

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

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Definition
µg/L	Microgram per Liter
AAL	Acute Aquatic Life
AFDM	Ash-Free Dry Mass
AL	Aquatic Life
ARM	Administrative Rules of Montana
AUM	Animal Unit Month
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practice
CAAP	Concentrated Aquatic Animal Production
CAL	Chronic Aquatic Life
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfu	Colony Forming Units
Cu	Copper
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
EPA	Environmental Protection Agency (U.S.)
EQIP	Environmental Quality Incentives Program
Fe	Iron
FWP	Fish, Wildlife & Parks (Montana)
g/m^2	Gram per Meter Squared
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HUC	Hydrologic Unit Code
IR	Integrated Report (Montana Water Quality)
LA	Load Allocation
lbs/day	Pounds per Day
MARS	Montana Aquatic Resources Services, Inc.
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
Mcfu/day	Million Colony Forming Units per Day
MEANSS	Method for Estimating Attenuation of Nutrients from Septic Systems
mg/m^2	Milligram per Meter Squared
mg/kg	Milligram per Kilogram
mg/L	Milligram per Liter
mL	Milliliter
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
N	Nitrogen
N/A	Not Applicable

Acronym or Abbreviation	**Definition**
ND	Non-detect
NHD	National Hydrography Dataset
NO_3+NO_2	Nitrate + Nitrite
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service (U.S. Dept. of Agriculture)
P	Phosphorus
Pb	Lead
PEL	Probable Effects Levels
RIT/RDG	Resource Indemnity Trust / Reclamation and Development Grants Program
Se	Selenium
SMCRA	Surface Mining Control & Reclamation Act
SME	Small Miner Exclusion
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area (Madison)
TR	Total Recoverable
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan

DOCUMENT SUMMARY

This document presents total maximum daily loads (TMDLs) and a water quality improvement plan for five impaired tributaries of the Madison River including: Elk Creek, Hot Springs Creek, Moore Creek, O'Dell Spring Creek, and South Meadow Creek.

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 Madison TMDL Planning Area (TPA) follows the mainstem of the Madison River from the Wyoming border near West Yellowstone to the river's mouth near Three Forks, encompassing approximately 2,583 square miles (1,653,311 acres) and includes the watersheds of tributary streams draining directly to the Madison River. The planning area includes portions of Madison and Gallatin counties (**Figure 1-1)**.

DEQ determined that five tributaries of the Madison River do not meet the applicable water quality standards for nutrients, *E. coli* and metals, and 15 TMDLs are included in this document (**Table DS-1**) that address 16 pollutant impairments. Although DEQ recognizes that there are other pollutant listings for this planning area, this document addresses only nutrient, *E. coli* and metals pollutant impairments.

Nutrients
Nine nutrient TMDLs are provided for five streams in the Madison TPA (**Table DS-1**), addressing the following pollutant and non-pollutant impairments: nitrate/nitrite, total nitrogen and total phosphorus in Elk Creek; total nitrogen and total phosphorus in Hot Springs Creek; total nitrogen and total phosphorus in Moore Creek; total nitrogen in O'Dell Spring Creek; and total nitrogen, total phosphorus, and chlorophyll-*a* in South Meadow Creek.

Nutrient and/or biological data in these streams indicate nutrients are present in concentrations that can cause algal growth that harms recreation and aquatic life beneficial uses. Water quality restoration goals for nutrients are based on Montana's numeric nutrient criteria, measures of algal growth/density, and biological metrics for macroinvertebrates and periphyton. DEQ's water quality assessment methods for nutrient impairment are designed to evaluate the most sensitive use, thus ensuring protection of all designated uses. For streams in western Montana, the most sensitive uses assessed for nutrients are aquatic life and primary contact recreation.

Nutrient loading in the Madison TPA is attributable to two source categories: natural sources such as local geology and the effects of natural events such as flooding and wildland fires; and human-caused nonpoint sources dispersed across the landscape from agriculture, residential development and subsurface wastewater disposal and treatment, historical mining, and timber harvest. Total nitrogen reductions needed to meet the TMDLs range from 0 to 57%; total phosphorus reductions needed range from 0 to 72%. Implementing the recommended best management practices for nonpoint sources identified in this plan are anticipated to achieve the reduction goals and meet the TMDLs.

E. coli

One *E. coli* TMDL is provided for one waterbody in the Madison TPA: Moore Creek. Elevated concentrations of *E. coli* can put humans at risk for contracting water-borne illnesses. Elevated instream concentrations of *E. coli* and other pathogenic pollutants can lead to impairment of a waterbody's primary contact recreation beneficial use. DEQ's water quality assessment methods for *E. coli* impairment are designed to evaluate the most sensitive use, thus ensuring protection of all designated uses. For streams in Montana, the most sensitive use assessed for *E. coli* is primary contact recreation. Water quality restoration goals for *E. coli* are established based on Montana's numeric water quality standards.

E. coli loading in the Madison TPA is attributable to both naturally-occurring and human-caused sources. The primary naturally occurring source of *E. coli* is wildlife excrement; the primary human-caused sources include agricultural practices and failing or malfunctioning septic systems. An *E. coli* reduction of 87% is needed in Moore Creek to meet the TMDL. Recommended strategies for achieving the *E. coli* water quality standards include improving septic wastewater conveyance and treatment systems, and implementing agricultural practices that limit *E. coli* from entering surface waters.

Metals

Five metals TMDLs are provided for three streams in the Madison TPA (**Table DS-1**) for: iron and selenium in Elk Creek, iron and lead in Hot Springs Creek, and copper in South Meadow Creek. Elevated concentrations of metals may impair the support of multiple beneficial uses for a waterbody. Elevated concentrations of metals can have a toxic, carcinogenic, or bioconcentrating effect on biota within aquatic ecosystems, and humans and wildlife can suffer acute and chronic effects from consuming water or fish with elevated metals concentrations. DEQ's water quality assessment methods for metals impairments are designed to evaluate the most sensitive use, thus ensuring protection of all designated uses. For metals, the most sensitive uses are drinking water and aquatic life. For the TMDLs in this document, aquatic life was the most sensitive use.

Water quality restoration goals for metals are established based on numeric water quality criteria defined in Montana's numeric water quality standards. DEQ believes that once these water quality goals are met, all water uses currently identified as being affected by metals will be restored.

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. This plan includes a monitoring strategy designed to track progress in meeting TMDL objectives and goals and to help refine the plan during its implementation

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Madison TMDL Planning Area with Completed TMDLs Contained in this Document

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Iron	Metals	Aquatic Life
		Selenium	Metals	Aquatic Life
		Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Nutrients	Aquatic Life, Primary Contact Recreation
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Iron	Metals	Aquatic Life
		Lead	Metals	Aquatic Life
		Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Nutrients	Aquatic Life, Primary Contact Recreation
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	*E. coli*	Pathogens	Primary Contact Recreation
		Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Nutrients	Aquatic Life, Primary Contact Recreation
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Total Nitrogen	Nutrients	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Nutrients	Aquatic Life, Primary Contact Recreation
		Copper	Metals	Aquatic Life

1.0 PROJECT OVERVIEW

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for nutrient, *Escherichia coli* (*E. coli*), and metals problems in the Madison TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Figure 1-1** shows a map of the Madison River watershed; the TMDL planning area, however, only encompasses the portion of the watershed within the state of Montana.

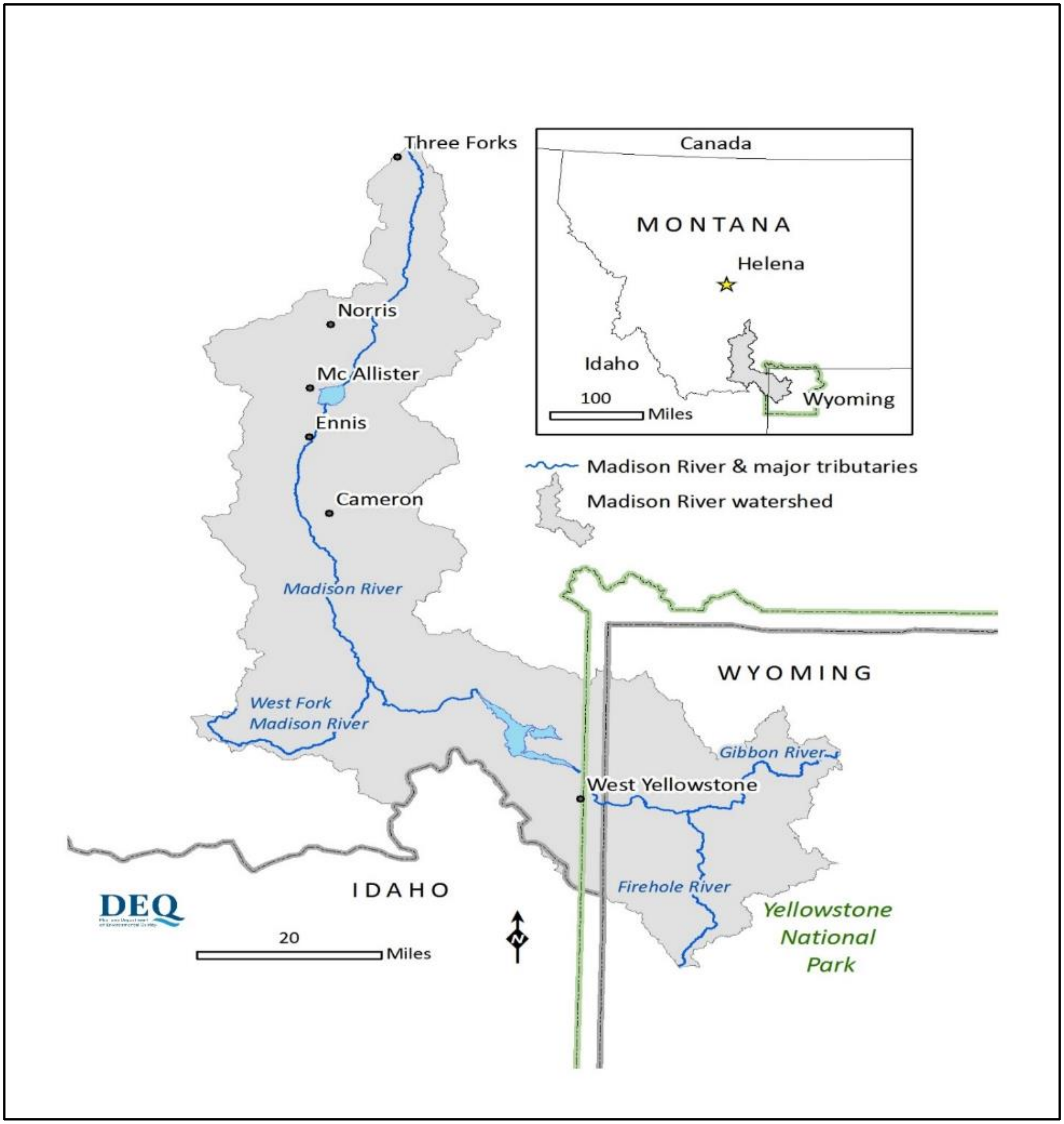

Figure 1-1. Location of Madison River Watershed

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 only the waterbody segments impaired by a pollutant, which require a TMDL; whereas TMDLs are not required for non-pollutant causes of impairments. **Tables 1-1** and **1-2** identify all impaired waters for the Madison TPA from Montana's 2016 303(d) List, and includes non-pollutant impairment causes included in Montana's "2016 Water Quality Integrated Report" (Montana Department of Environmental Quality, Water Quality Division, Water Quality Planning Bureau 2016). **Tables 1-1** and **1-2** provide the status of each impairment cause, identifying whether it has been addressed by TMDL development.

Additionally, waterbodies that have been monitored by the state are also referred to as "assessment units." Assessment units can be the full length of a stream or the full extent of a lake or reservoir, or they may be a portion of a stream (a stream segment) or lake. Streams may be broken into individual segments, determined by a variety of factors such as stream length for very long streams, or lakes may be broken by ownership boundaries (tribal versus state, for example). Due to its length and multiple dam impoundments, the Madison River has three assessment units / three stream segments (see **Table 1-2** below).

Both Montana state law (Section 75-5-701, Montana Code Annotated of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of TMDLs 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 (i.e., 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 8.0** and **9.0** 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 the impairment causes from the "2016 Water Quality Integrated Report" (Montana Department of Environmental Quality, Water Quality Division, Water Quality Planning Bureau 2016) that are addressed in this document. Each pollutant impairment falls within a TMDL pollutant category of nutrients, *E. coli*, or metals, and this document is organized by those categories.

TMDLs are completed for each waterbody – pollutant combination, and this document contains 15 TMDLs that address 16 pollutant impairments (**Table 1-1**). Additionally, one non-pollutant type of impairment is addressed by nutrient TMDLs this document: chlorophyll-*a* in South Meadow Creek (**Table 1-1**).

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

Waterbody (Assessment Unit)[1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category	Impairment Cause Status[2]
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Addressed by TN TMDL
		Nitrogen (Total)	Nutrients	TN TMDL completed
		Phosphorus (Total)	Nutrients	TP TMDL completed
		Iron	Metals	Iron TMDL completed
		Selenium	Metals	Selenium TMDL completed
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Iron	Metals	Iron TMDL completed
		Lead	Metals	Lead TMDL completed
		Nitrogen (Total)	Nutrients	TN TMDL completed
		Phosphorus (Total)	Nutrients	TP TMDL completed
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Escherichia coli	Pathogens	*E. coli* TMDL completed
		Nitrogen (Total)	Nutrients	TN TMDL completed
		Phosphorus (Total)	Nutrients	TP TMDL completed
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Nitrogen (Total)	Nutrients	TN TMDL completed

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

Waterbody (Assessment Unit)[1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category	Impairment Cause Status[2]
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Nitrogen (Total)	Nutrients	TN TMDL completed
		Phosphorus (Total)	Nutrients	TP TMDL completed
		Chlorophyll-*a*	Not Applicable; Non-Pollutant	Addressed by TN TMDL
		Copper	Metals	Copper TMDL completed

[1] All assessment units within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD).
[2] TN = Total Nitrogen, TP = Total Phosphorus, NO_2+NO_3 = Nitrite + Nitrate

1.3 Non-Pollutant Impairments

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. DEQ recognizes that non-pollutant impairments can limit a waterbody's ability to fully support all beneficial uses and these impairment causes are important to consider when improving water quality conditions in individual streams, and the Madison TMDL Planning Area as a whole. The non-pollutant impairments "chlorophyll-*a*" for South Meadow Creek and "excess algal growth" for Blaine Spring Creek (**Table 1-2**) are discussed in this section to increase awareness of the non-pollutant impairment definitions and typical sources, and should be considered during planning of watershed-scale restoration efforts.

"Chlorophyll-*a*" and "excess algal growth" impairments occur when excess levels of chlorophyll-*a* or algae in the stream impair aquatic life and/or primary contact recreation (Suplee et al., 2009). "Excess algal growth" refers to the often visual identification of impairment from phytoplankton/algal growth, while "chlorophyll-*a*" is a direct measure of plant productivity. These high levels of chlorophyll-*a* or algae are caused by excess concentrations of nutrients in the stream, which increases algal biomass (Suplee and Sada de Suplee, 2011). "Chlorophyll-*a*" impairments are typically addressed by nutrient TMDLs.

The chlorophyll-a impairment for South Meadow Creek is addressed by the total nitrogen and total phosphorous TMDLs contained in **Section 5.0** of this document. The "excess algal growth impairment for Blaine Spring Creek is not addressed through TMDLs in this document. A significant portion of nutrient loading to Blaine Spring Creek is naturally occurring (**Section 5.6.2.2**), and as such, no nutrient TMDLs were developed for Blaine Spring Creek. The algal growth impairment may be addressed through future water quality restoration planning that could include additional monitoring and/or possible TMDL development if nutrient impairment is found from sources other than those that are considered naturally occurring.

The monitoring and restoration strategies in **Sections 8.0** and **9.0** are presented to address both pollutant and non-pollutant issues for streams in the Madison TPA with TMDLs in this document, and they are equally applicable to streams listed for non-pollutant impairment causes. The strategies also apply to the entire Madison River watershed.

1.4 Future TMDL Development

Although DEQ recognizes that there are other pollutant listings for the Madison TMDL Planning Area without completed TMDLs (**Table 1-2**), this document only addresses those identified in **Table 1-1**. This is because DEQ sometimes develops TMDLs in a watershed at varying phases, with a focus on one or a few specific pollutant types.

The Madison River and many of its tributaries have sediment and temperature impairments (**Table 1-2**) that will be addressed through future TMDL development efforts. Related non-pollutant impairments of "alterations in stream-side or littoral vegetative covers," "low flow alterations," "other anthropogenic substrate alterations," and "physical substrate habitat alterations" for these waterbodies (**Table 1-**2) will either be addressed by sediment and temperature TMDLs or discussed in a future TMDL document. Additionally, nine waterbodies are included in the 2016 Integrated Report as impaired for arsenic (**Table 1-2**); however, sources are considered to be predominately natural (further discussed in **Section 7.4.3**).

Table 1-2. Water Quality Impairment Causes for the Madison to be Addressed in a Future Project

Waterbody (Assessment Unit)[1]	Waterbody ID (Assessment Unit ID)	Impairment Cause[2]	Pollutant Category
Antelope Creek, Headwaters to mouth (Cliff Lake)	MT41F004_140	Sediment/Siltation	Sediment
		Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant
		Low flow alterations	Not Applicable; Non-Pollutant
Bear Creek, Headwaters to mouth (O'Dell Spring Creek)	MT41F004_021	Sediment/Siltation	Sediment
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Sediment/Siltation	Sediment
		Excess Algal Growth	Not Applicable; Non-Pollutant
		Low flow alterations	Not Applicable; Non-Pollutant
		Arsenic	Metals
		Total Nitrogen	Nutrients
Buford Creek, Headwaters to confluence with West Fork Madison River	MT41F004_150	Arsenic	Metals
Cherry Creek, Headwaters to mouth (Madison River)	MT41F002_010	Sedimentation/Siltation	Sediment
		Temperature, water	Temperature

Table 1-2. Water Quality Impairment Causes for the Madison to be Addressed in a Future Project

Waterbody (Assessment Unit)[1]	Waterbody ID (Assessment Unit ID)	Impairment Cause[2]	Pollutant Category
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant
		Arsenic	Metals
		Turbidity	Not Applicable; Non-Pollutant
		Sedimentation/Siltation	Sediment
		Temperature, water	Temperature
Ennis Lake	MT41F005_030	Arsenic	Metals
		Low flow alterations	Not Applicable; Non-Pollutant
		Other anthropogenic substrate alterations	Not Applicable; Non-Pollutant
		Physical substrate alterations	Not Applicable; Non-Pollutant
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Sediment/Siltation	Sediment
		Low flow alterations	Not Applicable; Non-Pollutant
Indian Creek, Lee Metcalf Wilderness boundary to mouth (Madison River)	MT41F004_040	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant
		Low flow alterations	Not Applicable; Non-Pollutant
Jack Creek, Headwaters to mouth (Madison River, T5S R1W S23)	MT41F004_050	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant
		Low flow alterations	Not Applicable; Non-pollutant
Madison River, Hebgen Dam to Quake Lake	MT41F001_030	Arsenic	Metals
Madison River, Quake Lake to Ennis Lake	MT41F001_020	Arsenic	Metals
Madison River, Ennis Dam to mouth (Missouri River)[3]	MT41F001_010	Arsenic	Metals
		Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant
		Sedimentation/Siltation	Sediment
		Temperature, water	Temperature
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Arsenic	Metals
		Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant
		Sedimentation/Siltation	Sediment
		Temperature, water	Temperature
North Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_060	Low flow alterations	Not Applicable; Non-pollutant
		Sedimentation/Siltation	Sediment

Table 1-2. Water Quality Impairment Causes for the Madison to be Addressed in a Future Project

Waterbody (Assessment Unit)[1]	**Waterbody ID (Assessment Unit ID)**	**Impairment Cause**[2]	**Pollutant Category**
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Arsenic	Metals
		Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant
		Other anthropogenic substrate alterations	Not Applicable; Non-Pollutant
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant
Red Canyon Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant
		Low flow alterations	Not Applicable; Non-pollutant
		Sedimentation/Siltation	Sediment
Ruby Creek, Headwaters to mouth (Madison River)	MT41F004_080	Low flow alterations	Not Applicable; Non-Pollutant
		Sedimentation/Siltation	Sediment
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Sedimentation/Siltation	Sediment
Watkins Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_030	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant
		Low flow alterations	Not Applicable; Non-pollutant
		Sedimentation/Siltation	Sediment
Wigwam Creek, Headwaters to mouth (Madison River)	MT41F004_160	Sedimentation/Siltation	Sediment
West Fork Madison River, Headwaters to mouth (Madison River)	MT41F004_100	Low flow alterations	Not Applicable; Non-Pollutant
		Temperature, water	Temperature

[1] All assessment units within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD)
[2] Impairment causes contained in the 2016 Water Quality Integrated Report
[3] The waterbody location description for MT41F001_010 provides an incorrect name for the dam; the correct name is the Madison Dam. The waterbody location description will be corrected in the 2018 Water Quality Integrated Report.

1.5 What This Document Contains

This document addresses all 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, and additional technical details are contained in **Appendices A** and **B**. In addition to this introductory section, this document includes:

Section 2.0 Madison TMDL Planning Area Description:
Describes the physical characteristics and social profile of the Madison River watershed and the Madison TMDL Planning Area.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the Madison River watershed.

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

Sections 5.0 – 7.0 Nutrients, *E. coli*, and Metals 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 Water Quality Improvement Plan:
Discusses water quality restoration objectives and a strategy to meet the identified objectives and TMDLs.

Section 9.0 Monitoring for Effectiveness:
Describes a water quality monitoring plan for evaluating the long-term effectiveness of the "Madison Nutrient, *E. coli*, and Metal TMDLs and Water Quality Improvement Plan."

Section 10.0 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.

2.0 Madison TMDL Planning Area Description

This section describes the physical, ecological, and social characteristics of the Madison TMDL Planning Area, which encompasses the portion of the Madison River watershed within the state of Montana. These descriptions provide a context for the more detailed pollutant source assessments presented in **Sections 5.0 – 7.0**.

2.1 Physical Characteristics

The following information describes the physical geography of the planning area. This includes location, climate, hydrology, and geology.

2.1.1 Location

The Madison TMDL Planning Area follows the mainstem of the Madison River from the Wyoming border near West Yellowstone to the river's mouth near Three Forks. The area includes the watersheds of many tributary streams draining directly to the Madison River. The planning area encompasses approximately 2,583 square miles (1,653,311 acres) in western Montana, and includes portions of Madison and Gallatin counties (**Figure 1-1)**.

2.1.2 Topography

The topography is mapped below in **Figure 2-1**. Elevation ranges from 11,316 feet (Hilger Peak) in the Madison Range to 4,040 feet at the confluence with the Jefferson River.

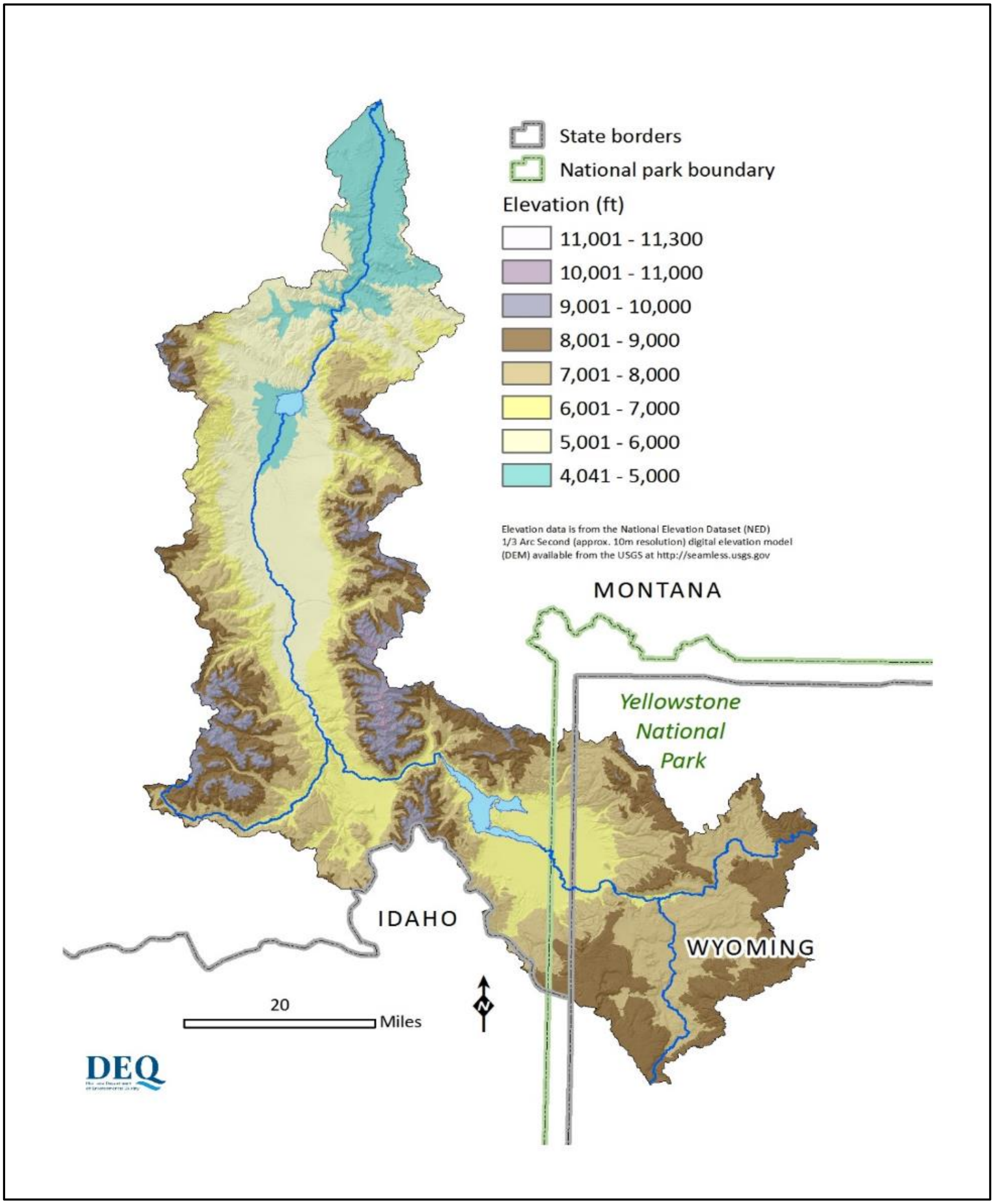

Figure 2-1. Topography of the Madison River Watershed

2.1.3 Climate

The TMDL planning area is large, and there is a measurable gradient in climate along its length. This is well illustrated by considering average precipitation and temperature. Average precipitation along the

Madison River corridor ranges from just over 24 inches per year near West Yellowstone to 11 inches per year at Three Forks, according to 30-year average precipitation data (http://prism.oregonstate.edu/explorer/). May and June are consistently the wettest months of the year, and winter precipitation is dominated by snowfall according to climate summaries of West Yellowstone and Ennis provided by the Western Regional Climate Center (http://www.wrcc.dri.edu/summary/Climsmnidwmt.html). Average annual precipitation is mapped below in **Figure 2-2**.

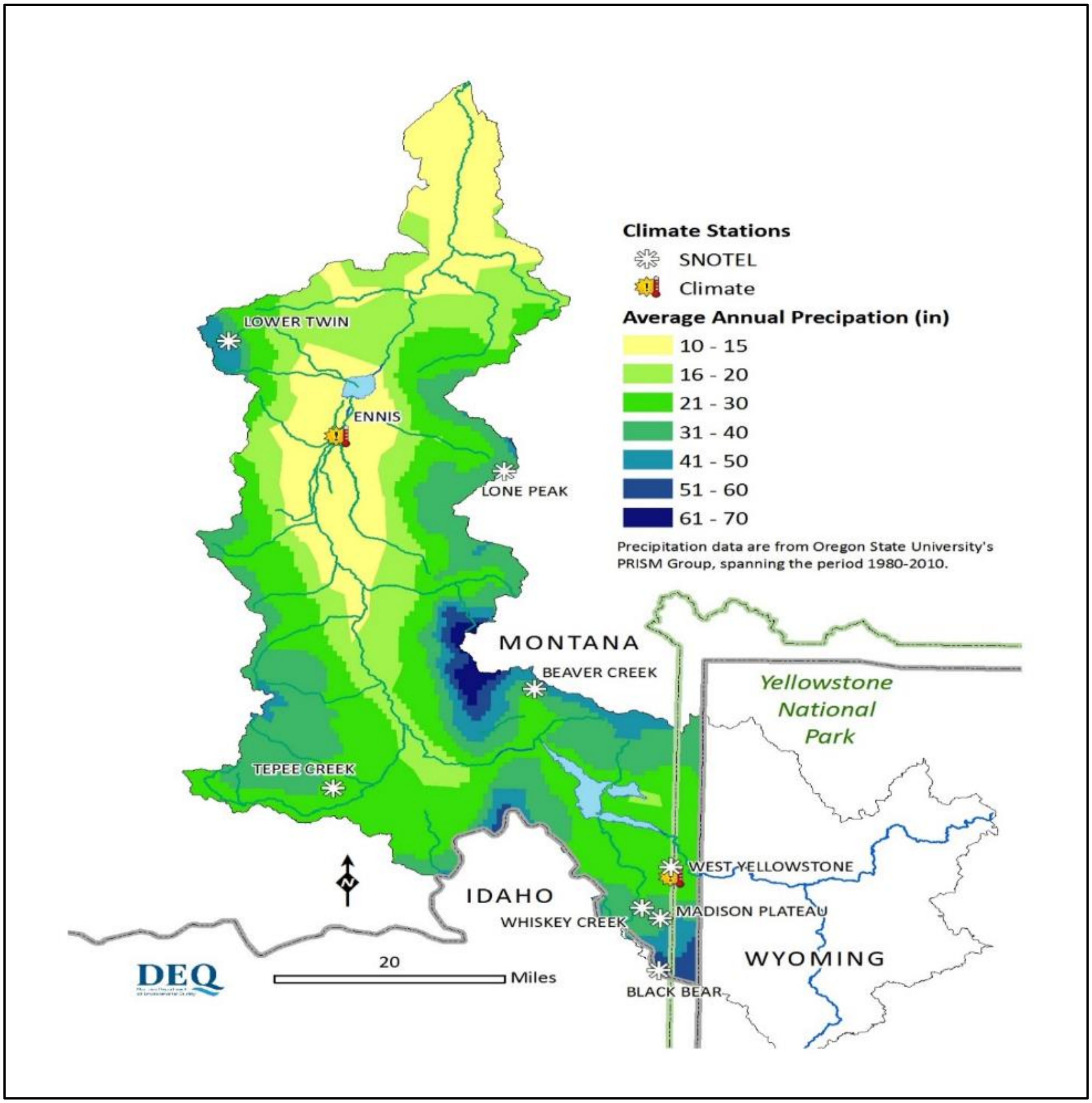

Figure 2-2. Average annual precipitation of the Madison TMDL Planning Area

The Madison Valley is a mid-elevation intermontane basin typified by cold winters and mild summers (Kendy and Tresch, 1996 1328). Precipitation is greater and average temperatures are lower in the higher-elevation valley around Hebgen Lake and West Yellowstone. Average annual temperatures are mapped below in **Figure 2-3**.

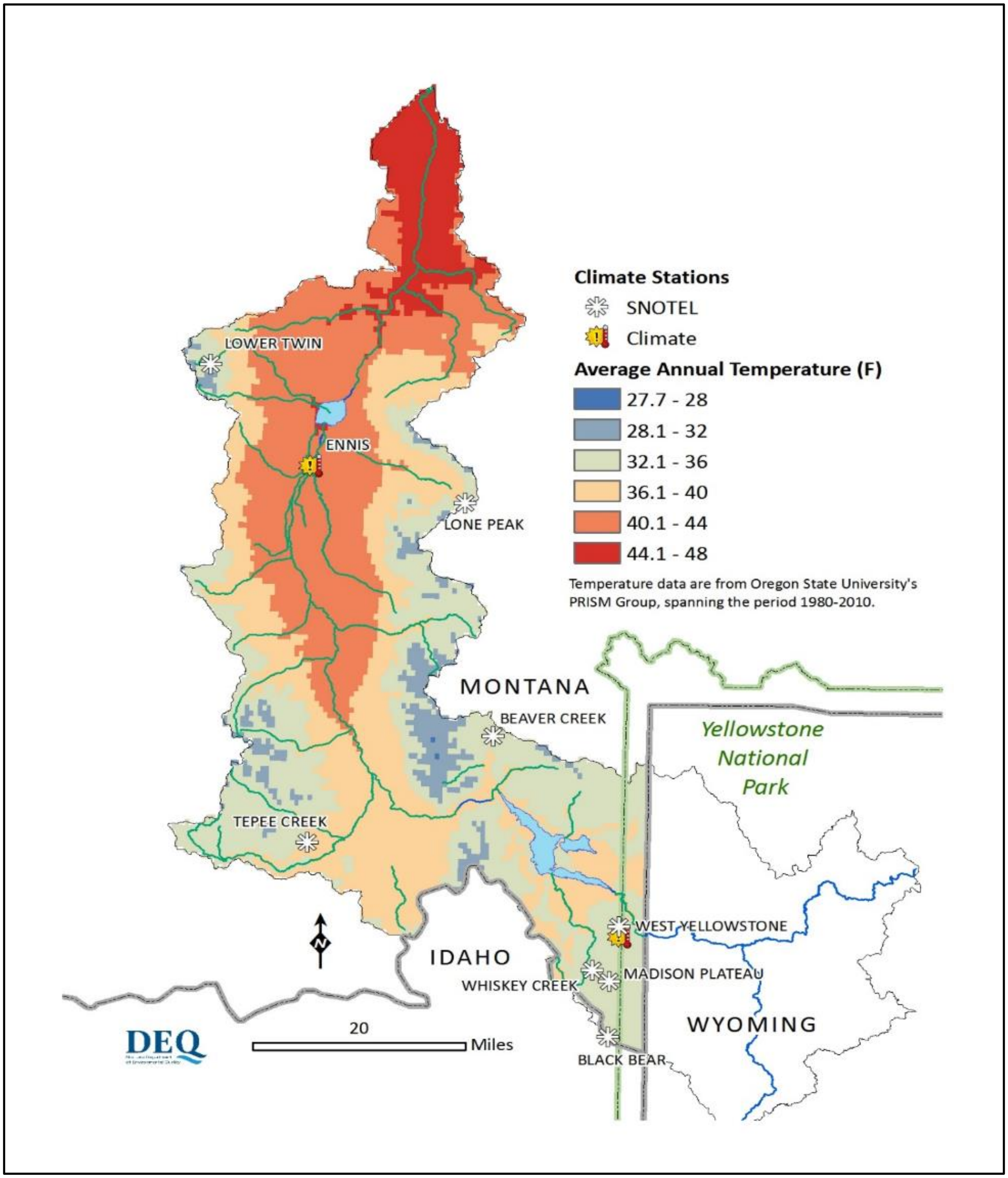

Figure 2-3. Average annual temperatures in the Madison TMDL Planning Area

2.1.4 Hydrology

The Madison River is one of the three forks of the Missouri River, which begins at the confluence of the Madison and Jefferson Rivers. The third fork, the Gallatin River, drains into the Missouri River a short distance below, at Three Forks. The Madison River begins at the confluence of the Firehole and Gibbon rivers in Yellowstone National Park in Wyoming. The drainage in the planning area is characterized by the mainstem of the Madison River and its tributary watersheds, mapped below in **Figure 2-4**. The Madison River is a 6th order stream at the outlet of Hebgen Dam. The major tributaries tend to be 3rd and 4th order streams.

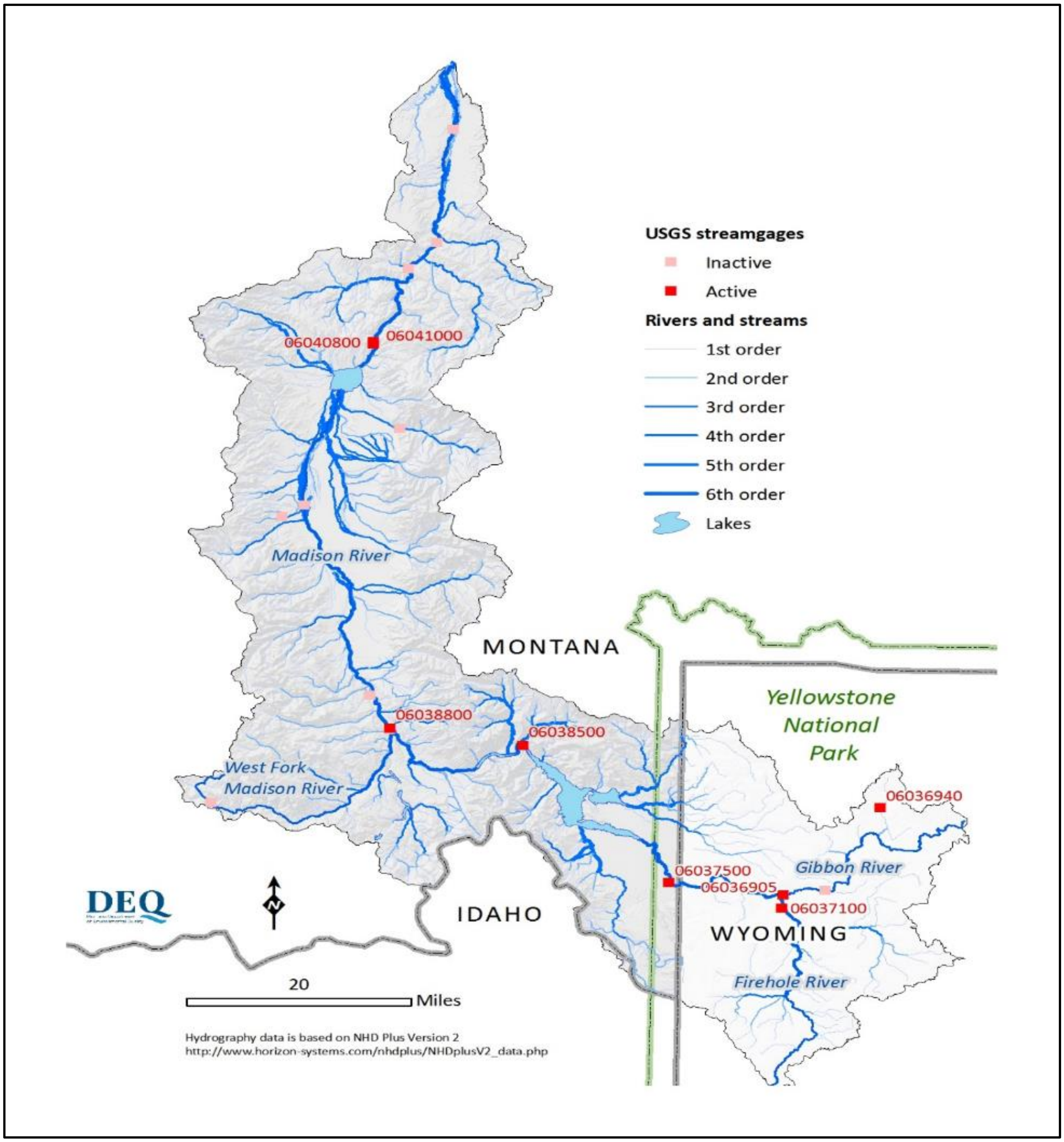

Figure 2-4. Hydrography of the Madison River Watershed

The tributary streams generally are not monitored by USGS gaging stations. Their streamflow generally follows a hydrograph typical for the region, highest in May and June. These are the months with the greatest amount of precipitation and snowmelt runoff. Streamflow begins to decline in late June or early July, reaching minimum flow levels in September when many streams go dry. Streamflow begins to rebound in October and November when fall storms supplement the base-flow levels.

2.1.5 Geology and Soils

The TMDL planning area is large and the geology is varied (**Figure 2-5**). Bedrock is dominated by Precambrian metamorphic rocks, with significant areas of Paleozoic and Mesozoic sedimentary rocks. Upstream of the planning area, in Wyoming, the watershed headwaters are underlain by mainly rhyolitic volcanic rocks of the Yellowstone caldera.

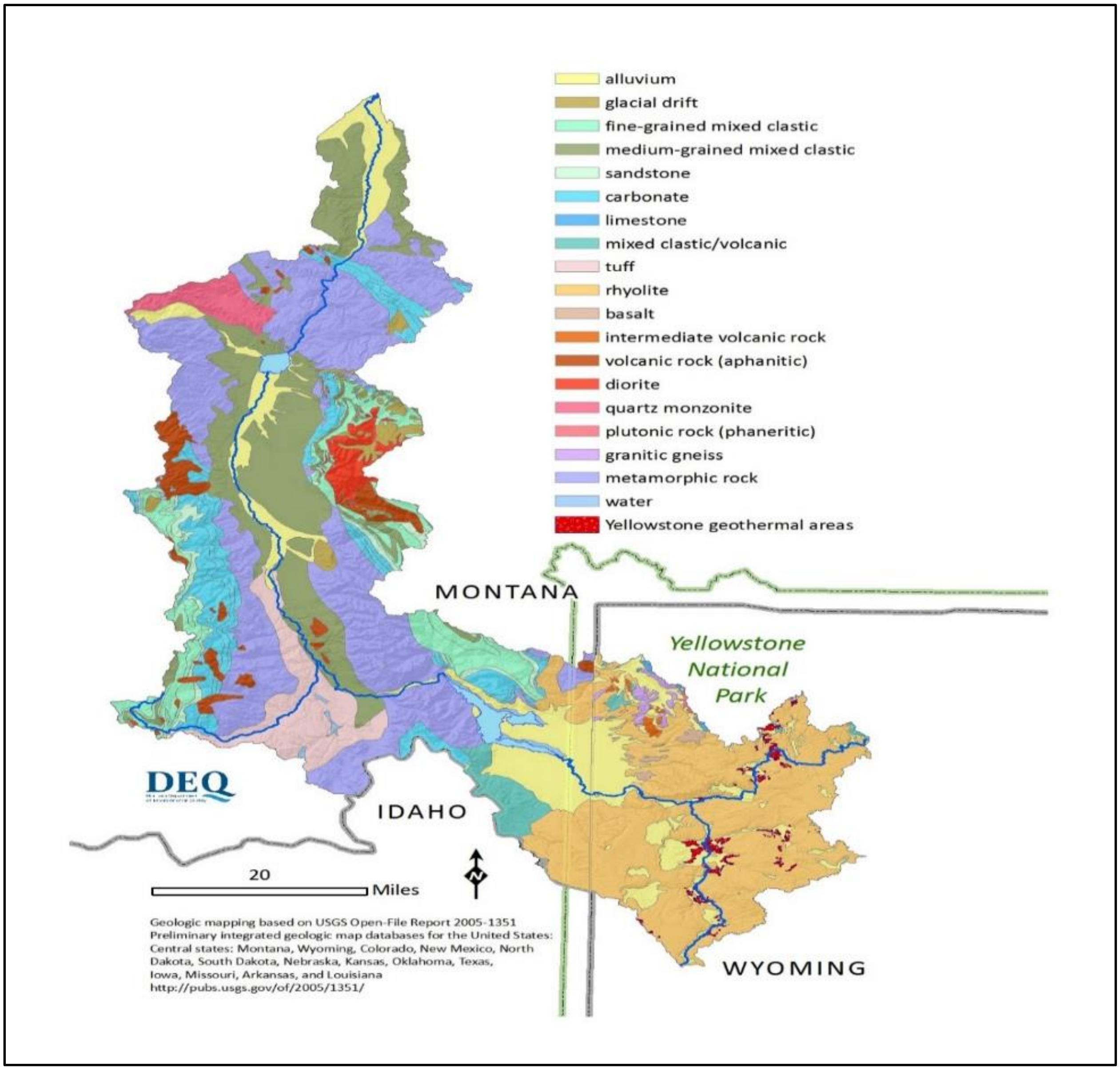

Figure 2-5. Generalized Geology of the Madison River Watershed

The USGS Water Resources Division (Schwartz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the USDA Natural Resources Conservation Service (NRCS) State Soil Geographic (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. It is important to realize, therefore, 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.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier & 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 below in **Figure 2-6**, 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. Despite the steep and rugged topography, the majority of the planning area is mapped with soils rated as having low and moderate-low erodibility. Soils mapped with moderate-high erodibility are largely found along the margin of the Gravelly Range. No values greater than 0.34 are mapped in the planning area.

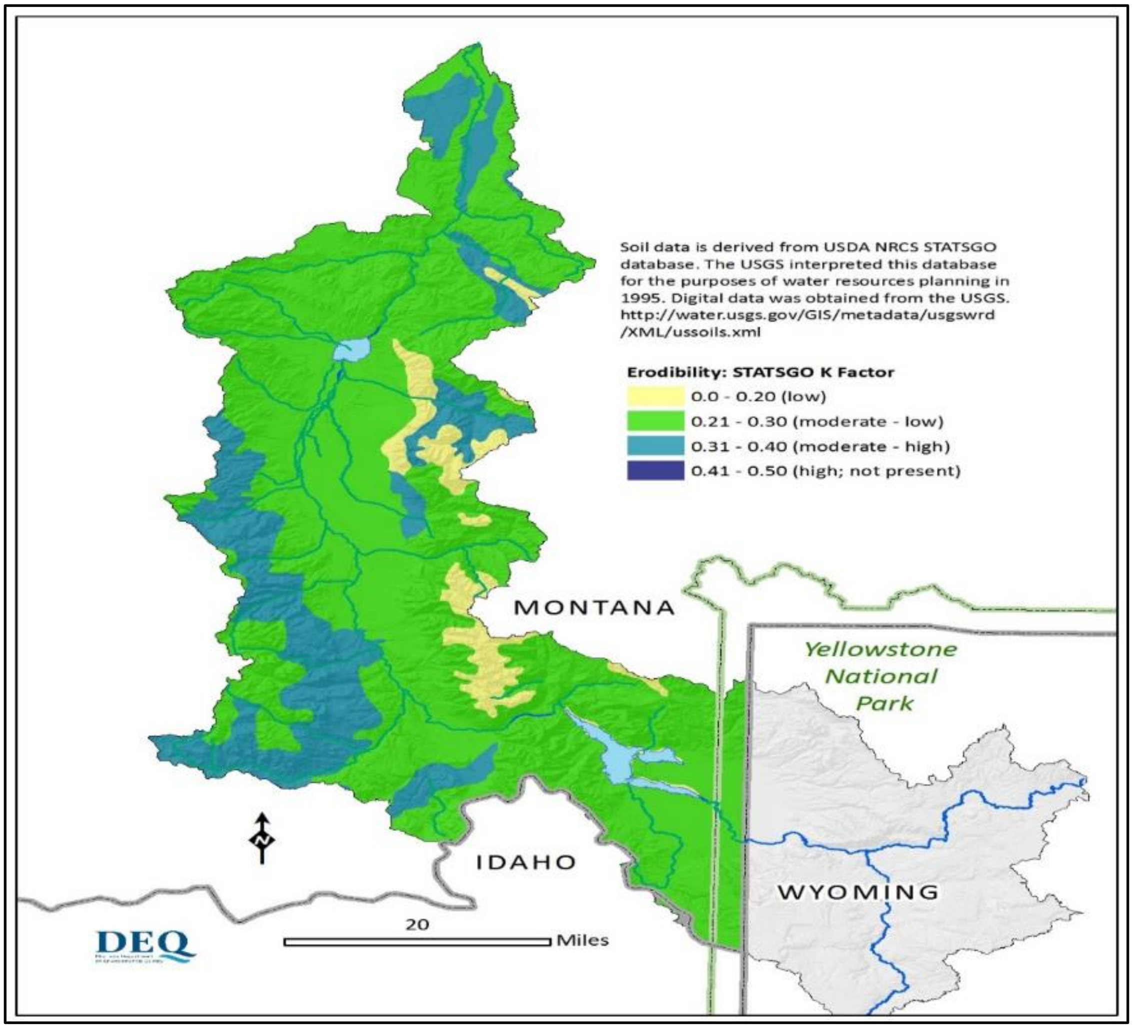

Figure 2-6. Soil erodibility of the Madison TMDL Planning Area

2.2 Ecological Profile

This section describes the ecology of the TMDL planning area, including the ecoregions mapped within it, land cover, fire history, and fish species of concern.

2.2.1 Ecoregions

The project is located within the Middle Rockies Level III Ecoregion (Woods, et al., 2002). Twelve Level IV ecoregions are mapped within the planning area. The Level IV Ecoregions are mapped below in **Figure 2-7**. More detailed information about the ecoregions is available on the Internet at: http://www.epa.gov/wed/pages/ecoregions/mt_eco.htm.

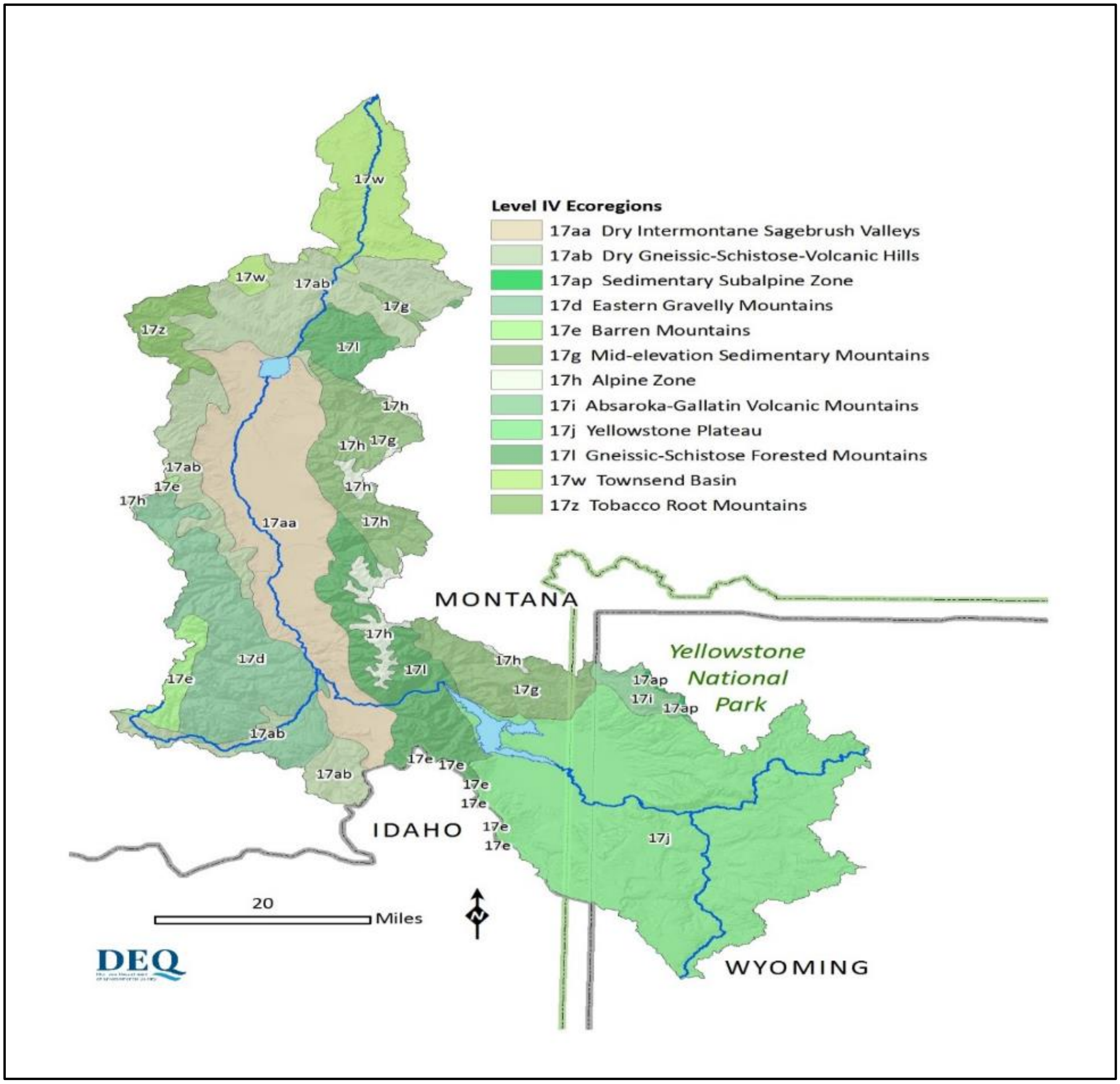

Figure 2-7. Level IV ecoregions in the Madison River Watershed

2.2.2 Land Cover

Land cover is mapped below in **Figure 2-8**, based on the USGS National Land Cover Dataset or NLCD (https://catalog.data.gov/dataset/usgs-national-land-cover-dataset-nlcd-downloadable-data-collection). As apparent in this figure, the planning area is dominated by evergreen forest in the uplands, and herbaceous and shrub/scrub cover in the lowlands. Development is largely limited to the larger communities of Ennis and West Yellowstone

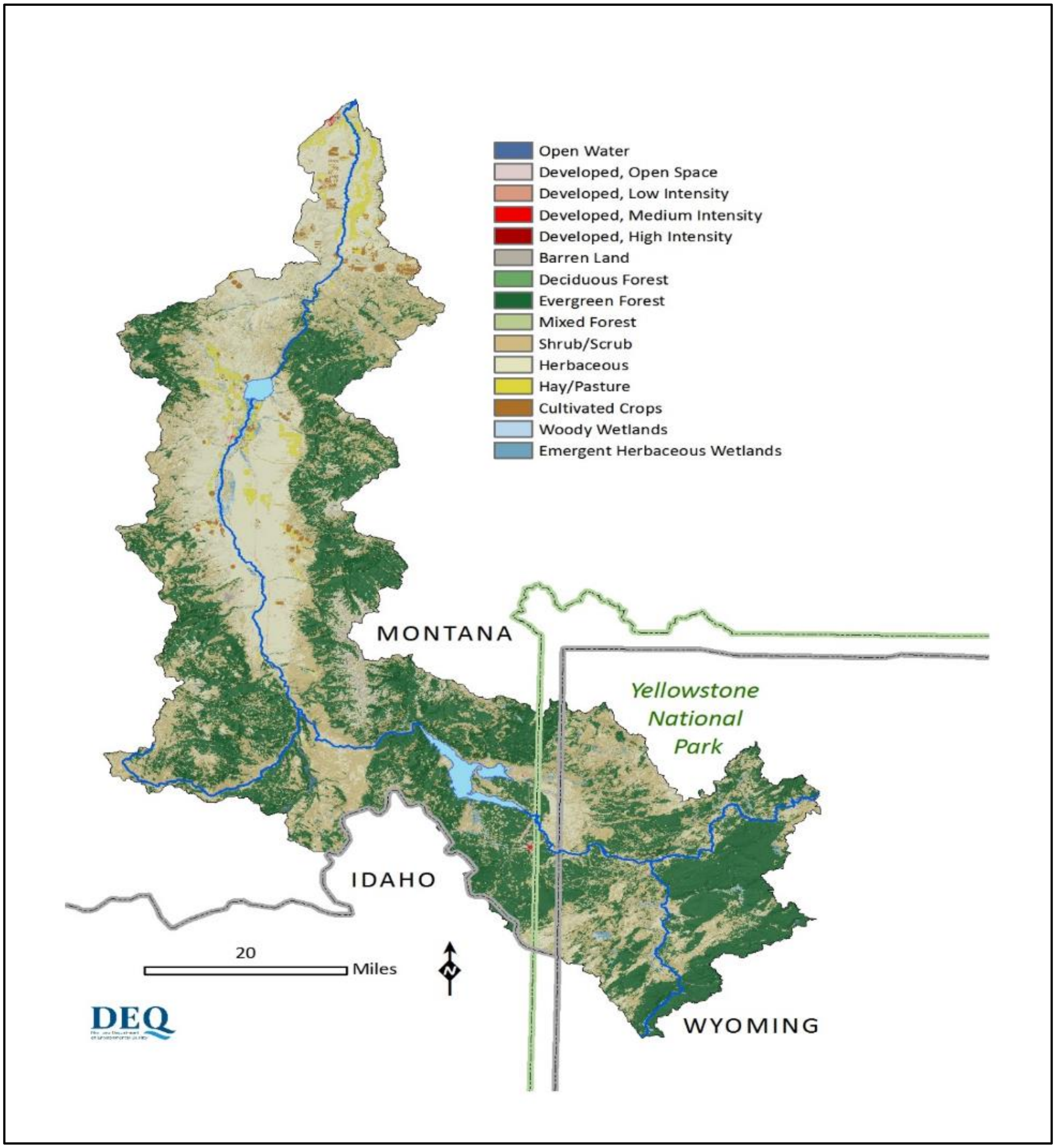

Figure 2-8. Land cover in the Madison River Watershed

2.2.3 Fire History

Recent fire history (1985-2013) is mapped below in **Figure 2-9**. Minor regions of the planning area burned within the last 10 years. The largest fire of recent years was the Beartrap Fire of 2012, which burned approximately 15,000 acres. Wildland fire in Madison and Gallatin counties in 2017 was limited. Madison County experience 8 wildfires for a total of 29 acres, Gallatin County experienced 3 wildfires for a total of one acre (https://gacc.nifc.gov/nrcc/predictive/intelligence/ytd_historical/eoy/2017-eoy-unit.htm).

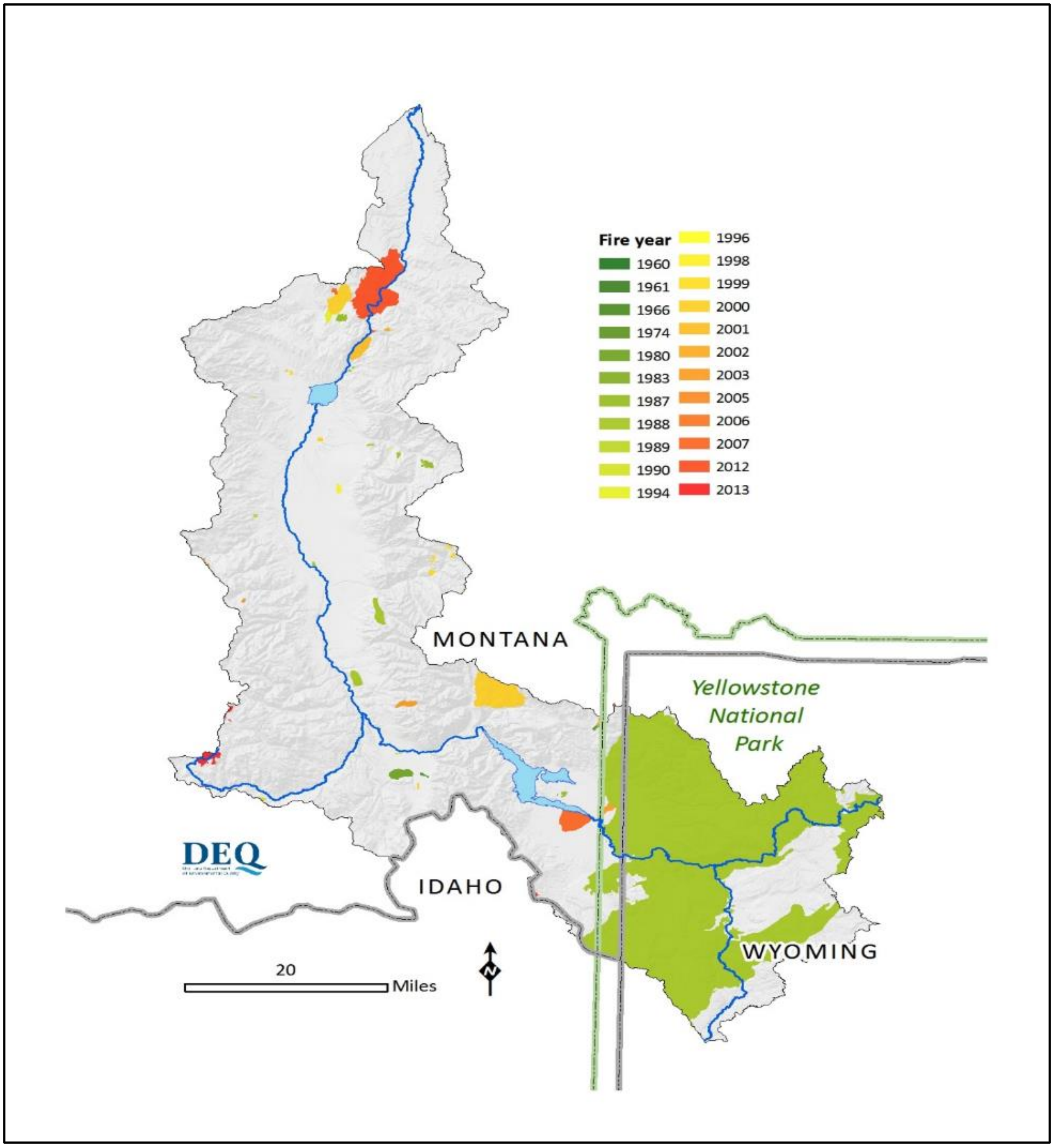

Figure 2-9. Fire history (1985-2013) of the Madison River Watershed

2.2.4 Fish distribution

The planning area provides habitat for Yellowstone cutthroat trout and westslope cutthroat trout, a Montana Species of Concern. Westslope cutthroat trout are found in tributary streams, particularly in the higher reaches. Yellowstone cutthroat trout are mapped in larger streams as well as in the mainstem Madison River. Arctic grayling are mapped in the Madison River and North Meadow Creek. The mapped distribution of these species is shown below in **Figure 2-10**, based on data provided by Montana Fish, Wildlife & Parks (http://fwp.mt.gov/gis/maps/mFish/?zoomFeatures=%7BlayerName:%22STREAMS%22,features:[%7BLLID:%221123386455677%22%7D],fadeOutTimer:4%7D). In addition, the Madison River is a designated Blue Ribbon fishery.

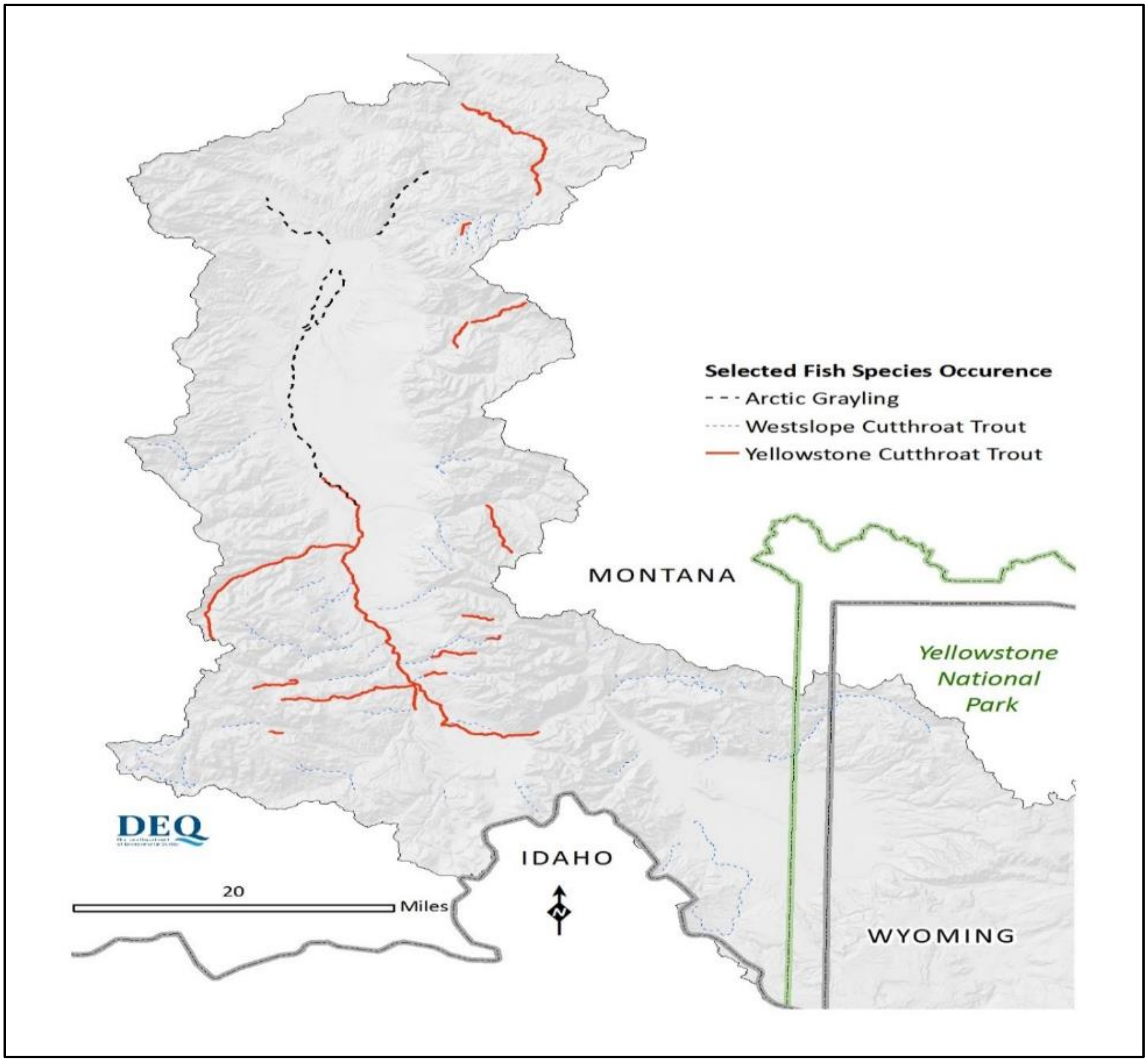

Figure 2-10. Arctic Grayling, Yellowstone Cutthroat Trout, and Westslope Cutthroat Trout distribution in the Madison TMDL Planning Area

2.3 Social Profile

The following section describes the human geography of the planning area. This includes population distribution, land ownership, and land management.

2.3.1 Population Density

There are no census geometries that exactly correspond to the planning area, but DEQ estimates the population at 2,544 people based on 2010 census GIS files. The population centers are Ennis (838 residents) and West Yellowstone (1,271 residents). Large areas of USFS land are uninhabited, although there are isolated inholdings. Population density is mapped below in **Figure 2-11**.

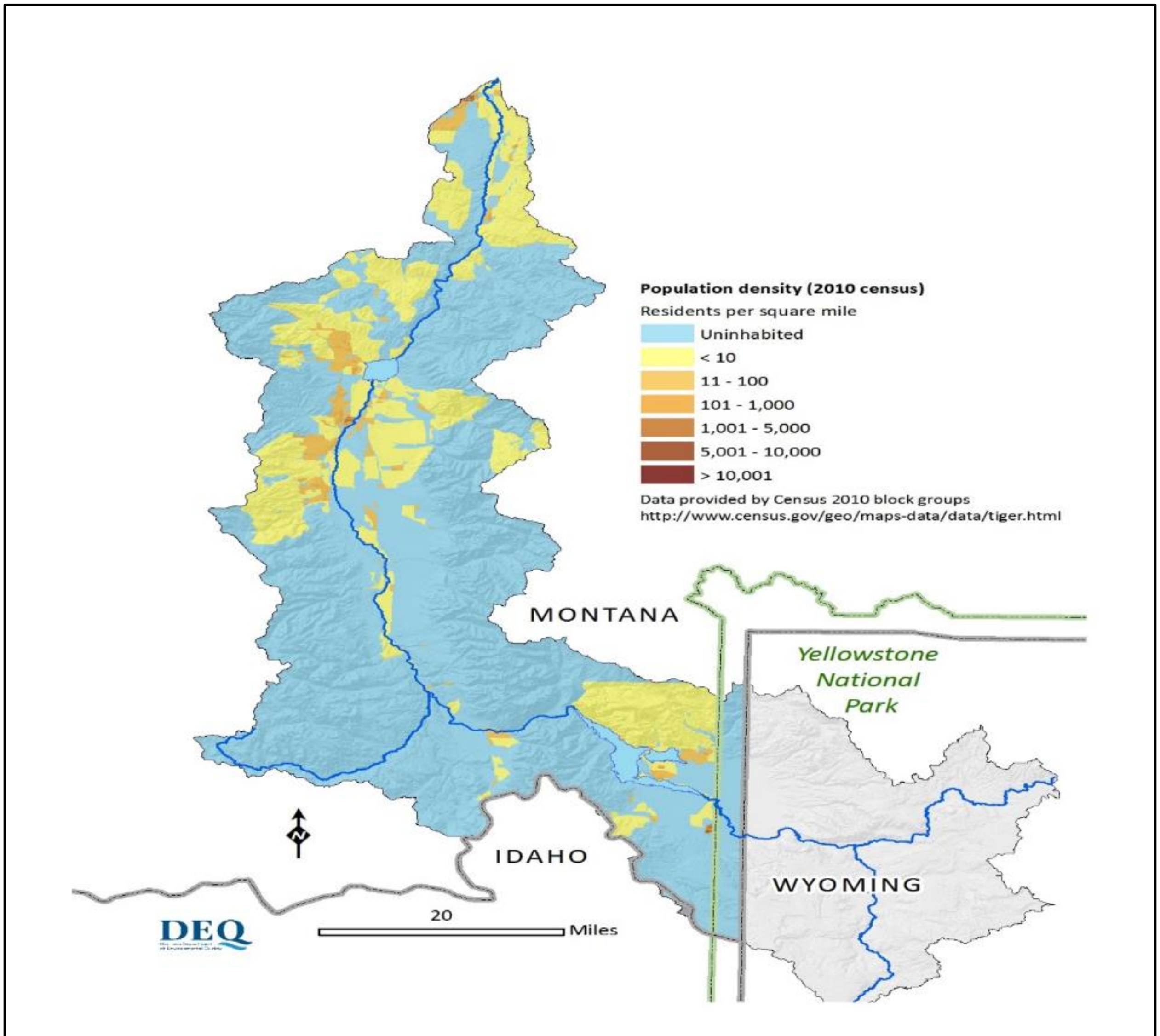

Figure 2-11. Population density in the Madison TMDL Planning Area

2.3.2 Land Management

Federal lands managed by the U.S. Forest Service (USFS) dominate the planning area, and are found mostly in the upland areas (**Figure 2-12**). The U.S. Bureau of Land Management (BLM) oversees significant lands in the valley and foothills. Private lands dominate the river corridor and valley bottoms.

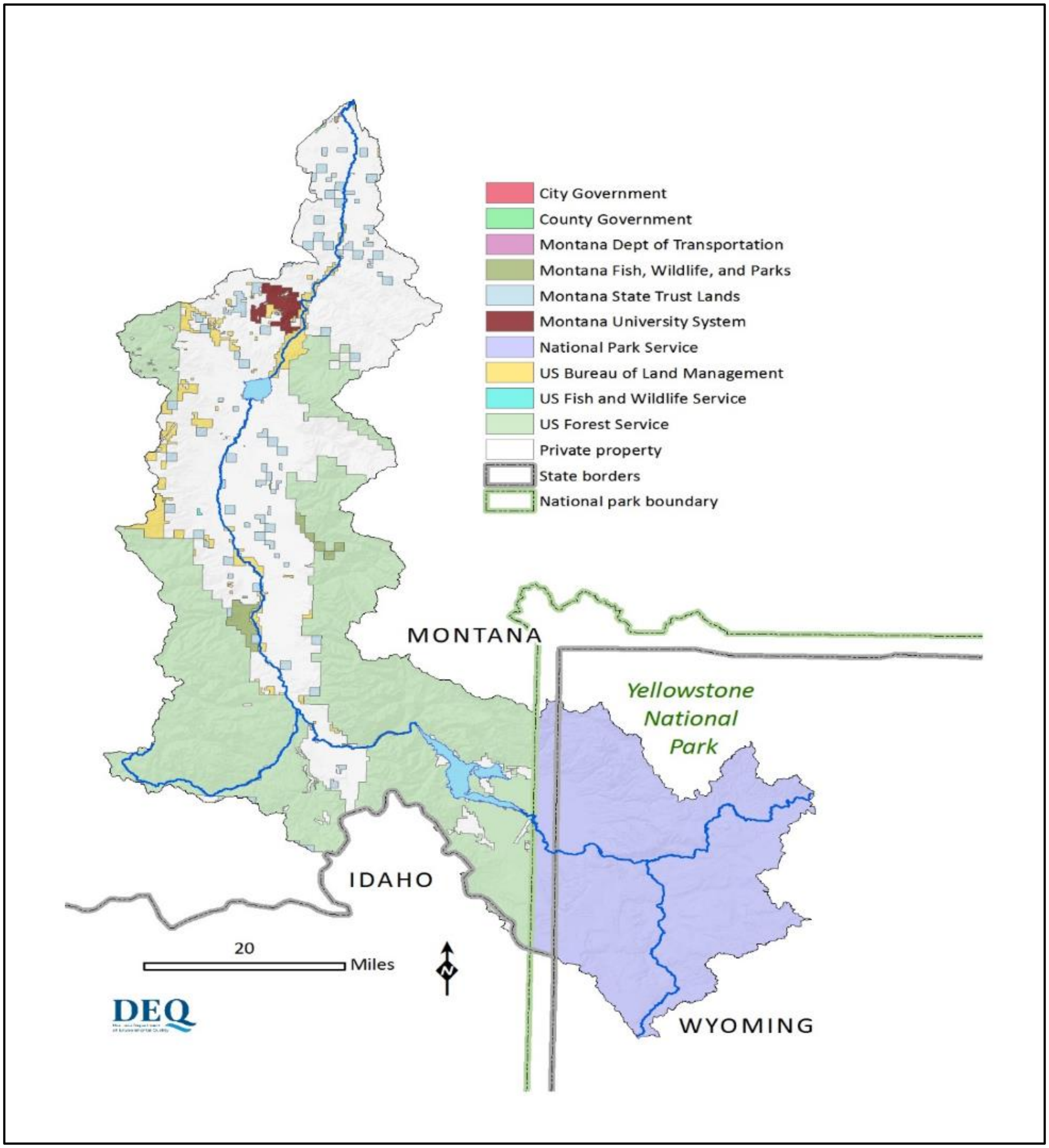

Figure 2-12. Land management in the Madison River Watershed

2.3.3 Agricultural Land Use

Montana Department of Revenue assesses agricultural land for taxation; the resulting dataset is known as the Final Land Unit (FLU) classification. The agricultural uses were determined by Department of Revenue GIS specialists, and confirmed by maps sent to private landholders for verification. Agricultural uses as determined in the Final Land Unit classification are mapped below in **Figure 2-13**. The Final Land Use data are available at:
ftp://ftp.geoinfo.msl.mt.gov/Data/Spatial/NonMSDI/Geodatabases/revenue_flu.zip.

Grazing is common on both private lands and forested public lands. BLM and USFS grazing allotments are shown on the map, totaling 138 and 559 square miles, respectively. Private grazing operations are not specifically identified; however, much of the gray area on the map includes private land where grazing occurs. Grazing allotments and operations are further discussed in **Sections 5.6.1.2**, **6.6.2.1**, and **7.6.3**.

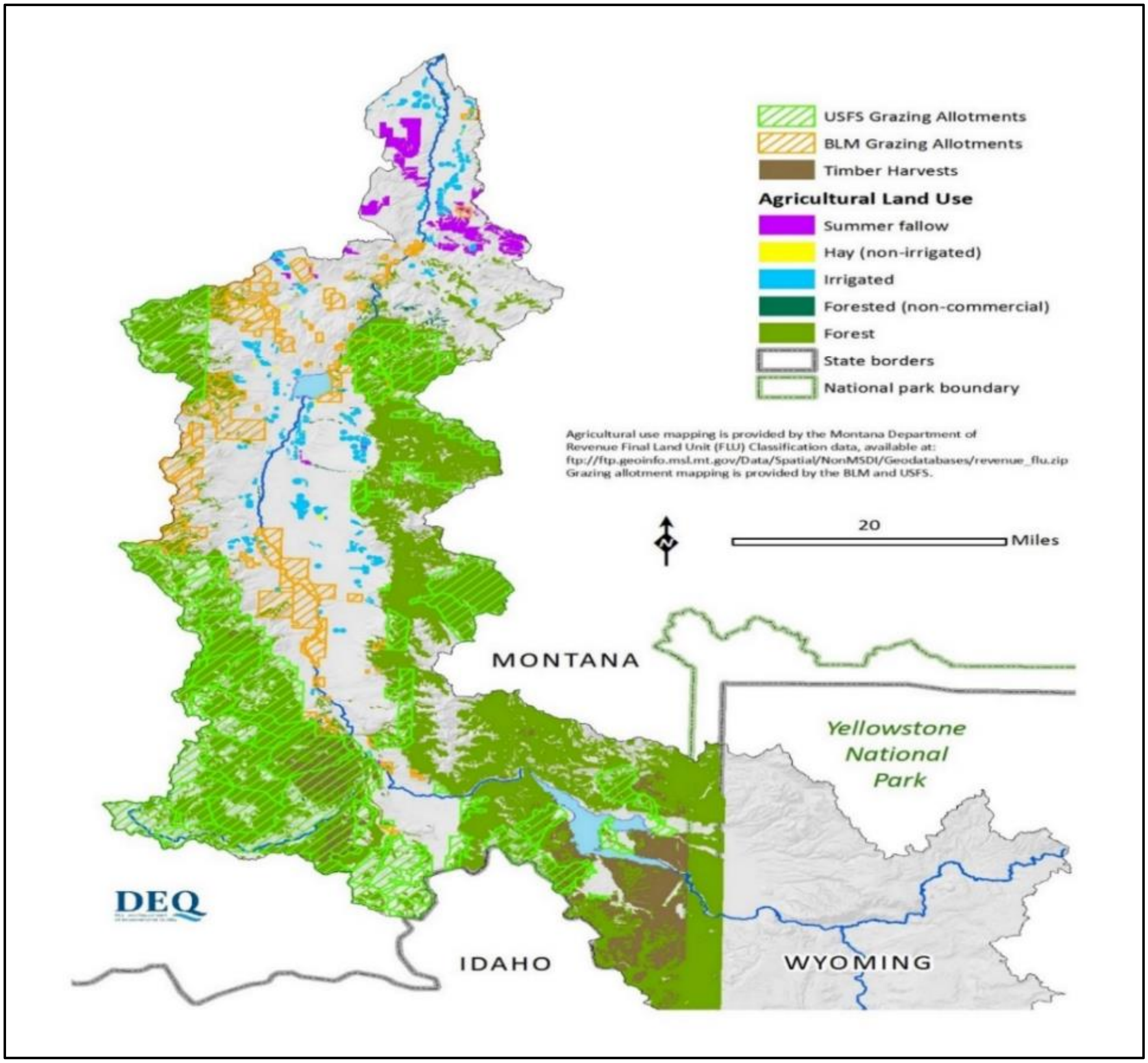

Figure 2-13. Agricultural use and grazing allotments in the Madison River Watershed

2.3.4 Road Networks

The Madison TMDL Planning Area includes significant roadless areas, particularly around the Lee Metcalf Wilderness Area. There are also extensive road networks both in the valley bottoms and in the timbered uplands. Some roads were constructed for timber harvesting, and may have been decommissioned. The planning area is too large to analyze the road network at this scale; however, **Figure 2-14** below provides a general idea of where the upland road networks are most extensive.

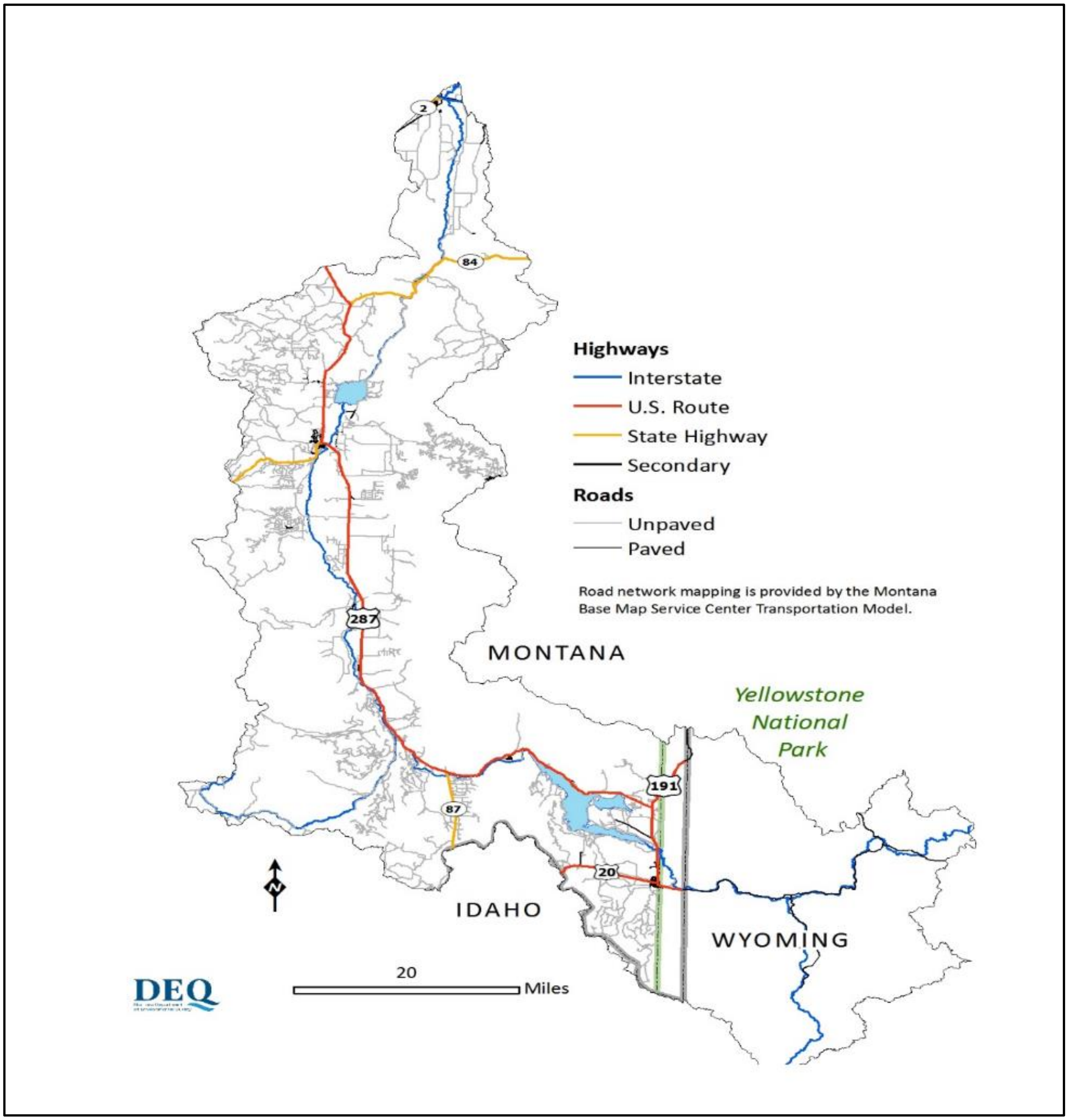

Figure 2-14. Road network in the Madison TMDL Planning Area

2.3.5 Wastewater Discharges

Sources of pollution originating from a point source wastewater discharge are permitted and regulated through the Montana Pollutant Discharge Elimination System (MPDES) administered by Montana DEQ. The goal of the MPDES program is to control point source discharges of wastewater such that water quality in state surface water is protected. Levels of water quality that are required to maintain the various beneficial uses of state surface waters are set forth in the water quality standards. There are two types of discharge permits: general and individual.

A MPDES General Permit is a permit for wastewater discharges associated with common activities, such as concentrated animal feeding operations and storm water discharges from construction or industrial activity. Authorizations for General Permits are issued if a facility or activity falls within the guidelines of the existing permit. Individual MPDES Permits regulate wastewater discharges from point sources that do not fall under the guidelines for a General Permit. The individual permitting process is more rigorous, as individual permits address the specific conditions of the facility or activity needing authorization.

All point sources of wastewater discharge are required to obtain and comply with MPDES permits. The effluent limitations and other conditions for certain categories of wastewaters are required to be treated to federally-specified minimum levels based on available and achievable water treatment technologies. Additionally, effluent limits and permit conditions are established to protect beneficial uses and applicable water quality standards. Each MPDES permit issued is designed to protect the state surface water quality at the point of discharge. In addition, recognizing the dynamic nature of streams and the potential additive or cumulative effects of pollutants, MPDES permits also address stream reach or basin-wide pollution problems. If a TMDL has been developed for a waterbody, any wasteload allocations (WLAs) incorporated into the applicable MPDES permits with discharges into that waterbody.

There are two MPDES permitted facilities that discharge to a waterbody in the Madison TMDL Planning Area, the Ennis National Fish Hatchery (permit number MTG13008) and the Ennis Wastewater Treatment Plant (permit number MT0030732). The permit for the Ennis National Fish Hatchery is a general permit for concentrated aquatic animal production. The permit for the Ennis Wastewater Treatment Plant is an individual MPDES permit for wastewater produced by the town of Ennis (**Table 2-1**). Neither Blaine Spring Creek or the Madison River have water quality impairments that are addressed by TMDLs in this document.

Table 2-1. Ennis National Fish Hatchery MPDES Permit details

Facility Name	Permit Number	Permit Expiration Date	Receiving Waterbody
Ennis National Fish Hatchery	MTG13008	June 30, 2021	Blaine Spring Creek
Ennis Wastewater Treatment Plant	MT0030732	April 20, 2019	Madison River

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

Montana's water quality standards also incorporate prohibitions against water quality degradation as well as point source permitting and other water quality protection requirements. That being said, Montana's 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 Montana Code Annotated (MCA)), Montana's Surface Water Quality Standards and Procedures (Administrative Rules of Montana (ARM) 17.30.601-670), Circular DEQ-7, Montana Numeric Water Quality Standards (Montana Department of Environmental Quality 2017), and Circular DEQ-12A, Montana Base Numeric Nutrient Standards (Montana Department of Environmental Quality 2014).

3.1 Stream Classifications and Designated Beneficial Uses

Stream classification is the assignment (designation) of a single 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. All Montana waters are classified for multiple uses. All streams and lakes within the Madison TMDL Planning Area are classified as B-1 (ARM 17.30.623). In accordance with ARM 17.30.623, waters classified as B-1 are to be maintained suitable for:

- 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. 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, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011). For streams in western Montana, the most sensitive use assessed for nutrients is aquatic life and primary contact recreation, and for metals is drinking water and/or aquatic life. For the Madison TPA, primary contact recreation is the most sensitive use assessed for *E. coli.* DEQ determined that five waterbody segments in the Madison TMDL Planning Area do not meet the nutrient, *E. coli* and/or metals water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and their Impaired Uses in the Madison TMDL Planning Area

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Impairment Cause[1]	Impaired Use(s)[2]
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Total Nitrogen	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Aquatic Life, Primary Contact Recreation
		NO_3+NO_2	Aquatic Life, Primary Contact Recreation
		Iron	Aquatic Life
		Selenium	Aquatic Life
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Total Nitrogen	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Aquatic Life, Primary Contact Recreation
		Iron	Aquatic Life
		Lead	Aquatic Life
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	*E. coli*	Primary Contact Recreation
		Total Nitrogen	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Aquatic Life, Primary Contact Recreation
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Total Nitrogen	Aquatic Life, Primary Contact Recreation
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Copper	Aquatic Life
		Total Nitrogen	Aquatic Life, Primary Contact Recreation
		Total Phosphorus	Aquatic Life, Primary Contact Recreation

[1] Only includes those pollutant impairments addressed by TMDLs in this document
[2] A full summary of beneficial use support Information for each waterbody is contained at cwaic.mt.gov

3.2 Numeric and Narrative Water Quality Standards

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations, frequency, and duration of specific pollutants so as not to impair designated uses.

Numeric standards apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, nutrients, *E. coli*, organic chemicals, and other toxic constituents). Human health standards are set at levels that protect against long-term (lifelong) exposure via drinking water and other pathways such as fish consumption, as well as short-term exposure through direct contact such as swimming. Numeric standards for aquatic life include chronic and acute values. Chronic aquatic life standards prevent long-term, low level exposure to pollutants. Acute aquatic life standards protect from short-term exposure to pollutants. Numeric standards also apply to other designated uses such as protecting irrigation and stock water quality for agriculture.

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 narrative standards are being met.

For the Madison TMDL Planning Area, a combination of numeric and narrative standards are applicable. The numeric standards apply to *E. coli*. and a combination of numeric and narrative standards are applicable for metals and nutrients. Numeric standards are applied as the primary targets for impairment determinations and subsequent TMDL development. These targets address allowable water column chemistry concentrations. Narrative standards are also used to develop supplemental targets to address metals concentrations in stream sediment and chlorophyll-*a* levels in benthic algal growth. The specific numeric and narrative standards for nutrients, *E. coli* and metals are discussed in **Sections 5.0**, **6.0**, and **7.0**, respectively.

For *E. coli*, there are numeric standards to protect human health relative to primary and secondary contact recreation. For Moore Creek, these numeric standards are found in ARM 17.30.623 (2)(a) and are applied as the primary targets for *E. coli* impairment determinations, and subsequent TMDL development. These targets address allowable water column *E. coli* concentrations. **Section 6.4** defines the water quality criteria for Moore Creek.

3.3 Nondegradation Provisions

Nondegradation is addressed via the nondegradation policy within Montana state statute (75-5-303, MCA) and via Montana’s nondegradation rules (ARM 17.30.7). The nondegradation policy states that existing uses of state waters and the level of water quality necessary to protect those uses must be maintained and protected (75-5-303(1), MCA). The nondegradation policy also addresses high-quality waters (75-5-303(2), MCA), which are further covered under Montana’s nondegradation rules.

Montana nondegradation rules apply to any new or increased point or nonpoint source resulting in a change of existing water quality in a high quality water occurring on or after April 29, 1993 (ARM 17.30.702). High quality waters are determined on a parameter-by-parameter basis. A water is high quality for a parameter if its ambient condition meets the standard or is better than the standard.

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. The ultimate goal of the TMDL is to identify an approach to achieve and maintain water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are often linked to community wastewater treatment or industrial facilities with discernible, confined and discrete conveyances, such as pipes or ditches from which pollutants are being, or may be, discharged to a waterbody. Some sources such as return flows from irrigated agriculture are not included in this definition. Pollutant loading sources that do not meet the definition of a point source are considered nonpoint sources. Nonpoint sources are associated with diffuse pollutant loading to a waterbody and are often linked to runoff from agricultural, urban, or forestry activities, as well as streambank erosion and groundwater seepage that can occur from these activities. Natural background loading and atmospheric deposition are both considered types of nonpoint sources.

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: $TMDL = \Sigma WLA + \Sigma LA + MOS$, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)
MOS = margin of safety

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation as shown. Alternatively, the MOS can be implicit in the TMDL, meaning that the explicit MOS in the above equation is equal to zero and can therefore be removed from the above equation. 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., changes in pollutant loading during the year, or seasonal water quality standards).

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.

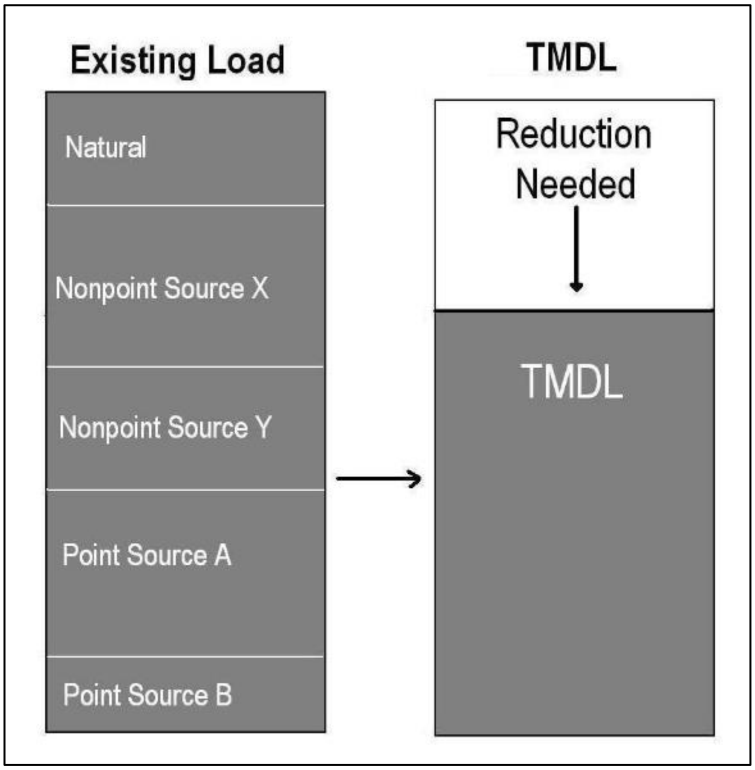

Figure 4-1: Schematic Example of TMDL Development

4.1 Developing Water Quality Targets

For each pollutant, TMDL water quality targets are based on the applicable numeric water quality standard and/or a translation of a narrative water quality standard(s). 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

The goal of TMDL source assessment is to identify all significant pollutant loading sources, including natural background loading, and quantify them 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 includes 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.

Source assessments are conducted on a watershed scale and can vary in level of detail resulting in reasonably accurate estimates or gross allotments, depending on the data availability and the techniques used for predicting the loading (40 CFR 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.

Nonpoint sources are quantified by source categories (e.g., septic systems or mines) and/or by land uses (e.g., crop production, 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, nonpoint pollutant sources in a sub-watershed or source area can be combined for quantification and TMDL load allocation purposes.

Additional detail is required for assessing pollutant loading from surface water point sources permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. This is because the allowable loading within each MPDES surface water permit conditions must be consistent with the assumptions and requirements of the available WLA developed within the TMDL (40 CFR 122.44).

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). Per EPA requirements (40 CFR 130.2), "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Where 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 results in a mass per unit time TMDL expression such as pounds per day. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

4.4 Determining Pollutant Allocations

Once the allowable load (the TMDL) is determined, that total must be divided among the contributing sources so that the sum of the allocations is equal to the TMDL, consistent with the above TMDL equation. Where a TMDL is variable based on streamflow, nonpoint source load allocations are often variable based on this same receiving streamflow. On the other hand, point source wasteload allocations are often based on conservative streamflow and discharge conditions and/or can be variable based on the point source discharge flow and a discharge concentration limit. Where the TMDL is a function of streamflow, the TMDL and allocations are calculated for example high and low flow stream conditions.

Figure 4-2 illustrates how, for a given streamflow condition, the TMDL is allocated to different sources using WLAs for point sources and load allocations (LA) for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the TMDL for all segments of the waterbody. **Figure 4-2** shows multiple point and nonpoint source allocations. In Montana, nonpoint source allocations are sometimes grouped into one composite allocation. This composite load allocation approach is applied in cases where data is limited, there is significant source assessment uncertainty, and/or DEQ has determined that the best approach is to provide stakeholders with flexibility in addressing sources, allowing them to choose where to focus on improved land management practices and other remediation or restoration efforts.

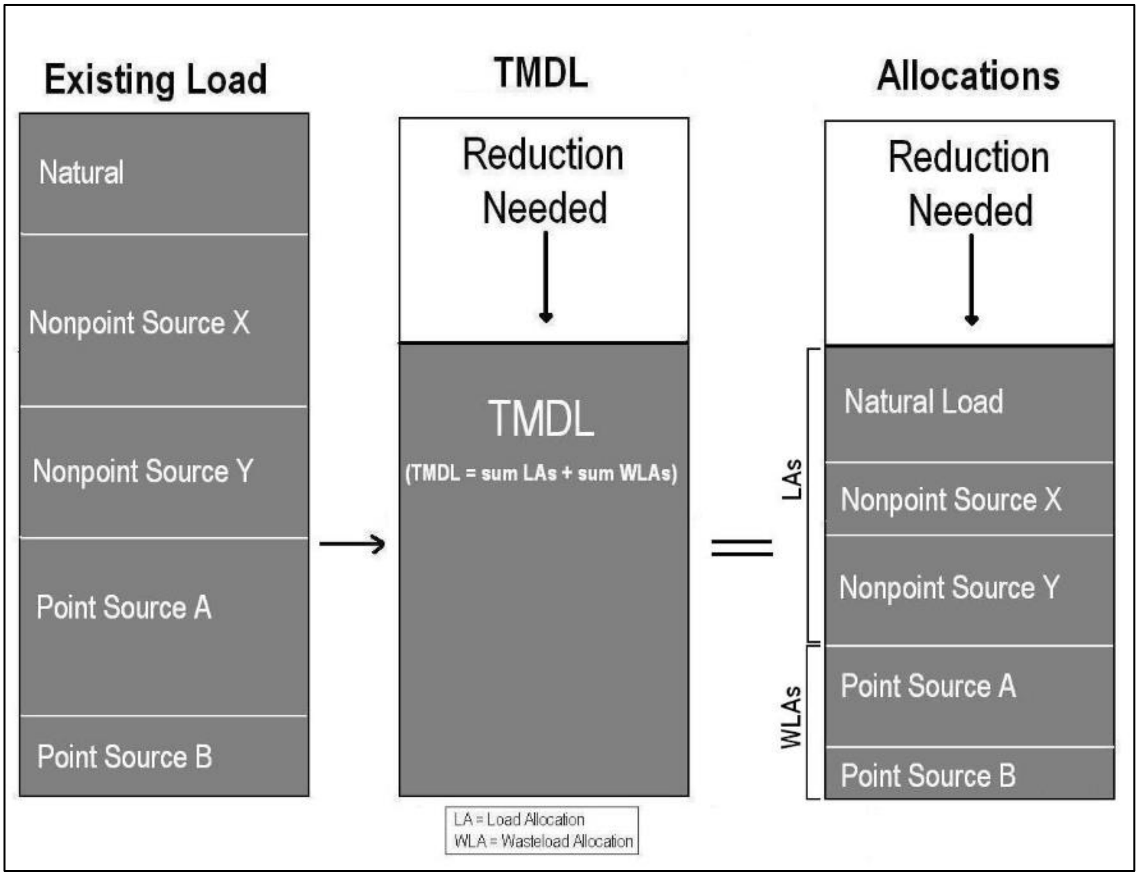

Figure 4.2: Schematic Diagram of a TMDL and its Allocations

4.5 IMPLEMENTING TMDL ALLOCATIONS

The Clean Water Act (CWA) and Montana state law (Section 75-5-703, MCA 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. Because of limited state and federal regulatory requirements, nonpoint source reductions linked to LAs are implemented primarily through voluntary measures, although there are some important nonpoint source regulatory requirements, such as Montana streamside management zone law and applicable septic system requirements. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 8.0** provides a water quality improvement plan that discusses restoration strategies by pollutant group and source category, and provides recommended best management practices (BMPs) per source category (e.g., grazing, cropland, septic systems, etc.). Site specific pollutant sources are discussed throughout this document and can be used to target implementation activities. DEQ's Nonpoint Source Program helps to coordinate water quality improvement projects for nonpoint sources of pollution throughout the state and provides resources to stakeholders to assist in nonpoint source BMPs. Montana's Nonpoint Source Management Plan (MT DEQ, 2017) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach for implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 9.2**). This includes a monitoring strategy and an implementation review that is required by Montana statute (Section 75-5-703, MCA of the Montana Water Quality Act). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 Nutrient TMDL Components

This portion of the document focuses on nutrients as a cause of water quality impairment in the Madison TMDL Planning Area. It describes: (1) how excess nutrients impair beneficial uses, (2) the affected stream segments (waterbodies), (3) the currently available data pertaining to nutrient impairments in the watershed, (4) the identification of nutrient targets and the comparison of those targets to the affected stream segments, (5) the nutrient TMDLs, (6) the sources of nutrients based on recent studies, (7) source allocations for each TMDL, and (8) the seasonality and margin of safety for the TMDLs.

5.1 Effects of Excess Nutrients on Beneficial Uses

Nitrogen and phosphorus are naturally occurring elements required for healthy functioning of aquatic ecosystems. Streams are dynamic systems that depend on a balance of nutrients, which can enter streams from various sources. Healthy streams strike a balance between organic and inorganic nutrients from sources such as natural erosion, groundwater discharge, and instream biological decomposition. This balance relies on autotrophic organisms (e.g., algae) to consume excess nutrients and on the cycling of biologically fixed nitrogen and phosphorus into higher levels on the food chain, as well as on nutrient decomposition (e.g., changing organic nutrients into inorganic forms). Human influences may alter nutrient cycling, damaging biological stream function and degrading water quality. The effects on streams of total nitrogen (TN), nitrate and nitrite (NO_3+NO_2; a component of TN), and total phosphorus (TP) are all considered in assessing the effects on beneficial uses.

Excess nitrogen in the form of dissolved ammonia (which is typically associated with wastewater) can be toxic to fish and other aquatic life. Excess nitrogen in the form of nitrate in drinking water can inhibit normal hemoglobin function in infants. In addition, excess nitrogen and phosphorus from human sources can cause excess algal growth, which in turn depletes the supply of dissolved oxygen, killing fish and other aquatic life. Excess nutrient concentrations in surface water can create nuisance algae blooms including blue-green algae blooms (Priscu 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans. Aside from the toxicity effects of blue-green algae, nuisance algae can reduce water clarity and shift the structure of macroinvertebrate communities, which may also negatively affect the fish that feed on macroinvertebrates (U.S. Environmental Protection Agency 2010). Additionally, changes in water clarity, fish communities, and aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al. 2009). Nuisance algae can also increase the cost of treating drinking water or pose health risks if ingested in drinking water (World Health Organization 2003). Where instream nutrient concentrations are grossly elevated over naturally occurring concentrations, net primary production may lead to anoxic conditions in the water column. Under redox conditions, some sediment-bound metals may be released into the water column further impairing water quality.

5.2 Stream Segments of Concern

The nutrient impaired stream segments of concern for the Madison TMDL Planning Area are based on the 2016 Integrated Report, and are shown in **Figure 5-1**. These include six different streams with 13 differing types of nutrient impairment as identified within **Table 5-1** (Montana Department of Environmental Quality, Water Quality Division, Water Quality Planning Bureau 2016).

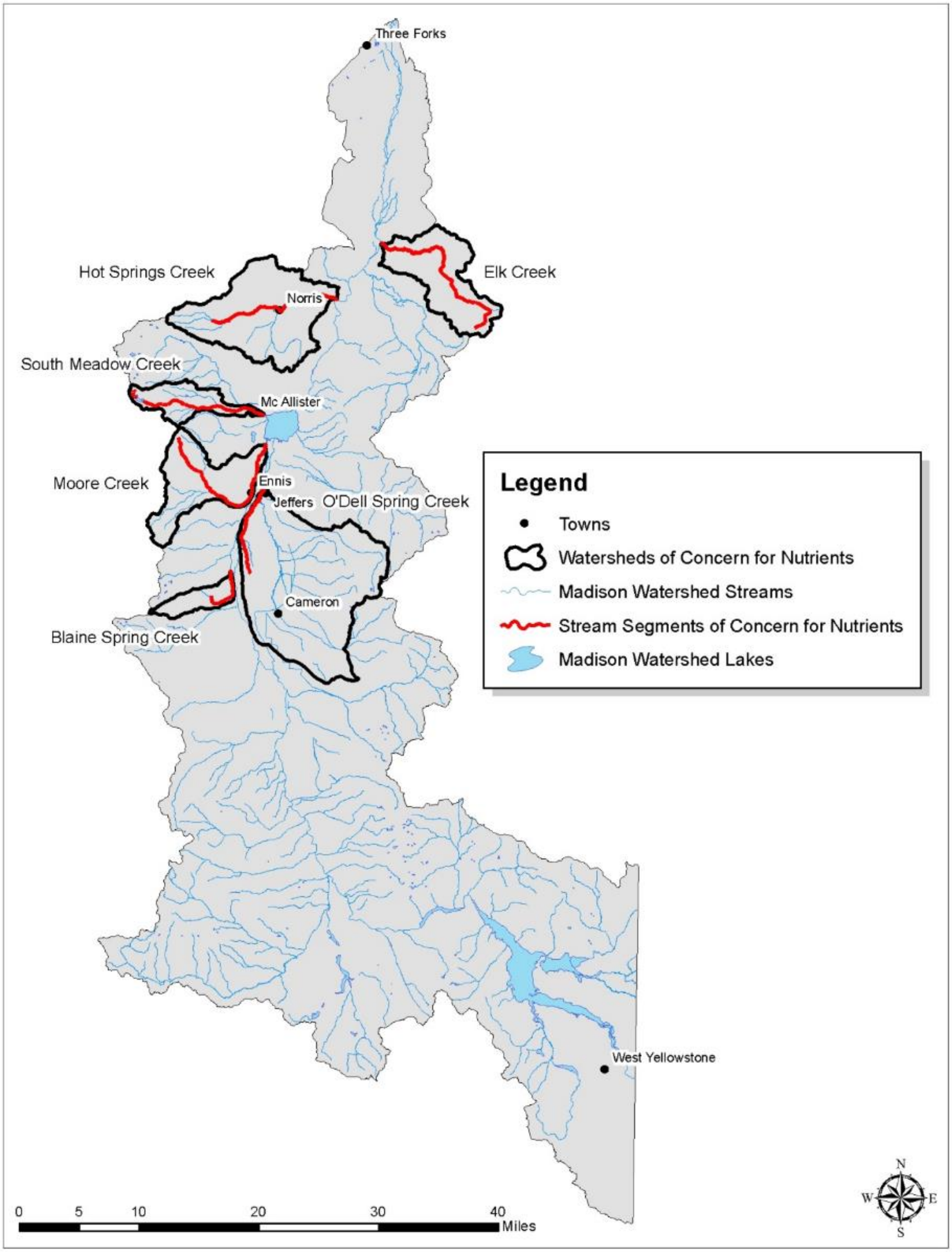

Figure 5-1. Map of the Stream Segments of Concern for Nutrients in the Madison Watershed

Table 5-1. Stream Segments of Concern for Nutrients and Nutrient Pollutant Impairments Based on the 2016 Integrated Report

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Nutrient Related Pollutant and Non-Pollutant Impairments Identified in the 2016 Integrated Report[1]
Blaine Spring Creek, Headwaters to mouth (Madison River)	MT41F004_010	TN, excess algal growth
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	TN, NO_3+NO_2, TP
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	TN, TP
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	TN, TP
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	TN
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	TN, TP, chlorophyll-*a*[2]

[1] TN = Total Nitrogen, NO_3+NO_2 = nitrate plus nitrite, TP = Total Phosphorus
[2] Chlorophyll-*a* is a measure of algal growth

5.3 Information Sources

The information sources used to develop the TMDL components include data used to determine impairments (see **Section 3.0**), in addition to data obtained during the TMDL development process. The data collected by DEQ, its contractors, other agencies, and volunteer monitoring groups, was catalogued within DEQ's centralized water quality database and can also be found in **Appendix A** of this document and in the national Water Quality Portal. Data and information used for impairment determination, source assessment, and TMDL development consisted of:

- Water chemistry, biological, and streamflow data collected by DEQ and the Madison Stream Team
- Fisheries inventories conducted by Montana Fish, Wildlife & Parks
- Streamflow data collected by the United States Geological Survey (USGS)
- Grazing management plans developed by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS)
- Cropland data collected by the USDA
- Discharge Monitoring Report (DMR) data collected by the U.S. Fish & Wildlife Service, Ennis National Fish Hatchery (MTG13008)
- Data and reports form the DEQ Abandoned Mine Lands program
- Aerial photography and Geographic Information System (GIS) data and analysis
- Literature reviews

5.4 Water Quality Targets

Water quality targets are numeric indicators used to evaluate attainment of water quality standards, and are discussed in further detail in **Section 4.0**. Water quality targets for nutrients in the Madison

TMDL Planning Area are based on values found within Department Circular DEQ-12A "Montana Base Numeric Nutrient Standards"(Montana Department of Environmental Quality 2014), the "Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers" (Suplee et al. 2008), and the "Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers: Update 1" (Suplee and Watson 2013).

5.4.1 Nutrient Target Values and Assessment Methodology

5.4.1.1 Nutrient Target Values

Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae chlorophyll-*a* (a form of undesirable aquatic life at elevated concentrations). The target concentrations for nitrogen and phosphorus are established at levels believed to protect aquatic life and recreation. Since 2002, DEQ has conducted a number of studies in order to develop numeric criteria for nutrients (N and P forms). Nutrient criteria for TN and TP, and threshold concentrations for chlorophyll-*a*, are based on two factors: (1) the results of public perception surveys (Suplee et al., 2009) on 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 (Suplee et al., 2007; Suplee and Watson, 2013).

Nutrient targets for TN and TP, are based on the numeric standards in DEQ-12A. DEQ-12A contains base numeric nutrient standards for wadeable streams in all level III ecoregions in Montana. Streams in the Madison TMDL Planning Area fall within the Middle Rockies ecoregion and therefore, those standards are applied to the stream segments of concern discussed in **Section 5.2**. The numeric nutrient standards that apply for the Madison TMDL Planning Area can be found in **Table 5-2**.

Table 5-2. Numeric Nutrient Standards for the Madison TMDL Planning Area

Ecoregion and Number	Ecoregion Level	Period when Criteria Apply	Numeric Nutrient Standard	
			Total Phosphorus (µg/L)	**Total Nitrogen (µg/L)**
Middle Rockies (17)	III	July 1 to September 30	30	300

In addition to TN and TP, targets are developed for measures of chlorophyll-*a*, ash-free dry mass (AFDM), and NO_3+NO_2. Chlorophyll-*a* and AFDM target concentrations are indicators of algal growth and are based on Suplee and Watson (2013), while the NO_3+NO_2 target is based on research by DEQ (Suplee et al. 2008; Suplee, Michael W., personal communication 11/14/2013). All nutrient target values can be found in **Table 5-3**. The target values are based on the most sensitive uses; therefore, the nutrient TMDLs are protective of all designated uses.

Macroinvertebrates were also included in the nutrient target suite as a biometric indicator. For macroinvertebrates, the Hilsenhoff Biotic Index (HBI) score is used. The HBI value increases as the amount of pollution tolerant macroinvertebrates in a sample increases; the macroinvertebrate target is an HBI score equal to or less than 4.0 (**Table 5-3**) (Suplee and Sada de Suplee 2011).

Because numeric nutrient chemistry is established to maintain algal levels below target chlorophyll-*a* and AFDM concentrations, target attainment applies and is evaluated during the summer growing season (July 1–September 30 for the Middle Rockies level III ecoregion) when algal growth will most likely affect beneficial uses. Targets in this document are established specifically for nutrient TMDL development in the Madison TMDL Planning Area and may or may not apply to streams in other TMDL project areas.

Table 5-3. Nutrient Targets for the Madison TMDL Planning Area

Parameter	Middle Rockies Level III Ecoregion 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*	≤ 125 mg/m^2
Ash Free Dry Mass (AFDM)	≤ 35 g/m^2
Hilsenhoff's Biotic Index (HBI)	< 4.0

5.4.1.2 Nutrient Assessment Methodology

Each waterbody is compared to target values based on DEQ's assessment methodology as defined within "2011 Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nitrogen and Phosphorus Levels" (Suplee and Sada de Suplee 2011). 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, water quality targets are not attained (a) when nutrient chemistry data have a target exceedance rate of >20% (Exact Binomial Test), (b) when the results of mean water quality nutrient chemistry exceed target values (Student's T-test), or (c) when a single chlorophyll-*a* result exceeds benthic algal target concentrations (125 mg/m^2 or 35 g AFDM/m^2). When applying the T-test for assessment, for sample values that were below detection limits, one-half the detection limit was used. In some cases, the chlorophyll-*a s*tandard operating procedure allows for a visual assessment where the collector determines that at all sampling transects, chlorophyll-*a* densities are less than 50 mg/m^2. In these cases, samples are not collected and the site is qualitatively assessed as having a chlorophyll-*a* density < 50 mg/m^2. Where water chemistry and algae data do not provide a clear determination of impairment status, or when other limitations exist, the Hilsenhoff Biotic Metric (HBI) biometric is considered in further evaluating whether nutrient targets have been achieved, as directed by the assessment methodology. The HBI is a biometric based on tolerance values. A large number of macroinvertebrate taxa have been assigned a numeric value that represents the organism's tolerance to organic pollution (Barbour et al. 1999). HBI is then calculated as a weighted average tolerance value of all individuals in a sample (Suplee and Sada de Suplee 2011). Higher index values indicate increasing tolerance to pollution.

Periphyton biometrics were developed by DEQ for Montana as an indicator of impairment. The exception to this use of diatoms is the Middle Rockies Level III ecoregion, for which there are no validated diatom increaser metrics. Periphyton data were not collected in the Madison TMDL Planning Area, as all the streams in the planning area fall within the Middle Rockies Level III ecoregion.

To ensure a higher degree of certainty for removing an impairment determination and making any new determination, it is important to note that the statistical tests are configured differently for an unlisted nutrient form than for a listed nutrient form, which may result in a different number of allowable exceedances for nutrients within a single stream segment. This helps assure that assessment reaches do not vacillate between listed and delisted status by the change in results from a single additional sample.

Because TN and (NO_3+NO_2) are both forms of nitrogen with similar sources and source control practices, DEQ will normally only identify TN as the nutrient impairment if water quality data show elevated concentrations for both of these forms of nitrogen and if NO_3+NO_2 is not already identified as an impairment cause on Montana's 303(d) list.

5.4.2 Existing Conditions and Comparison to Targets

DEQ evaluated nutrient target attainment by comparing existing water quality conditions with the water quality targets in **Table 5-3** and applying the assessment methodology described in **Section 5.4.1.2**. For each waterbody segment, a data summary is presented along with a comparison of existing data with targets, using the assessment methodology, and a TMDL development determination was made. TMDL development determinations depend on results of the data evaluation, and these updated impairment determinations are captured in the 2016 Water Quality Integrated Report (IR) (Montana Department of Environmental Quality, Water Quality Division, Water Quality Planning Bureau 2016). **Figure 5-2** shows all the stream segments of concern for nutrients in the Madison TMDL Planning Area, and their ratios of exceedance of the TN, NO_3+NO_2, and TP targets. This figure displays the 80^{th} percentile of the data (to account for a 20% allowable target exceedance per the above referenced assessment methodology) and has been normalized to show how that 80^{th} percentile relates to the target ratio of 1.0. This allows TN, NO_3+NO_2, and TP values to be compared side-by-side for each waterbody to determine the extent that a parameter is over or under the water quality target. A value of less than 1.0 indicates that the data is meeting the water quality target, while a value of greater than 1.0 indicates that the data is exceeding the target. Because lower values indicate better water quality, terms such as "exceeding a target" or "target exceedance" are equivalent to be above a target value and thus an indicator of a water quality problem.

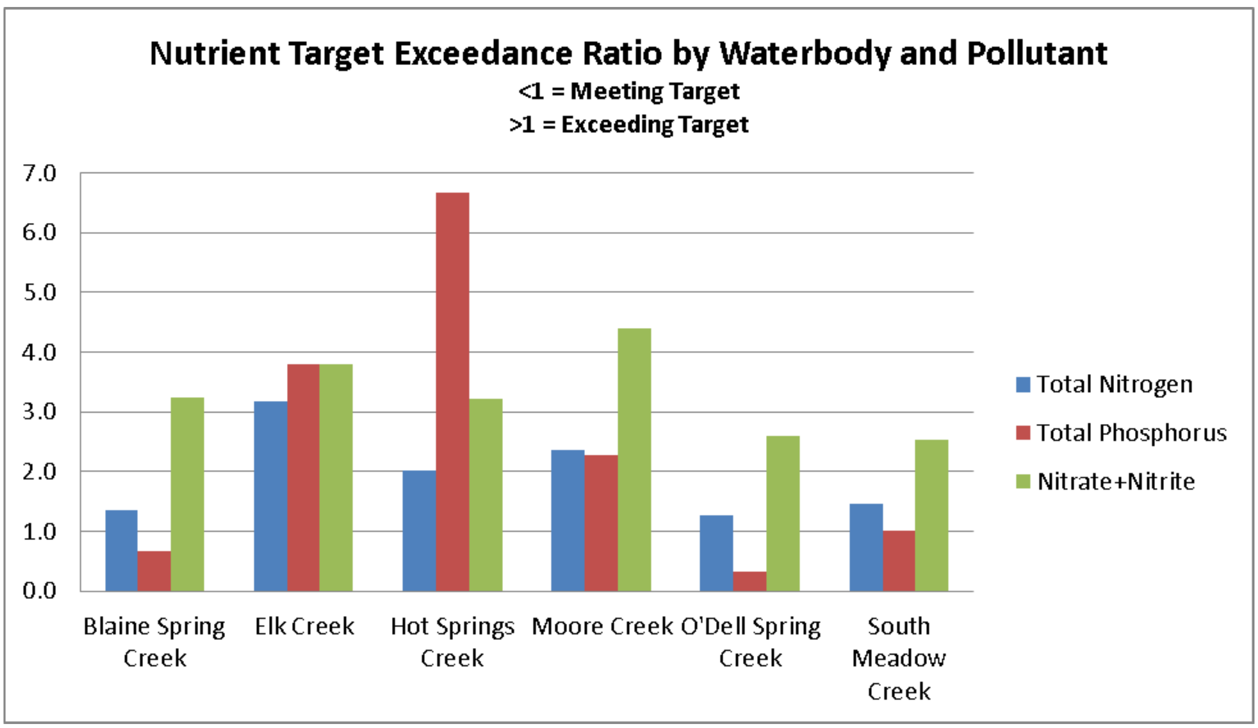

Figure 5-2. Chart showing the nutrient target exceedance ratio by stream for TN and TP in the Madison TMDL Planning Area

5.4.2.1 Blaine Spring Creek Comparison to Targets

Blaine Spring Creek flows approximately 4.9 miles from its source at Blaine Spring to its confluence with the Madison River. Blaine Spring Creek was first listed as impaired in 2006 for TP and TN, with excess algal growth added as a cause of impairment in 2008. Water quality data collected in 2012-2014 has indicated that TP is no longer a cause of impairment on Blaine Spring Creek, but TN and excess algal growth are still causing impairment. This is reflected in the 2016 IR and is shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for Blaine Spring Creek is provided in **Table 5-4**. A total of 22 nutrient (TN, NO_3+NO_2, and TP) samples were collected between 2012 and 2014. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from 0.150 mg/L to 1.380 mg/L with 15 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from 0.090 mg/L to 0.370 mg/L with 21 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from < 0.003 mg/L to 0.066 mg/L with one sample exceeding the TP target of 0.030 mg/L.

Two chlorophyll-*a* and Ash Free Dry Mass (AFDM) samples were collected in 2012 and 2013, as well as six visual observations for chlorophyll-*a* observed between 2012 and 2014. Chlorophyll-*a* values ranged from < 0.01 mg/m^2 to 7.8 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. There were also six visual estimates, which were all estimated at < 50 mg/m^2. AFDM values ranged from 6.17 g/m^2 to 38.37 g/m^2 with one sample exceeding the target value of 35 g/m^2. Two macroinvertebrate samples were collected, one in 2012 and one in 2013, both of which exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

Table 5-4. Nutrient Data Summary for Blaine Spring Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
TN (mg/L)	2012-2014	22	0.150	1.380	0.350	0.408
NO_3+NO_2 (mg/L)	2012-2014	22	0.090	0.336	0.305	0.325
TP (mg/L)	2012-2014	22	< 0.003	0.066	0.014	0.020
Chlorophyll-*a* (mg/m^2)	2012-2013	2[2]	< 0.01	7.8	NA	NA
AFDM (g/m^2)	2012-2013	2	6.17	38.37	NA	NA
Macroinvertebrate HBI	2012-2013	2	4.93	5.44	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2] Six additional visual estimate samples of < 50 mg/m^2 were not included in the summary statistics.

TN and NO_3+NO_2 failed both statistical tests, while TP passed both tests (**Table 5-5**). Further investigation into naturally high levels of nitrogen may determine that a nutrient TMDL may not be required for this waterbody pending the potential development of site specific nutrient standards. This is discussed in further detail in **Section 5.6.2**.

Table 5-5. Assessment Method Evaluation Results for Blaine Spring Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	22	0.300	15	**FAIL**	**FAIL**	PASS	**FAIL**	**FAIL**	**YES**[1]
NO_3+NO_2	22	0.100	21	**FAIL**	**FAIL**				NO[2]
TP	22	0.030	1	PASS	PASS				NO

[1] No TMDL will be developed for TN, as natural background water quality data indicate high concentrations of TN (**Section 5.6.2.2**) Further investigation into naturally high levels of nitrogen may determine that a TMDL may not be required for this waterbody pending the potential development of site specific nutrient standards.
[2] Per DEQ assessment approach, although NO_3+NO_2 fails the binomial and T-tests, it is not added as a new impairment; it is instead addressed via identification of a TN impairment.

5.4.2.2 Elk Creek Comparison to Targets

Elk Creek flows approximately 18.3 miles from its headwaters in the Madison Range to its confluence with the Madison River. Elk Creek was first listed as impaired in 2000 for TP and NO_3+NO_2. Water quality data collected in 2007-2013 has indicated that TN is also causing impairment on Elk Creek. This is reflected in the 2016 IR and is shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for Elk Creek is provided in **Table 5-6**. A total of 14 nutrient samples were collected between 2007 and 2013. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from 0.134 mg/L to 1.280 mg/L with 8 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from < 0.005 mg/L to 0.670 mg/L with 4 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from 0.052 mg/L to 0.190 mg/L with 14 samples exceeding the TP target of 0.030 mg/L.

Four chlorophyll-*a* and Ash Free Dry Mass (AFDM) samples were collected in 2012 and 2013. Chlorophyll-*a* values ranged from 13.8 mg/m^2 to 47.62 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. AFDM values ranged from 0.93 g/m^2 to 76.0 g/m^2 with one sample exceeding the target value of 35 g/m^2. Five macroinvertebrate samples were collected in 2012 and 2013, four of which exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

Table 5-6. Nutrient Data Summary for Elk Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
TN (mg/L)	2007-2013	14	0.134	1.280	0.440	0.950
NO_3+NO_2 (mg/L)	2007-2013	14	< 0.005	0.670	0.005	0.380
TP (mg/L)	2007-2013	14	0.052	0.190	0.097	0.114
Chlorophyll-*a* (mg/m^2)	2012-2013	4	13.80	47.62	NA	NA
AFDM (g/m^2)	2012-2013	4	0.93	76.0	NA	NA
Macroinvertebrate HBI	2012-2013	5	3.88	6.60	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.

TN, NO_3+NO_2, and TP failed both statistical tests (**Table 5-7**). TN and TP TMDLs will be developed based on the results of the statistical tests and the number of target exceedances. Because the NO_3+NO_2 impairment is reflected in the TN data, a TMDL for NO_3+NO_2 will not be developed but will be addressed by the TN TMDL.

Table 5-7. Assessment Method Evaluation Results for Elk Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	14	0.300	8	**FAIL**	**FAIL**				**YES**
NO_3+NO_2	14	0.100	4	**FAIL**	**FAIL**	PASS	**FAIL**	**FAIL**	NO[1]
TP	14	0.030	14	**FAIL**	**FAIL**				**YES**

[1] Addressed via TN impairment

5.4.2.3 Hot Springs Creek Comparison to Targets

Hot Springs Creek flows approximately 14 miles from its headwaters in the Tobacco Root Mountains to its confluence with the Madison River. Hot Springs Creek was not previously identified by Montana DEQ as impaired for nutrients, but water quality data collected in 2012-2013 has indicated that phosphorus (total) and nitrogen (total) are causing impairment in Hot Springs Creek and is reflected in the 2016 IR and shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for Hot Springs Creek is provided in **Table 5-8**. A total of 13 nutrient samples were collected between 2012 and 2013. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from 0.260 mg/L to 0.637 mg/L with 11 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from <0.010 mg/L to 0.494 mg/L with 7 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from 0.033 mg/L to 0.426 mg/L with all 13 samples exceeding the TP target of 0.030 mg/L.

Three chlorophyll-*a* and two Ash Free Dry Mass (AFDM) samples were collected in 2012 and 2013. Chlorophyll-*a* values ranged from 10.90 mg/m^2 to 12.51 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. AFDM values ranged from 5.02 g/m^2 to 34.30 g/m^2 with no samples exceeding the target value of 35 g/m^2. Five macroinvertebrate samples were collected in 2012 and 2013, four of which exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

TN, NO_3+NO_2, and TP failed both statistical tests (**Table 5-9**). TN and TP TMDLs will be developed based on the results of the statistical tests and the number of target exceedances. It is not necessary to identify NO_3+NO_2 as a cause of impairment on Montana's 303(d) list because it will be adequately addressed by the TN TMDL.

Table 5-8. Nutrient Data Summary for Hot Springs Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
TN (mg/L)	2012-2013	13	0.260	0.637	0.480	0.604
NO_3+NO_2 (mg/L)	2012-2013	13	< 0.010	0.494	0.150	0.322
TP (mg/L)	2012-2013	13	0.033	0.426	0.112	0.200

Table 5-8. Nutrient Data Summary for Hot Springs Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
Chlorophyll-*a* (mg/m^2)	2012-2013	3	10.90	12.51	NA	NA
AFDM (g/m^2)		2	5.02	34.30	NA	NA
Macroinvertebrate HBI	2012-2013	5	4.96	6.04	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.

Table 5-9. Assessment Method Evaluation Results for Hot Springs Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	13	0.300	11	**FAIL**	**FAIL**	PASS	PASS	**FAIL**	**YES**
NO_3+NO_2	13	0.100	7	**FAIL**	**FAIL**				NO[1]
TP	13	0.030	13	**FAIL**	**FAIL**				**YES**

[1] Addressed via TN impairment and subsequent TN TMDL development

5.4.2.4 Moore Creek Comparison to Targets

Moore Creek flows approximately 15.8 miles from its headwaters in the Tobacco Root Mountains to its confluence with the Madison River. Moore Creek was not previously identified by Montana DEQ as impaired for nutrients, but water quality data collected in 2012-2014 has indicated that phosphorus (total) and nitrogen (total) are causing impairment in Moore Creek and is reflected in the 2016 IR and shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for Moore Creek is provided in **Table 5-10**. A total of 27 TN samples, 29 NO_3+NO_2 samples, and 29 TP samples were collected between 2012 and 2014. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from 0.230 mg/L to 1.170 mg/L with 20 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from < 0.010 mg/L to 0.65 mg/L with 22 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from 0.016 mg/L to 0.090 mg/L with 17 samples exceeding the TP target of 0.030 mg/L.

Two chlorophyll-*a* and Ash Free Dry Mass (AFDM) samples were collected in 2012, as well as 13 visual observations for chlorophyll-*a* observed between 2011 and 2014. Chlorophyll-*a* values ranged from 9.2 mg/m^2 to 35.2 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. There were also thirteen visual estimates, which were estimated at < 50 mg/m^2. AFDM values ranged from 6.12 g/m^2 to 19.35 g/m^2 with no samples exceeding the target value of 35 g/m^2. Two macroinvertebrate samples were collected in 2012, both of which exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

TN, NO_3+NO_2, and TP failed both statistical tests (**Table 5-11**). TN and TP TMDLs will be developed based on the results of the statistical tests and the number of target exceedances. It is not necessary to identify NO_3+NO_2 as a cause of impairment on Montana's 303(d) list because it will be adequately addressed by the TN TMDL.

Table 5-10. Nutrient Data Summary for Moore Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
TN (mg/L)	2012-2014	27	0.230	1.170	0.530	0.708
NO_3+NO_2 (mg/L)	2012-2014	29	< 0.010	0.650	0.240	0.440
TP (mg/L)	2012-2014	29	0.016	0.090	0.035	0.068
Chlorophyll-*a* (mg/m^2)	2012	2[2]	9.2	35.2	NA	NA
AFDM (g/m^2)	2012	2	6.12	19.35	NA	NA
Macroinvertebrate HBI	2012	2	6.05	6.63	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2] Thirteen additional visual estimate samples of < 50 mg/m^2 were not included in the summary statistics.

Table 5-11. Assessment Method Evaluation Results for Moore Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	27	0.300	20	**FAIL**	**FAIL**				**YES**
NO_3+NO_2	29	0.100	22	**FAIL**	**FAIL**	PASS	PASS	**FAIL**	NO[1]
TP	29	0.030	17	**FAIL**	**FAIL**				**YES**

[1] Addressed via TN impairment and subsequent TN TMDL development

5.4.2.5 O'Dell Spring Creek Comparison to Targets

O'Dell Spring Creek flows approximately 13.1 miles from its source below the Cameron Bench to its confluence with the Madison River. O'Dell Spring Creek was not previously identified by Montana DEQ as impaired for nutrients, but water quality data collected in 2012-2014 has indicated that nitrogen (total) is causing impairment in O'Dell Spring Creek and is reflected in the 2016 IR as shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for O'Dell Spring Creek is provided in **Table 5-12**. A total of 34 TN samples, 33 NO_3+NO_2 samples, and 33 TP samples were collected between 2012 and 2014. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from 0.200 mg/L to 0.450 mg/L with 15 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from 0.140 mg/L to 0.270 mg/L with all 33 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from 0.004 mg/L to 0.013 mg/L with no samples exceeding the TP target of 0.030 mg/L.

Two chlorophyll-*a* samples and one Ash Free Dry Mass (AFDM) sample were collected in 2012 and 2014, as well as 15 visual observations for chlorophyll-*a* observed between 2011 and 2014. Chlorophyll-*a* values ranged from 18.4 mg/m^2 to 33.5 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. There were also nine visual estimates, which were estimated at < 50 mg/m^2. The AFDM value was 34.73 g/m^2, and did not exceed the target value of 35 g/m^2. One macroinvertebrate sample was collected in 2012 and exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

TN and NO_3+NO_2 failed both statistical tests, while TP passed both tests (**Table 5-13**). Although TN and NO_3+NO_2 concentrations have the potential to be naturally high at the spring source, the anthropogenic nitrogen sources present throughout the watershed are likely a significant contributor to TN impairment. This is discussed in further detail in **Section 5.6.6**.

Table 5-12. Nutrient Data Summary for O'Dell Spring Creek

Nutrient Parameter	Sample Timeframe	n	Min	Max	Median	80th percentile
TN (mg/L)	2012-2014	34	0.200	0.450	0.300	0.380
NO_3+NO_2 (mg/L)	2012-2014	33	0.140	0.270	0.210	0.260
TP (mg/L)	2012-2014	33	0.004	0.013	0.007	0.010
Chlorophyll-*a* (mg/m^2)	2012-2014	2[1]	18.4	33.5	NA	NA
AFDM (g/m^2)	2014	1	34.73	34.73	NA	NA
Macroinvertebrate HBI	2012	1	5.69	5.69	NA	NA

[1] Nine additional visual estimate samples of < 50 mg/m^2 were not included in the summary statistics

Table 5-13. Assessment Method Evaluation Results for O'Dell Spring Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	34	0.300	15	**FAIL**	**FAIL**				**YES[1]**
NO_3+NO_2	33	0.100	33	**FAIL**	**FAIL**	PASS	PASS	**FAIL**	NO[2]
TP	33	0.030	0	PASS	PASS				NO

[1] Further investigation into naturally high levels of nitrogen may determine that a TMDL may not be required for this waterbody pending the potential development of site specific nutrient standards.

[2] Per DEQ assessment approach, although NO_3+NO_2 fails the binomial and T-tests, it is not added as a new impairment; it is instead addressed via identification of a TN impairment and subsequent TN TMDL development.

5.4.2.6 South Meadow Creek Comparison to Targets

South Meadow Creek flows approximately 12.9 miles from its headwaters in the Tobacco Root Mountains to its confluence with North Meadow Creek near Ennis Lake. South Meadow Creek was first listed as impaired in 2008 for chlorophyll-*a*. Water quality data collected in 2012-2014 has indicated that nitrogen (total) and phosphorus (total) are also causing impairment on South Meadow Creek. This is reflected in the 2016 IR and is shown in **Table 5-1**.

A statistical summary of the nutrient data and assessment method outcome for South Meadow Creek is provided in **Table 5-14**. A total of 31 nutrient samples were collected between 2012 and 2014. Only data collected within the July 1 - September 30 timeframe were used for nutrient assessment purposes to coincide with the time in which the nutrient standards apply. TN values ranged from < 0.040 mg/L to 0.530 mg/L with 10 samples exceeding the TN target of 0.300 mg/L. NO_3+NO_2 values ranged from <0.010 mg/L to 0.310 mg/L with 9 samples exceeding the NO_3+NO_2 target of 0.100 mg/L. TP values ranged from < 0.003 mg/L to 0.047 mg/L with 6 samples exceeding the TP target of 0.030 mg/L.

Three chlorophyll-*a* and Ash Free Dry Mass (AFDM) samples were collected in 2011 and 2014. Chlorophyll-*a* values ranged from 4.4 mg/m^2 to 29.6 mg/m^2 with no samples exceeding the target value of 125 mg/m^2. There were also twelve visual estimates, which were estimated at < 50 mg/m^2. AFDM values ranged from 2.14 g/m^2 to 55.0 g/m^2 with one sample exceeding the target value of 35 g/m^2. Three macroinvertebrate samples were collected in 2012 and 2013, all three of which exceeded the target value of a Hilsenhoff's Biotic Index (HBI) score of 4.

TN and TP failed the binomial statistical tests, but passed their respective T-tests, while NO_3+NO_2 failed both statistical tests (**Table 5-15**). TN and TP TMDLs will be developed based on the number of target exceedances. It is not necessary to identify NO_3+NO_2 as a cause of impairment on Montana's 303(d) list because it will be adequately addressed by the TN TMDL.

Table 5-14. Nutrient Data Summary for South Meadow Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
TN (mg/L)	2012-2014	31	< 0.040	0.530	0.190	0.440
NO_3+NO_2 (mg/L)	2012-2014	31	< 0.010	0.310	0.050	0.254
TP (mg/L)	2012-2014	31	< 0.003	0.047	0.012	0.030
Chlorophyll-*a* (mg/m^2)	2011-2014	3[2]	4.4	29.6	NA	NA
AFDM (g/m^2)	2012-2013	3	2.14	55.0	NA	NA
Macroinvertebrate HBI	2012-2013	3	4.09	4.41	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2] Twelve additional visual estimate samples of < 50 mg/m^2 were not included in the summary statistics.

Table 5-15. Assessment Method Evaluation Results for South Meadow Creek

Nutrient Parameter	n	Target Value (mg/L)	Target Exceedance	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
TN	31	0.300	10	**FAIL**	PASS				**YES**
NO_3+NO_2	31	0.100	9	**FAIL**	**FAIL**	PASS	**FAIL**	**FAIL**	NO[1]
TP	31	0.030	6	**FAIL**	PASS				**YES**

[1] Addressed via TN impairment and subsequent TN TMDL development

5.5 Total Maximum Daily Loads (TMDLs)

This section summarizes the approach used for TMDL development, and then presents the TMDLs, allocations, and estimated reductions necessary to meet water quality targets for five of the six nutrient impaired streams, as TMDLs for Blaine Spring Creek will not be developed at this time. A NO_3+NO_2 TMDL was not developed for Elk Creek because that impairment is addressed by the TN TMDL that was developed for Elk Creek. TMDLs are also not developed for non-pollutant impairments such as excess algal growth and chlorophyll-*a*, as those impairments are typically addressed by the associated pollutant TMDLs that were developed for those waterbodies. **Table 5-16** shows the waterbodies and the specific nutrient TMDLs developed for each waterbody. Loading estimates and load allocations are established for the summer growing season time period and are based on observed water quality data and flow conditions measured during this time period.

Table 5-16. Nutrient TMDLs developed in the Madison TMDL Planning Area

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Nutrient Related Pollutant and Non-Pollutant Impairments	TMDL(s) Developed[1]
Blaine Spring Creek, Headwaters to mouth (Madison River)	MT41F004_010	TN, excess algal growth	None
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	TN, NO_3+NO_2, TP	TN, TP
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	TN, TP	TN, TP
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	TN, TP	TN, TP
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	TN	TN
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	TN, TP, Chlorophyll-*a*	TN, TP

[1] TN = Total Nitrogen, NO_3+NO_2 = nitrate plus nitrite, TP = Total Phosphorus

Because streamflow varies seasonally, TMDLs are not expressed as a static value, but as an equation of the appropriate target multiplied by flow as shown in **Equation 5-1**:

Equation 5-1: TMDL = (X) (Y) (5.4)

TMDL = Total maximum daily load in lbs/day
*X = water quality target in mg/L (0.3 for TN or 0.03 for TP) (**Table 5-3**)*
Y = streamflow in cubic feet per second (cfs)
5.4 = conversion factor

As flow increases, the allowable load (TMDL) increases as shown by the TN TMDL in **Figure 5-3** and the TP TMDL in **Figure 5-4**. For example, at a flow rate of 5 cfs, the application of **Equation 5-1** would result in a TN TMDL of 8.1 lbs/day and a TP TMDL of 0.81 lbs/day. Like the water quality targets, the TMDLs are applied only to the summer growing season (July 1st through Sept 30th).

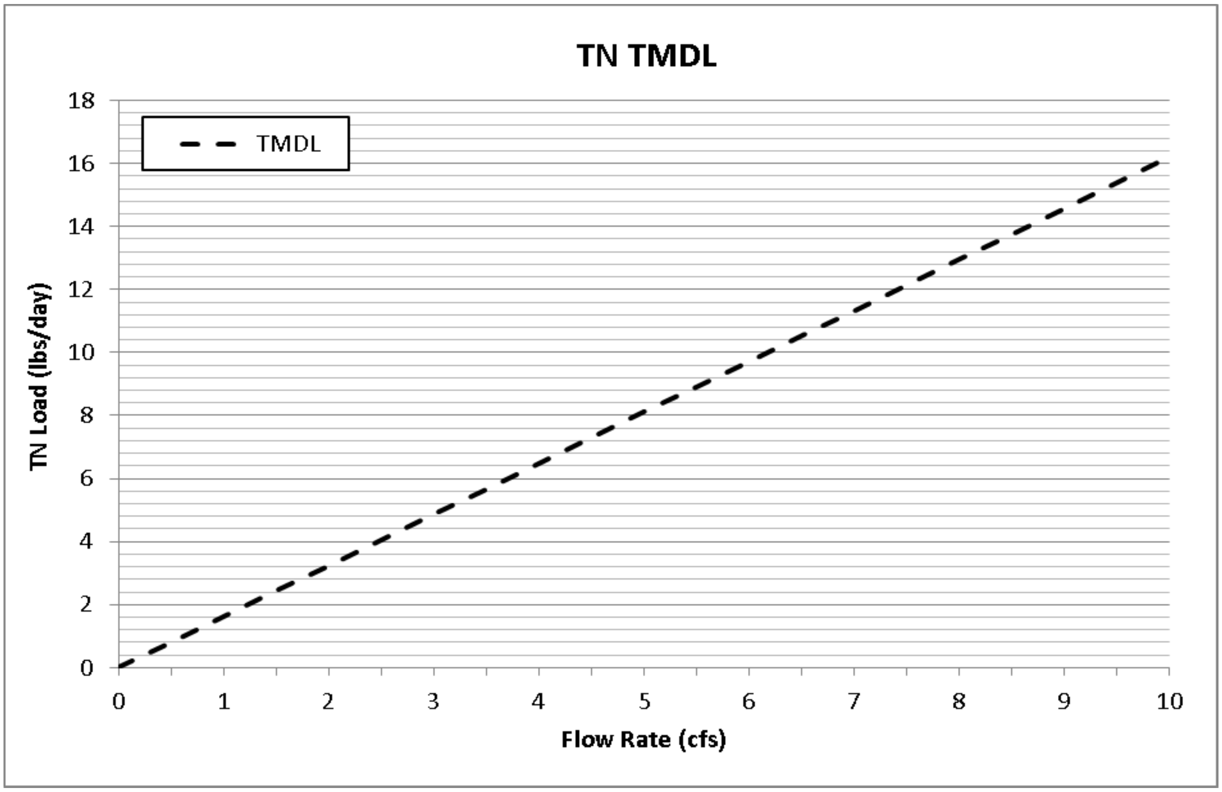

Figure 5-3. TMDL for TN for streamflows ranging from 0 to 10 cfs

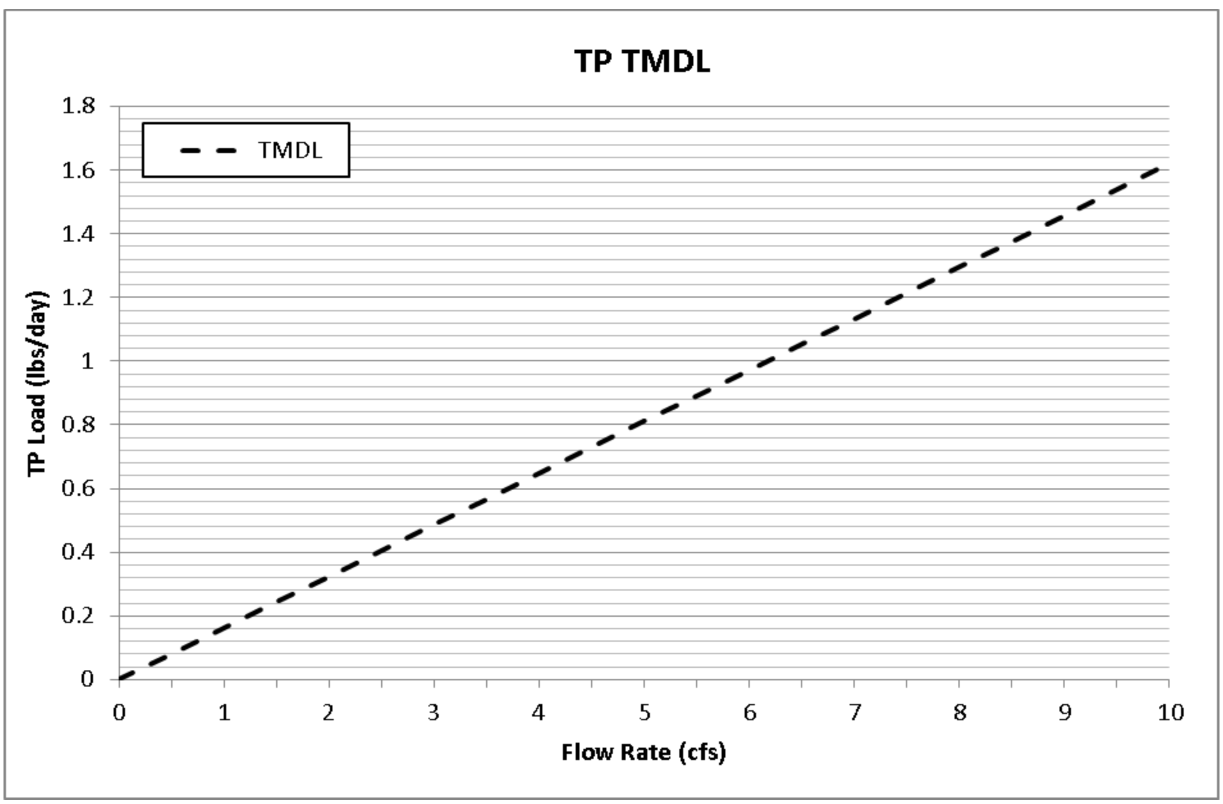

Figure 5-4. TMDL for TP for streamflows ranging from 0 to 10 cfs

5.6 Source Assessment

This section provides the approach used for source assessment, which characterizes the type, magnitude, and distribution of sources contributing to nutrient loading to impaired streams, and establishes the approach used to develop TMDLs for each stream and allocations to specific source categories in five of the six watersheds identified in **Table 5-1**. Nutrient source assessment was performed on Blaine Spring Creek, and is discussed below in **Section 5.6.2**, but nutrient TMDLs will not be developed for Blaine Spring Creek at this time, as discussed above in **Section 5.5**. Source characterization and assessment to determine the major sources in each of the nutrient impaired waterbodies was conducted by using monitoring data collected from the Madison TMDL Planning Area from 2007-2016, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Assessment of existing nutrient (i.e., TN, NO_3+NO_2, and TP) sources is needed to understand Load Allocations (LAs), and load reductions for different source categories. Source characterization links nutrient sources, nutrient loading to streams, and water quality response, and supports the formulation of the allocation portion of the TMDL.

Land use in the Madison TMDL Planning Area primarily consists of agriculture (dryland and irrigated cropland, pasture, and rangeland), silviculture (timber harvest and forest roads), historical mining, and residential development, including subsurface wastewater disposal and treatment. There is one permitted point source discharge, which is on Blaine Spring Creek. Nutrient loading in the Madison TMDL Planning Area is coming from three source types: 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering; 2) human-caused nonpoint sources dispersed across the landscape (e.g., agriculture, residential development, historical mining, and timber harvest); and 3) human-caused point sources (permitted discharges). These sources may include a variety of discrete and diffuse pollutant inputs that have differing pathways to a waterbody. Ideally sampling is conducted in a way that helps with the identification of these pathways.

The most recent water quality sampling data used to determine existing nutrient water quality conditions and potential sources in the Madison TMDL Planning Area were collected between 2007 and 2016. These data were collected to 1) evaluate attainment of water quality targets, 2) assess load contributions from nutrient sources, and 3) provide rationale for specific TMDL allocations. Data used to conduct these analyses are publicly available at: http://www.epa.gov/storet/dw_home.html.

5.6.1 Description of Nutrient Sources

5.6.1.1 Point Source Discharges

Sources of pollution originating from a point source wastewater discharge are permitted and regulated through the Montana Pollutant Discharge Elimination System (MPDES) administered by Montana DEQ. The goal of the MPDES program is to control point source discharges of wastewater such that water quality in state surface water is protected. Levels of water quality that are required to maintain the various beneficial uses of state surface waters are set forth in the water quality standards. There are two types of discharge permits: general and individual. A MPDES General Permit is a pre-existing permit for wastewater discharges associated with common activities, such as concentrated animal feeding operations and storm water discharges from construction or industrial activity. Authorizations for General Permits are issued if a facility or activity falls within the guidelines of the existing permit. Individual MPDES Permits regulate wastewater discharges from point sources that do not fall under the guidelines for a General Permit. The individual permitting process is more rigorous, as individual permits address the specific conditions of the facility or activity needing authorization.

All point sources of wastewater discharge are required to obtain and comply with MPDES permits. The effluent limitations and other conditions for certain categories of wastewaters are required to be treated to federally-specified minimum levels based on available and achievable water treatment technologies. Additionally, effluent limits and permit conditions are established to protect beneficial uses and applicable water quality standards. Each MPDES permit issued is designed to protect the state surface water quality at the point of discharge. In addition, recognizing the dynamic nature of streams and the potential additive or cumulative effects of pollutants, MPDES permits also address stream reach or basin-wide pollution problems. If a TMDL has been developed for a waterbody, any appropriate wasteload allocations (WLAs) will be incorporated into the MPDES permits discharging to that waterbody.

Montana Pollutant Discharge Elimination (MDPES) Permitted Facilities
There is one MPDES permitted facility that discharges to a waterbody of concern in the Madison TMDL Planning Area: the Ennis National Fish Hatchery (**Table 5-17**). The permit for the Ennis National Fish Hatchery is a Concentrated Aquatic Animal Production general permit.

Table 5-17. Ennis National Fish Hatchery MPDES Permit Details

Facility Name	Permit Number	Permit Expiration Date	Receiving Waterbody
Ennis National Fish Hatchery	MTG13008	June 30, 2021	Blaine Spring Creek

The Ennis National Fish Hatchery is owned and operated by the U.S. Fish & Wildlife Service. The hatchery has been in operation since 1933 and is in the headwaters of Blaine Spring Creek. This facility raises broodstock trout as part of the National Broodstock Program to produce about 20 million eggs annually. In addition to egg production, the facility also produces fingerling trout for stocking at lakes throughout Montana. The hatchery captures Blaine Springs at three sources, where water is gravity fed to hatchery buildings for use, and then discharges water that has passed through raceways via five surface water discharge points back into Blaine Spring Creek. This discharge and its potential nutrient loading impacts are further discussed in the Blaine Spring Creek source assessment (**Section 5.6.2**).

5.6.1.2 Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include: reduction in vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas as a result of over grazing, breakdown of excrement and loading via surface and subsurface pathways delivery from grazed forest and rangeland during the growing season, transport of fertilizer applied in late spring via overland flow and groundwater, and the increased mobility of phosphorus caused by irrigation-related saturation of soils in pastures (Green and Kauffman, 1989). Agricultural sources of excess nutrients are identified by looking at cropland data, grazing allotment data and management plans, aerial imagery, observed land use impacts, and land use history in relation to water quality and sediment monitoring sites. This approach can help identify hot spots that excess nutrients are likely coming from.

Irrigated and Dryland Cropping
Cropping in the watersheds of nutrient impaired waterbodies in the Madison River TMDL Planning Area is minimal (**Figure 2-13**). Cropland in these watersheds is predominately irrigated production of alfalfa

hay and pasture/hay, with smaller acreages of irrigated and dryland cultivated cropland. Irrigated lands are usually in continuous production and have annual soil disturbance and fertilizer inputs. Dryland cropping may have fallow periods of 16 to 22 months, depending on site characteristics and landowner management. Nutrient pathways include overland runoff, deep percolation, and shallow groundwater flow, which transport nutrients off site.

Livestock Grazing

Grazing on rangeland and in pastures is common in the Madison River TMDL Planning Area (**Figure 2-13**). Cattle are allowed to roam and are generally not concentrated along the valley bottoms during the growing season when many pasture systems are hayed. Horses may also be allowed to roam and graze though they have been mostly observed on small acreage lots that are fenced. Pastures are managed for hay production during the summer and for grazing during the fall through spring. Hay pastures are thickly vegetated in the summer; less so in the fall through spring. The winter grazing period is typically long (October–May) and trampling and feeding further reduces biomass when it is already low. Commercial fertilizers are used infrequently in the watershed, and naturally applied cattle manure is a more significant source of nutrients. Cattle manure occurs in higher quantities on pasture ground from October through May because of much higher cattle density than that found on range and forested areas. Rangeland is typically grazed during the summer in the watershed. Rangeland differs from pasture in that rangeland has much less biomass and therefore contributes fewer nutrients from biomass decay. However, manure deposition does play a role. This manure deposition can result in significant nutrient contribution to an impaired waterbody.

Although no livestock grazing data were collected for private or state managed lands, grazing allotment data were collected from the BLM and USFS on the federally managed lands and were compiled per impaired waterbody watershed as total Animal Unit Months (AUM) per drainage. An assumption was made that livestock management on private and state lands is similar to the federally managed lands. The BLM does not make an annual “count” of the livestock that graze on BLM-managed lands because the actual number of livestock grazing on public lands on any single day varies throughout the year and livestock are often moved from one grazing allotment to another. Instead, the BLM compiles information on the number of AUMs used each year, which takes into account both the number of livestock and the amount of time they spend on public lands (U.S. Department of Interior, Bureau of Land Management 2016).

Total AUMs were determined only for allotments that have some areas draining to an impaired waterbody. These numbers constitute the existing permits for grazing leases on public lands within grazing allotments and represent a maximum number of AUMs possible at any one time. AUMs are reported for public lands within each allotment. However, since allotment boundaries differ from the watershed boundaries, a distinction is made between grazing on public land within the entire allotment and on public land within the allotment that also lies within the sub-watershed boundary. No attempts were made to verify actual grazing practices or current stocking densities and this compilation is for coarse source assessment purposes only.

5.6.1.3 Residential Development and Subsurface Wastewater Disposal and Treatment

Residential development in a watershed can contribute to nutrient issues through lawn fertilization (including parks, golf courses, etc.), and increased stormwater runoff due to an increase in impermeable surfaces. Residential development in the Madison watershed is concentrated around the Ennis area and Moore Creek, although several watersheds containing nutrient streams of concern are impacted by residential development, specifically Blaine Spring Creek, South Meadow Creek, Hot Springs Creek around the town of Norris, and lower O'Dell Spring Creek near Ennis. The Elk Creek watershed has relatively low levels of residential development (**Figure 5-10**).

Discharge of septic effluent from individual and community septic systems that discharge to groundwater may contribute to nutrient loading in streams depending on a combination of discharge, soils, and distance from the downgradient waterbody. Septic systems, even when operating as designed, can contribute nutrients to surface water through subsurface pathways. These sources are accounted for by using septic density mapping and water quality data to determine if subsurface wastewater treatment and disposal was having an identifiable effect on nutrient loading. The Method for Estimating Attenuation of Nutrients from Septic Systems (MEANSS) model was used to determine the nutrient load coming from septic systems in a particular watershed, model results are provided for impaired waterbodies in **Section 5.6** and **Appendix B**.

5.6.1.4 Silviculture

A significant portion of the Madison TMDL Planning Area is on forested lands administered by the U.S. Forest Service (USFS) specifically the Beaverhead-Deerlodge and Gallatin National Forests, and lands administered by the Bureau of Land Management (BLM). Silviculture practices inevitably cause some measure of downstream effects that may or may not be significant over time. Changes in land cover will alter the rate at which water evapotranspires and thus the water balance; in that the distribution of water between base flow and runoff will change. Disturbances of the ground surface will also disrupt the hydrological cycle. The combination of these changes can alter water yield, peak flows, and water quality (Jacobson, 2004). Changes in biomass uptake and soil conditions will affect the nutrient cycle. Elevated nitrate concentrations result from increased leaching from the soil as mineralization is enhanced. This increase generally only lasts up to 2 or 3 years before returning to pre-harvest levels (Feller and Kimmins 1984; Likens et al. 1978) (Martin and Harr 1989). Nutrient uptake by biomass is also greatly reduced after timber harvest, leaving more nutrients available for runoff. Loading from silviculture is not estimated in this document because timber harvest occurs in specific locations within a watershed that differ from one year to the next. In addition, the effect of timber harvest on instream nutrient levels is short term and would be difficult to model as a general effect. In lieu of loading estimates, water quality data were examined in relationship to harvest records to determine if timber harvest is having an identifiable effect.

An assessment of timber harvest operations for the watersheds of interest in the Madison TMDL Planning Area that have nutrient impaired waterbodies was made based on harvest data collected by the U.S. Forest Service from 1820 to present, and by using the Montana Spatial Data Infrastructure geospatial land cover data layer. The extent of timber harvest operations is displayed in the source assessment maps for each waterbody. These data were used to better understand recent operations by scale and location in comparison with available water chemistry data.

5.6.1.5 Mining

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. Nutrient impacts from mining can result from the use of blasting (e.g., TNT), which introduces nitrate, and the use of cyanide, which introduces TN. Concentration of potential contaminants depends on whether these methods were used, the timing of when mining has taken place, mechanism of chemical release, streamflow, and water chemistry. Mining has taken place at specific locations within the Madison TMDL Planning Area, and much of the mining ceased during or before the mid-1900s. As a result, loading from mining was not estimated; instead, water quality data were examined in relationship to specific mine locations to determine if mining was having an identifiable effect on nutrient loading.

5.6.1.6 Natural Background

Load allocations for natural background sources in all impaired segments are based on median concentration values from reference sites in the Middle Rockies Level III Ecoregion, as applicable, during the July 1 to September 30 growing season. For the Middle Rockies Ecoregion, these values are TN = 0.095 mg/L, TP = 0.01 mg/L (Suplee and Watson 2013), and NO_3+NO_2 = 0.02 mg/L (Suplee et al. 2007). Reference sites were chosen to represent stream conditions where human activities may be present but do not negatively harm stream uses. Natural sources of nutrients such as wildlife excrement, and the effects of natural events such as flooding, fire, and beetle kill may be captured at these sites. Nutrient contributions from these sources vary from site to site, but using the median concentration value accounts for site specific variability. Natural background loads are calculated by multiplying the median reference concentration by the streamflow.

5.6.2 Blaine Spring Creek Source Assessment

Nutrient inputs to Blaine Spring Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed), and one point source, which are shown in **Figure 5-5**. DEQ identified the following source categories that contribute nutrients in the Blaine Spring Creek watershed:

- Point source discharges
- Agriculture (irrigated cropping and pasture/rangeland/forest grazing, excluding aquaculture)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Natural background

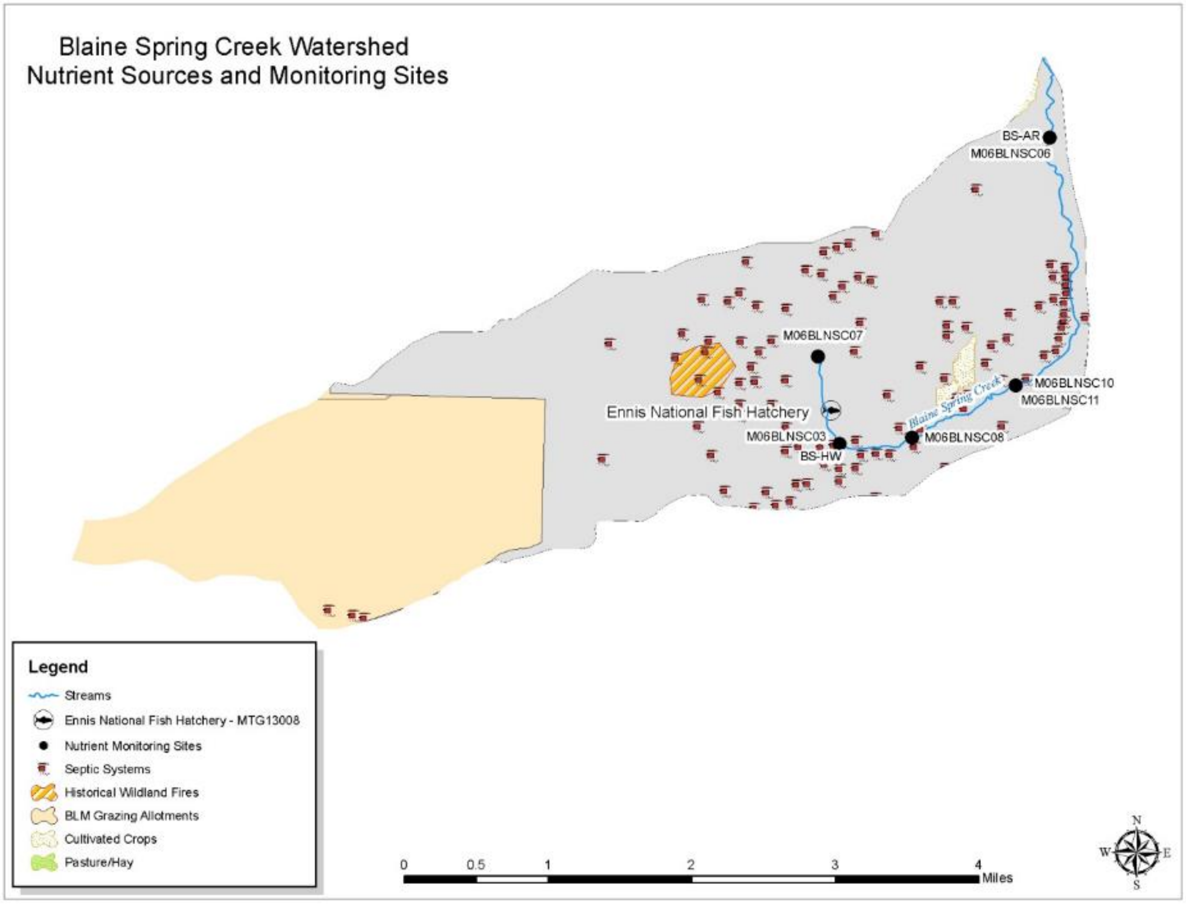

Figure 5-5. Map showing water quality monitoring sites and sources of nutrients in the Blaine Spring Creek watershed

Figures 5-6, 5-7, and **5-8** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on Blaine Spring Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

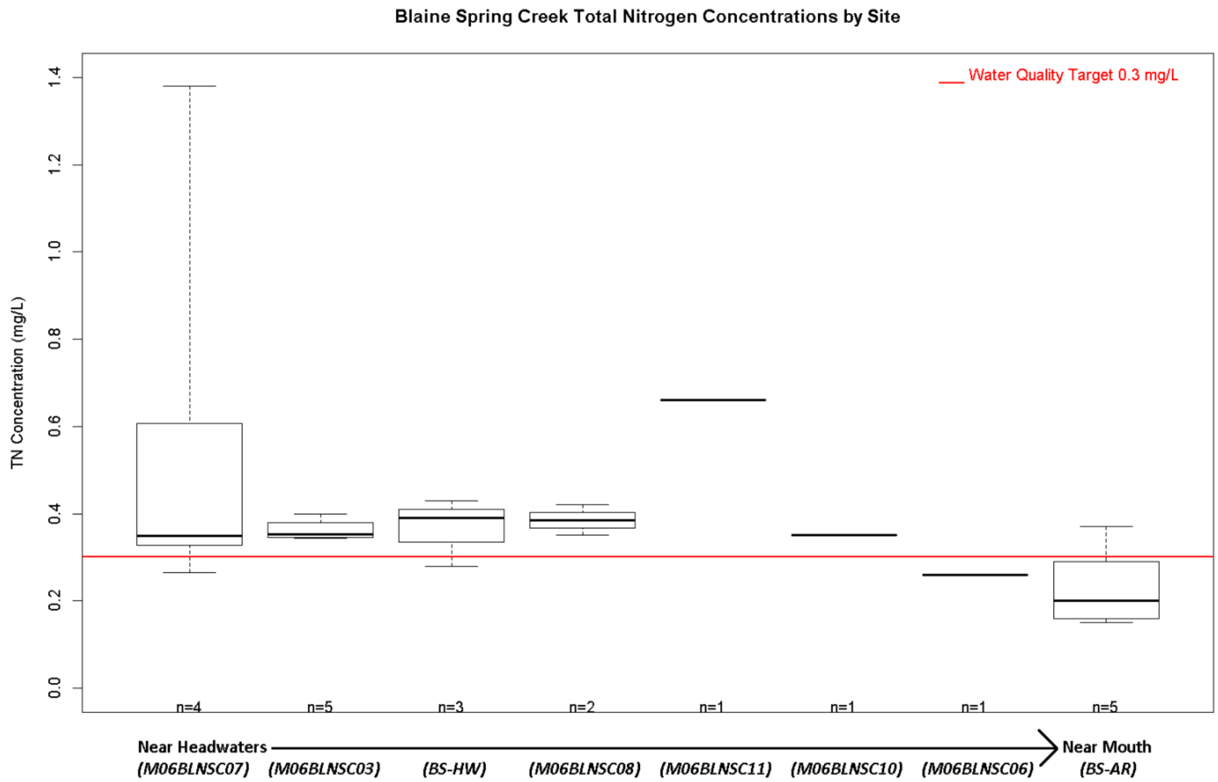

Figure 5-6. Box plot displaying the TN concentration data by monitoring site for Blaine Spring Creek

As shown in **Figure 5-6**, TN concentrations are routinely greater than the TN target of 0.3 mg/l near the headwaters of Blaine Spring Creek. As flows increase further downstream, the in-stream TN concentrations remain elevated, which implies that there are TN sources downstream of the fish hatchery causing an increased overall TN load.

Monitoring sites M06BLNSC11 and M06BLNSC10 were unique samples conducted for source assessment purposes outside of the routine nutrient sampling effort, and the elevated TN concentration at site M06BLNSC11 may indicate that there was a localized nutrient source that particular day. M06BLNSC11 was located upstream of the intersection with the Shewmaker Ditch, and M06BLNSC10 was located downstream of the intersection with the Shewmaker Ditch, indicating that there was some dilution from the Shewmaker Ditch on the day of sampling. This is further described in **Section 5.6.2.2**. The two furthest downstream monitoring sites (M06BLNSC06 and BS-AR) are located in the floodplain of the Madison River and are likely receiving groundwater inputs to the stream in that section, which is having a dilution effect on TN concentrations.

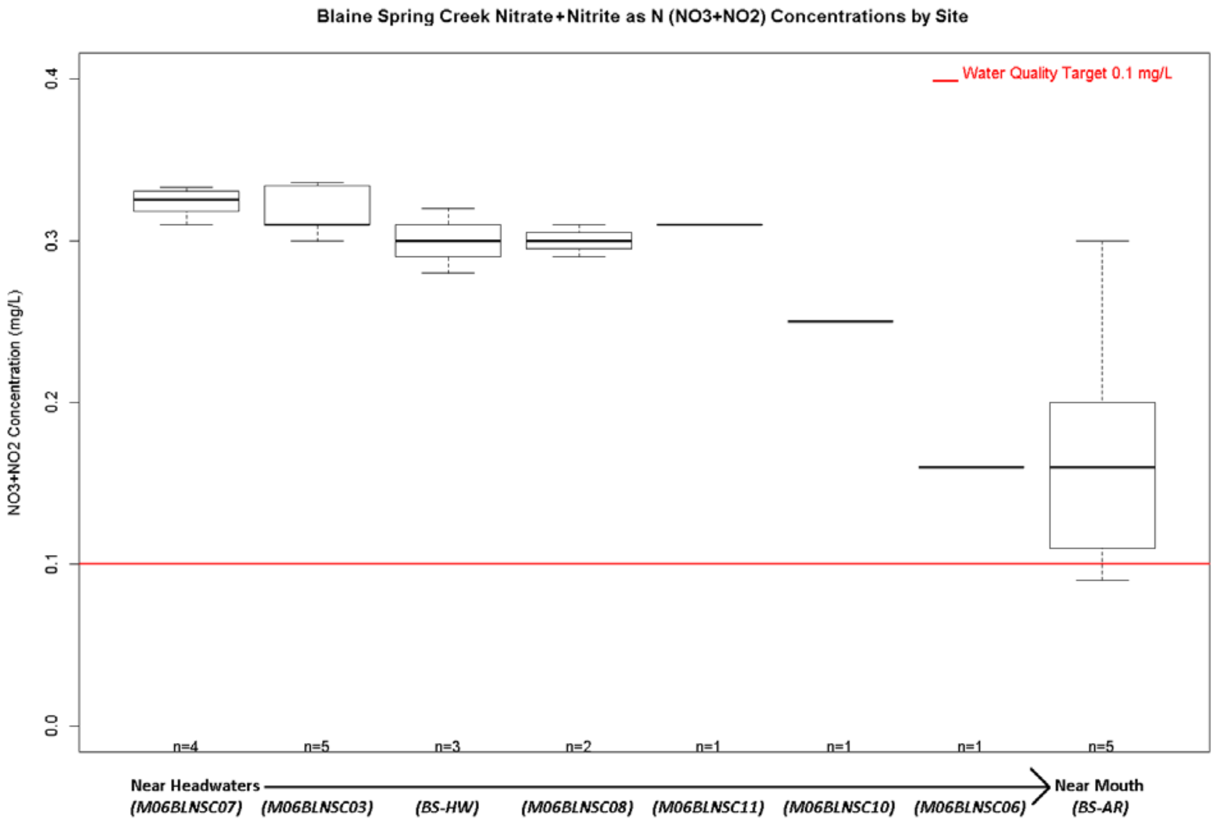

Figure 5-7. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for Blaine Spring Creek

NO_3+NO_2 concentrations follow a similar pattern to TN concentrations, with elevated NO_3+NO_2 concentrations near the headwaters of Blaine Spring Creek, and lower NO_3+NO_2 concentrations as the stream enters the Madison River floodplain and gains flow via groundwater. Sources of TN and NO_3+NO_2 are similar, which is reflected in the data, and visually in **Figures 5-6** and **5-7**.

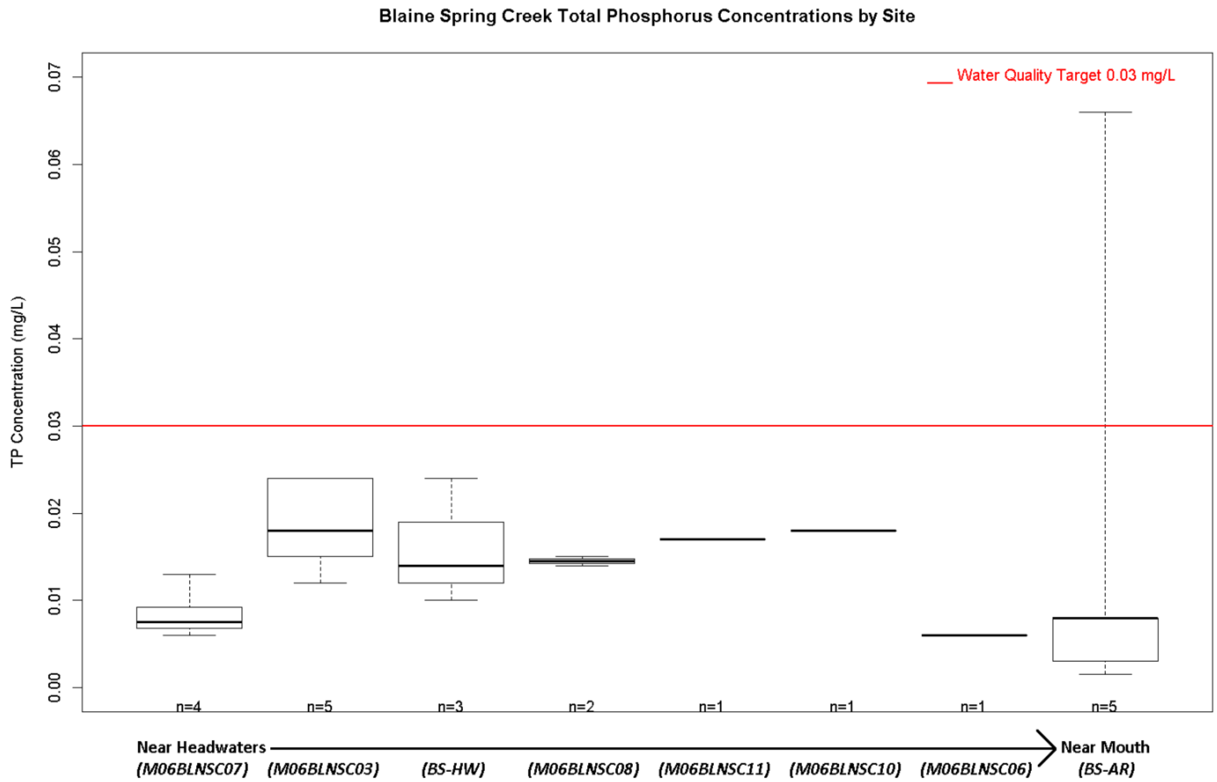

Figure 5-8. Box plot displaying the TP concentration data by monitoring site for Blaine Spring Creek

TP concentrations in Blaine Spring Creek are generally low throughout the length of the stream, except for one sample near the mouth that contained elevated concentrations of TP, likely due to a localized source of TP at the time of sampling. It was determined that Blaine Spring Creek is not impaired by TP.

5.6.2.1 Blaine Spring Creek Point Sources of Nutrients

There is one permitted point source in the Blaine Spring Creek watershed: the Ennis National Fish Hatchery, which is owned and operated by the U.S. Fish & Wildlife Service, is located in the headwaters of Blaine Spring Creek at the spring source. This facility has a Montana Pollutant Discharge Elimination System permit, covered under the Concentrated Aquatic Animal Production (CAAP) General Permit.

This facility raises broodstock trout as part of the National Broodstock Program to produce about 20 million eggs annually. In addition to egg production, the facility also produces fingerling trout for stocking at lakes throughout Montana. Operating as a continuous flow-through system, the hatchery captures Blaine Spring Creek at three sources, where water is gravity fed to hatchery buildings for use, and then discharges water that has passed through raceways via five surface water discharge points back into Blaine Spring Creek. Prior to 2016, facilities permitted under Montana's CAAP General Permit were not required to monitor for nutrients in their effluent; therefore, effluent nutrient data for the Ennis National Fish Hatchery did not exist when the nutrient source assessment discussed in this document was conducted for Blaine Spring Creek.

Aquaculture facilities can contribute significant loads of nutrients, as well as suspended solids, to a waterbody. During cleanings of the raceways and hatchery tanks, pulses of nutrients and suspended solids were entering Blaine Spring Creek. It is unlikely that the water quality data collected by Montana DEQ and the Madison Stream Team (**Appendix A**) was able to accurately capture these pulses of nutrients and TSS moving through the system to help quantify the load coming from the hatchery.

In 2016, the hatchery began operating a subsurface vertical-flow wetlands treatment system that discharges to an underground drainfield. The system is designed to remove nutrients and capture solids during cleanings of the raceways and hatchery tanks. The data presented in this document for Blaine Spring Creek was collected prior to 2016 before the wetland treatment system was installed, and therefore represents pre-treatment conditions.

5.6.2.2 Blaine Spring Creek Nonpoint Sources of Nutrients

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-5** shows the location of agricultural land in the Blaine Spring Creek watershed in relation to water quality monitoring sites.

Irrigated and Dryland Cropping

Cropland in the Blaine Spring Creek watershed is primarily hay and pasture land, most of which is non-irrigated (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Nutrient pathways include overland runoff, deep percolation to groundwater, and shallow groundwater flow, all of which may transport nutrients off site. Lower in the watershed, the Shewmaker Ditch, an irrigation supply ditch containing water from the Madison River crosses Blaine Spring Creek. Water quality sampling above and below this crossing was conducted by DEQ in September 2014, and indicated that water from the Shewmaker Ditch is mixing with Blaine Spring Creek water; see **Figure 5-9**. TN and NO_3+NO_2 concentrations in the ditch were lower than those in Blaine Spring Creek; therefore, the mixing is having a dilution effect for those nutrient parameters. TP concentrations however were slightly higher in the ditch than in Blaine Spring Creek, possibly due to a higher concentration of TSS in the ditch, and therefore the Shewmaker Ditch is acting as a source of TP to Blaine Spring Creek. These trends are shown in **Figures 5-6, 5-7,** and **5-8** at monitoring sites M06BLNSC011 (upstream of intersection with ditch) and M06BLNSC010 (downstream of intersection with ditch).

Figure 5-9. Photo showing Shewmaker Ditch crossing Blaine Spring Creek and mixing on the left of the photo

Livestock Grazing

Grazing on rangeland and pastures is common in the Blaine Spring Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of nutrients. Livestock manure from corrals must also be properly managed to avoid runoff into surface water. In addition to private land grazing, there is one public land grazing allotment in the Blaine Spring Creek watershed, the Axolotl Lakes allotment on BLM managed land (**Figure 5-5**). The allotment is described as follows in **Table 5-18**. The 2009 Madison Watershed Assessment Report from the BLM indicated that the Axolotl Lakes allotment is currently meeting BLM's healthy rangeland standards for upland, riparian wetland, and air quality, but not biodiversity due to loss of whitebark pine. It was determined by the BLM that livestock management was not a significant factor in failing to meet the standard for biodiversity (U.S. Department of the Interior, Bureau of Land Management (BLM) 2009a; BLM 2009b).

Table 5-18. Public Land Grazing Leases in the Blaine Spring Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Axolotl Lakes	BLM	2,174.2	4,296	51%	749	No[1]

Table 5-18. Public Land Grazing Leases in the Blaine Spring Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives

[1] The allotment is not meeting the standard for biodiversity, but it was determined that livestock management is not the cause

Residential Development and Subsurface Wastewater Treatment and Disposal

There is a fair amount of residential development in the Blaine Spring Creek watershed, and as a result, septic system densities are relatively high in the middle to lower portions of the watershed (**Figure 5-5)**. Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the Blaine Spring Creek watershed can be found in **Table 5-19** below.

Table 5-19. Nutrient Loading Estimates from Septic Systems in the Blaine Spring Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	131	47.48%	10.95	5.75
Total Phosphorus	131	92.44%	2.31	0.17

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Natural Background

Water quality data collected at the source of Blaine Springs above the influence of the fish hatchery (monitoring site M06BLNSC07) indicates elevated concentrations of TN above the current nutrient standard of 0.30 mg/L, with a large proportion of that being inorganic nitrogen (nitrate + nitrite as N). Because the water coming out of the springs is elevated in TN and there is generally a lack of upstream nutrient sources contributing loads to groundwater, the potential exists that the source of TN is likely natural and therefore further investigation is needed as to whether site-specific nutrient standards will need to be developed for Blaine Spring Creek. Because TN levels in Blaine Spring Creek exceed the current nutrient standard, it will remain listed as impaired by TN in the 2016 Integrated Report, but a TMDL for TN is not scheduled to be completed at this time until the relationship of natural sources of TN to the anthropogenic sources of TN is better understood in Blaine Spring Creek (Montana Department of Environmental Quality, Water Quality Division, Water Quality Planning Bureau 2016).

One wildland fire has occurred in the Blaine Spring Creek watershed in 1989. **Figure 5-5** shows the location of the wildland fire in the Blaine Spring Creek watershed, and **Table 5-20** shows the fire details. Wildland fire can affect the nutrient concentrations in streams by contributing to increased sediment deposition due to lack of upland ground cover. Nutrients, especially phosphorus, can be associated with these soil particles. Although the burned area is located upstream of the Blaine Spring Creek source, any historical nutrient loading caused by this fire would not be expressed at the spring source (monitoring site M06BLNSC07), nor would any nutrient loading effects from this fire be expressed in current water chemistry data, due to the age of the burn.

Table 5-20. Wildland Fires in the Blaine Spring Creek Watershed

Fire Name	Acres Burned	Year
Hatchery	79	1989

5.6.3 Elk Creek Source Assessment

Nutrient inputs to Elk Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed), which are shown in **Figure 5-10**. There are no permitted point sources in the Elk Creek watershed. DEQ identified the following source categories that contribute nutrients in the Elk Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Mining
- Natural background

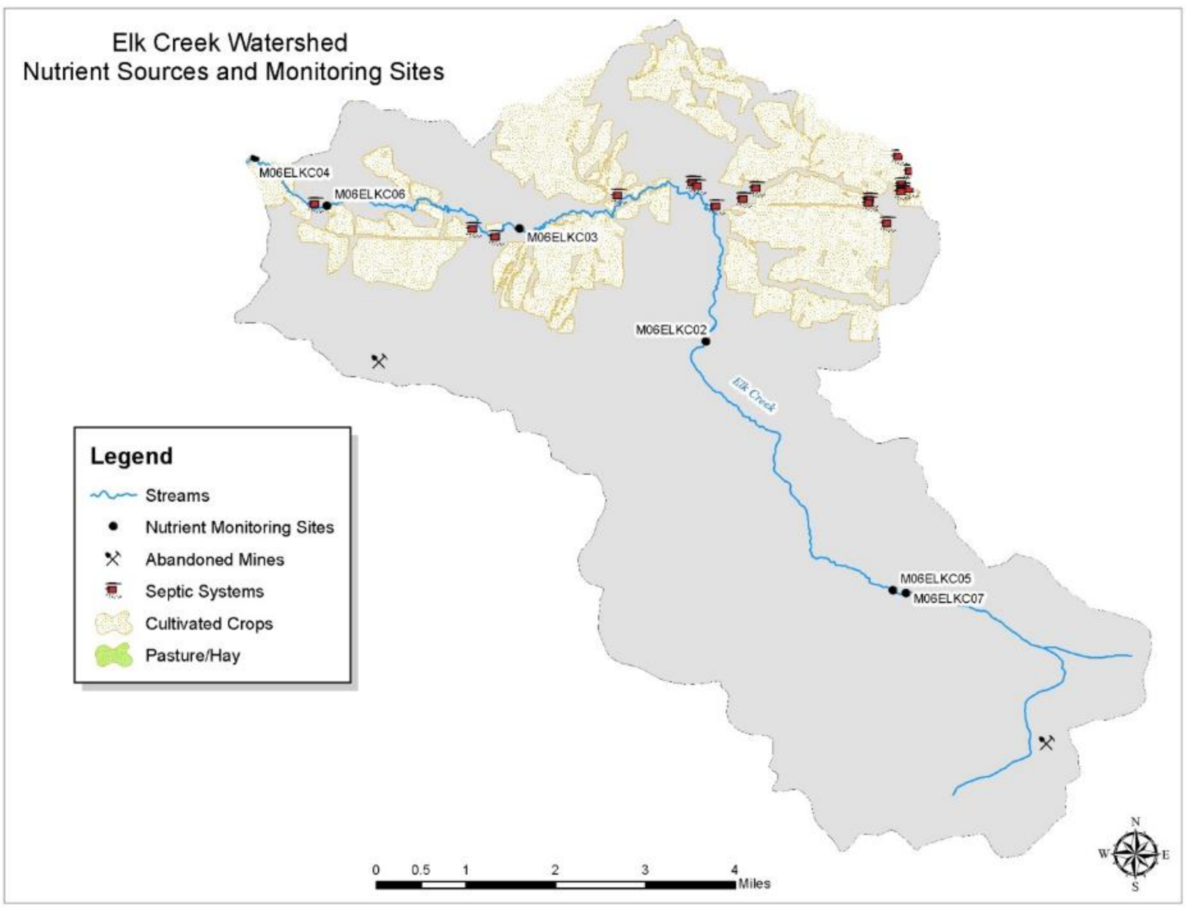

Figure 5-10. Map showing water quality monitoring sites and sources of nutrients in the Elk Creek watershed

This section contains nutrient source assessment information for the Elk Creek watershed**. Figures 5-11, 5-12**, and **5-13** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on Elk

Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

Figure 5-11. Box plot displaying the TN concentration data by monitoring site for Elk Creek

Elk Creek near the headwaters has relatively low concentrations of TN (**Figure 5-11**). Moving downstream, TN concentrations in Elk Creek generally increase, with exceedances of the 0.3 mg/L TN target at the furthest three downstream monitoring sites. This indicates that there are few sources of TN near the headwaters of Elk Creek, and the majority of the TN load enters the stream between monitoring sites M06ELKC02 and M06ELKC03. There is a land use change in this area from rangeland to cultivated crops (**Figure 5-10**), indicating that agricultural practices may be contributing to the increase in TN loads to Elk Creek. Individual septic systems found in this area can also be sources of TN loading to Elk Creek. This is further discussed in **Section 5.6.3.2**.

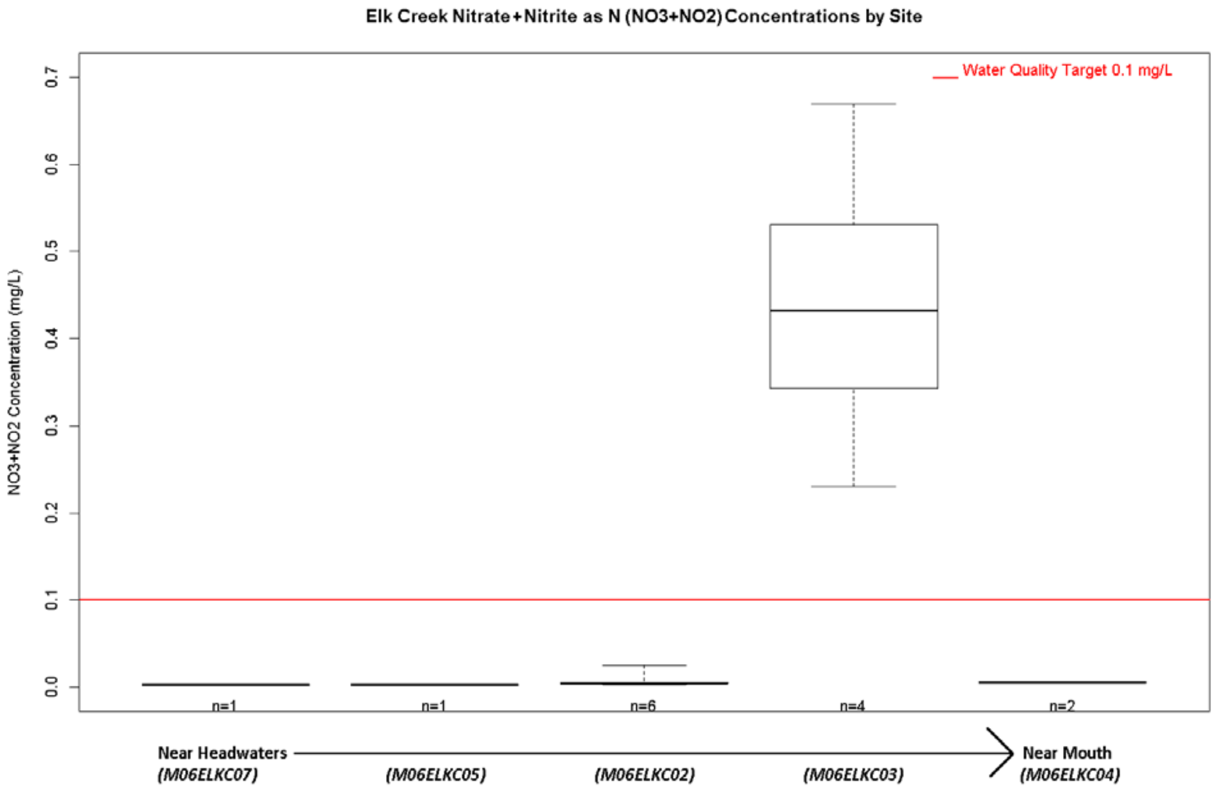

Figure 5-12. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for Elk Creek

NO_3+NO_2 concentrations in Elk Creek are generally low except for monitoring site M06ELKC03, which had all four samples from that location exceed the NO_3+NO_2 target of 0.1 mg/L. This indicates that there may be a localized source of NO_3+NO_2 in this area, and directly corresponds with the increase in TN at this location. This is likely due to agricultural practices and individual septic systems in the area and is discussed in further detail in **Section 5.6.3.2**.

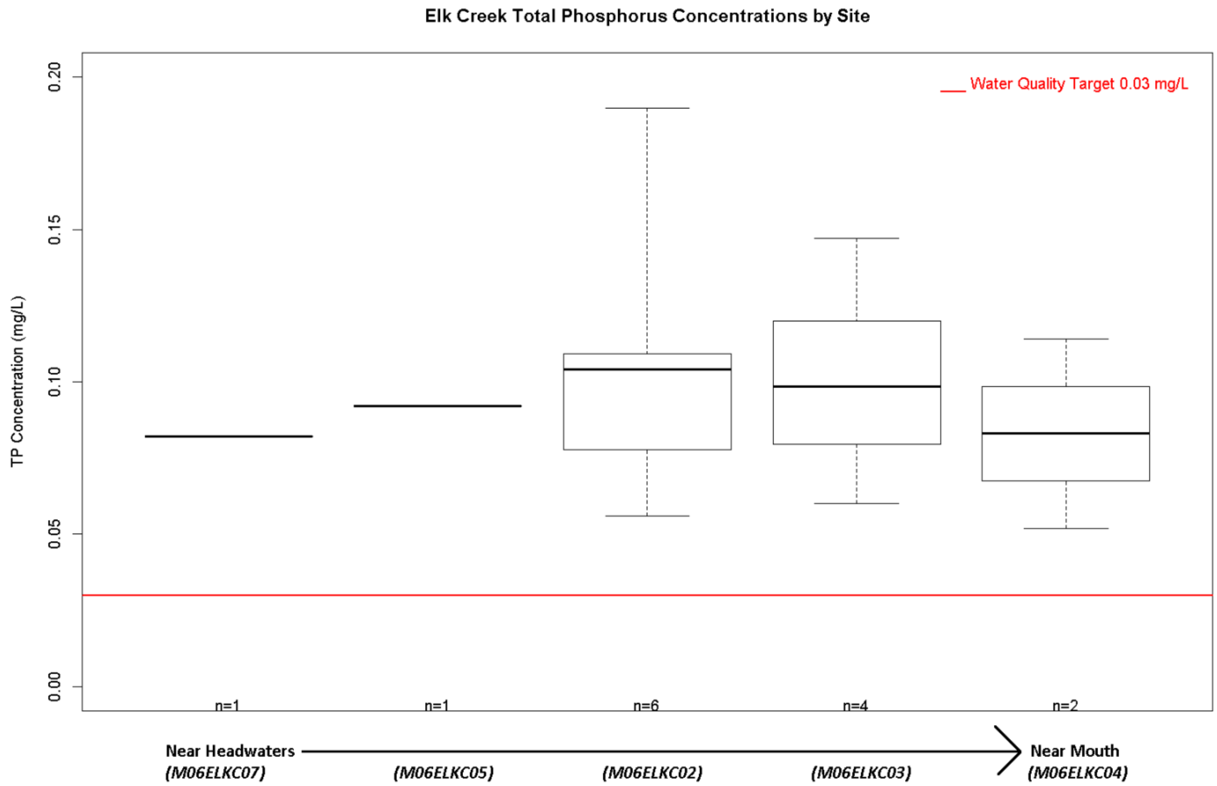

Figure 5-13. Box plot displaying the TP concentration data by monitoring site for Elk Creek

As shown in **Figure 5-13**, TP concentrations are routinely greater than the TP target of 0.03 mg/l near the headwaters of Elk Creek. As flows increase further downstream, the in-stream TP concentrations remain elevated, which implies that there are TP sources throughout Elk Creek causing an elevated TP load.

5.6.3.1 Elk Creek Point Sources of Nutrients

No permitted point source discharges have been identified in the Elk Creek watershed.

5.6.3.2 Elk Creek Nonpoint Sources of Nutrients

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-10** shows the location of agricultural land in the Elk Creek watershed in relation to water quality monitoring sites.

Irrigated and Dryland Cropping

Cropland in the Elk Creek watershed is primarily dryland small grains production (specifically wheat and barley) and irrigated and dryland hay and pasture land (grass and alfalfa) (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Dryland cropping may have fallow periods, depending on site characteristics and landowner management. At the water quality monitoring site M06ELKC03, there is a noticeable spike in TN and NO_3+NO_2 concentrations, which is located downstream of cropland area. The three upstream sites (M06ELKC02, M06ELKC05, and M06ELKC07) are all upstream of any crop production, suggesting that the spike in TN and NO_3+NO_2 concentrations may be caused by loading from excess nitrogen fertilizer applied on cropland. These trends are shown in **Figures 5-11** and **5-12**. Cropland can be a source of TP to Elk Creek also, and although TP concentrations are elevated near the headwaters, they remain elevated throughout Elk Creek, which indicates that there are sources of TP along the entirety of Elk Creek.

<u>Livestock Grazing</u>

Grazing on rangeland and pastures is common in the Elk Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. There are no public land grazing allotments in the Elk Creek watershed, and all the grazing occurs on privately owned lands (**Figure 5-10**). Livestock grazing occurs in the upper portions of the Elk Creek watershed, and could be contributing to the elevated TP concentrations in Elk Creek found at monitoring sites M06ELKC07, M06ELKC05, and M06ELKC02. Between monitoring sites M06ELKC02 and M06ELKC03, there are areas where livestock corrals are located adjacent to Elk Creek, which could be a potential source of TN and TP to the stream if animal waste is not properly managed.

Residential Development and Subsurface Wastewater Treatment and Disposal

Septic systems in the Elk Creek watershed are at relatively low densities, and are all located downstream of the monitoring site M06ELKC02 (**Figure 5-10)**. This also correlates with a spike in TN and NO_3+NO_2 at the next downstream monitoring site, M06ELKC03 **(Figures 5-11** and **5-12)**. The spike in TN and NO_3+NO_2 could be related to loading from septic systems in addition to loading from excess nitrogen fertilizer applied to cropland (as discussed above). Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the Elk Creek watershed can be found in **Table 5-21** below.

Table 5-21. Nutrient Loading Estimates from Septic Systems in the Elk Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	17	65.88%	1.42	0.48
Total Phosphorus	17	96.47%	0.30	0.01

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Mining

The density of abandoned mines in the Elk Creek watershed is much less than that of neighboring watersheds like the Hot Springs Creek watershed. Two abandoned mines have been identified in the Elk Creek watershed, one near the headwaters of Elk Creek, and another at the headwaters of a tributary to lower Elk Creek (**Figure 5-10**). These mines have not been designated as priority sites by the DEQ Abandoned Mine Lands program, and therefore are not anticipated to be a significant contributor of nutrients in the Elk Creek watershed. The TN and NO_3+NO_2 concentration data collected in relation to abandoned mine locations on Elk Creek confirm that abandoned mines are likely not a significant contributor of nutrients to Elk Creek.

Natural Background
Natural background concentrations of nutrients have been quantified for Elk Creek as discussed above in **Section 5.6.1.6**.

5.6.4 Hot Springs Creek Source Assessment

Nutrient inputs to Hot Springs Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed), which are shown in **Figure 5-14**. There are no permitted point sources in the Hot Springs Creek watershed. DEQ identified the following source categories that contribute nutrients in the Hot Springs Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Silviculture (timber harvest)
- Mining
- Natural background

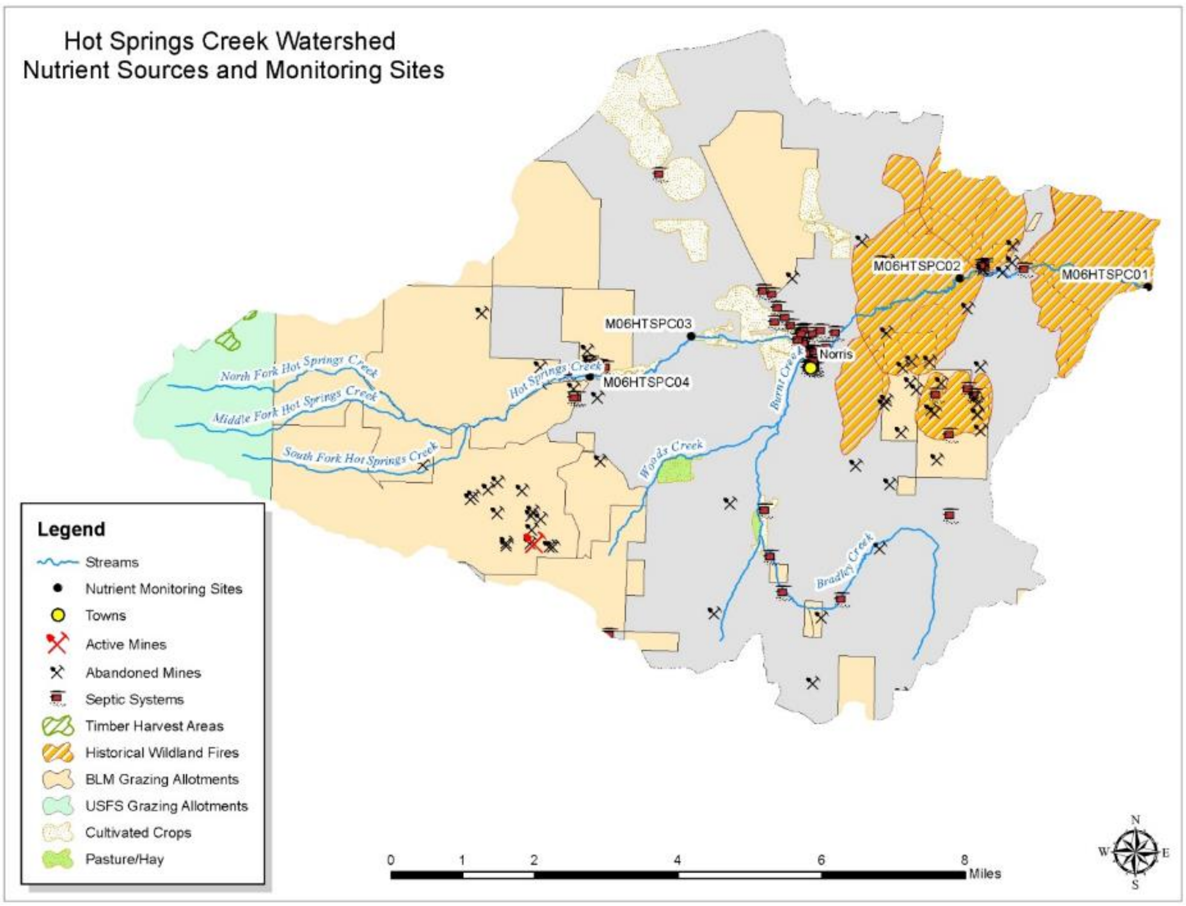

Figure 5-14. Map showing water quality monitoring sites and sources of nutrients in the Hot Springs Creek watershed

This section contains nutrient source assessment information for the Hot Springs Creek watershed. **Figures 5-15, 5-16,** and **5-17** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on Hot Springs Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

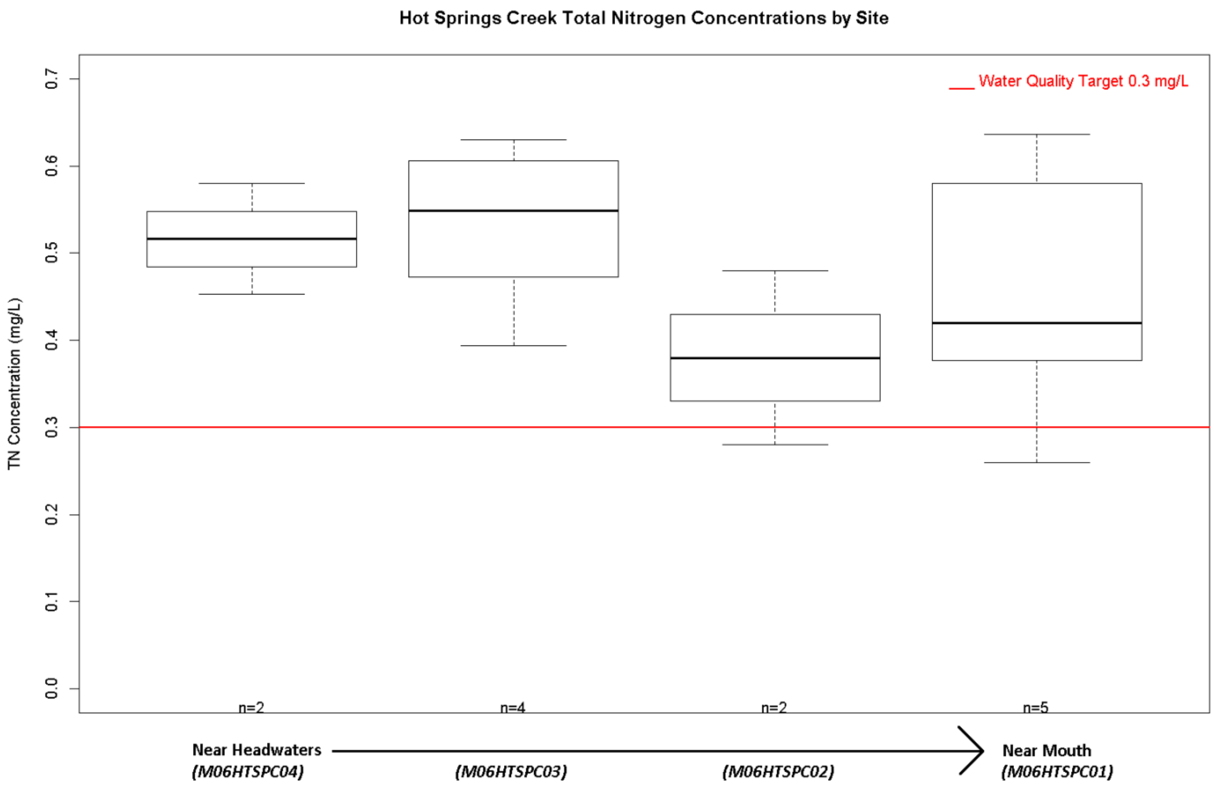

Figure 5-15. Box plot displaying the TN concentration data by monitoring site for Hot Springs Creek

As shown in **Figure 5-15**, TN concentrations are elevated at the most upstream monitoring site (M06HTSPC04), and remain above the target concentration of 0.3 mg/L TN throughout the length of Hot Springs Creek. This indicates that sources of TN are present in the headwaters of Hot Springs Creek, and although flow is increasing downstream, the TN concentrations remain relatively constant, indicating that there are sources of TN throughout the rest of the watershed. Sources of TN in the headwaters are likely livestock grazing and abandoned mines, while further down in the watershed, cropland and residential development are found in addition to livestock grazing and abandoned mines (**Figure 5-14**).

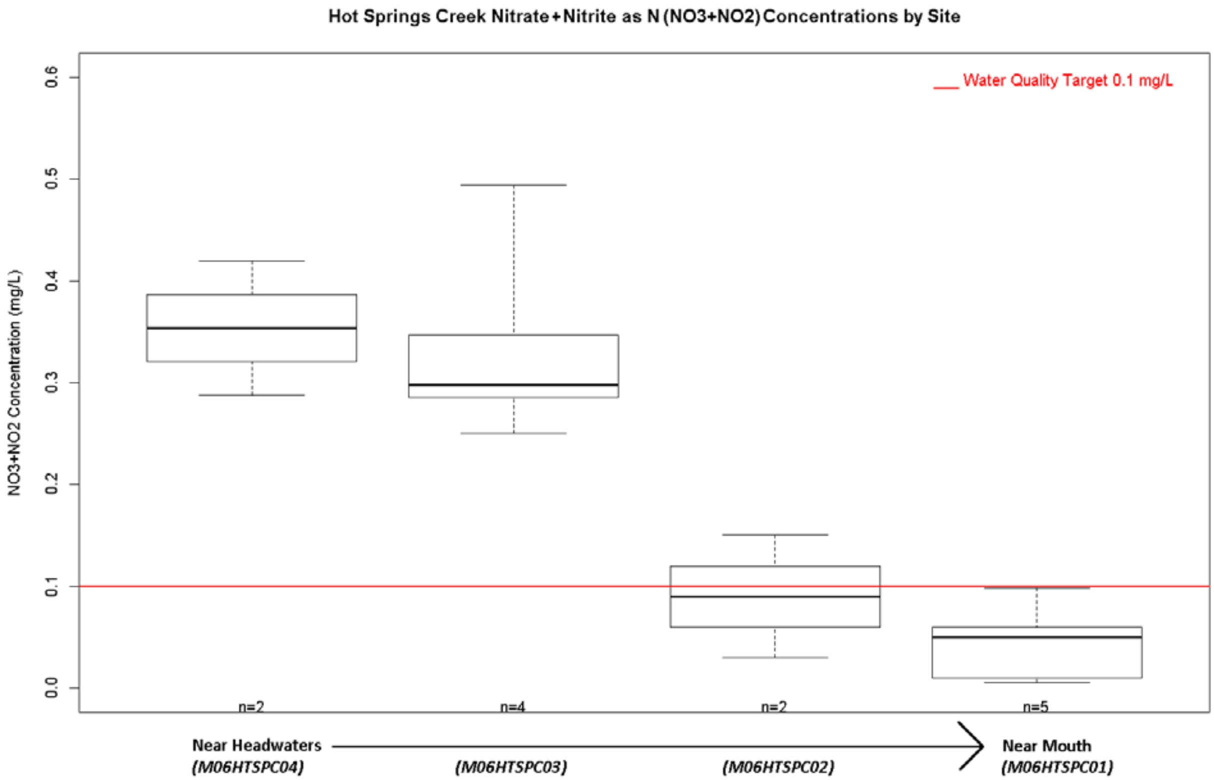

Figure 5-16. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for Hot Springs Creek

Sources of elevated NO_3+NO_2 in the Hot Springs Creek watershed are similar to the sources of TN. NO_3+NO_2 concentrations in Hot Springs Creek display a similar pattern to TN at the two uppermost monitoring sites, M06HTSPC04 and M06HTSPC03 (**Figure 5-16**), but NO_3+NO_2 concentrations are greatly reduced further downstream in comparison to TN. This indicates that the TN loads to Hot Springs Creek near the headwaters are comprised mainly of NO_3+NO_2 (inorganic nitrogen), while the TN loads further downstream are comprised mainly of organic nitrogen. There are multiple land uses potentially contributing nitrogen in the area between monitoring sites M06HTSPC03 and M06HTSPC02, such as the Town of Norris, Norris Hot Springs, livestock grazing, and recent wildland fires, so it is unclear at this point as to where exactly the organic nitrogen load is coming from. Additional source assessment monitoring may be able to assist with identifying the major nitrogen sources between monitoring sites M06HTSPC03 and M06HTSPC02. The lower NO_3+NO_2 concentrations also indicates that NO_3+NO_2 is being consumed more readily by benthic algae as evidenced by the increase in chlorophyll-*a* from monitoring site M06HTSPC03 (10.9 mg/m^2) to monitoring site M06HTSPC01 (12.51 mg/m^2) in 2012 (**Appendix A**).

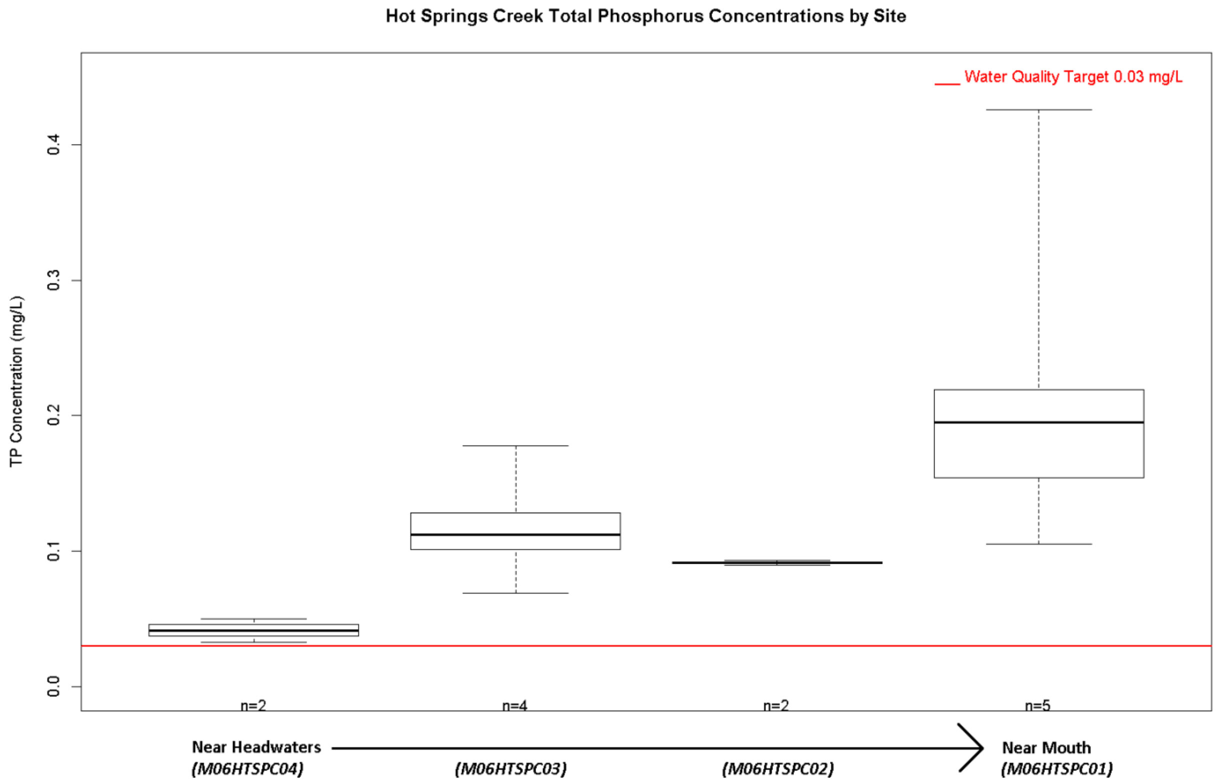

Figure 5-17. Box plot displaying the TP concentration data by monitoring site for Hot Springs Creek

TP concentrations are elevated at the most upstream monitoring site (M06HTSPC04), and remain above the target concentration of 0.03 mg/L TP throughout the length of Hot Springs Creek, with TP concentrations increasing further downstream (**Figure 5-17**). This indicates that sources of TP are present in the headwaters of Hot Springs Creek, and present at higher levels further downstream. Sources of TP are likely livestock grazing, cropland production, residential development in and around the Town of Norris including Norris Hot Springs, and natural sources including recent wildland fires (**Figure 5-14**).

5.6.4.1 Hot Springs Creek Point Sources of Nutrients

No permitted point source discharges have been identified in the Hot Springs Creek watershed. Norris Hot Springs, although not a permitted point source discharge, discharges its pool water to Hot Springs Creek on a daily basis. Since nothing is added to the water, Montana DEQ determined that the facility does not need a Montana Pollutant Discharge Elimination System (MPDES) permit. The water quality of the discharge is unknown, and therefore nutrient loads cannot be accurately quantified at this time.

5.6.4.2 Hot Springs Creek Nonpoint Sources of Nutrients

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-14** shows the location of agricultural land in the Hot Springs Creek watershed in relation to water quality monitoring sites.

Irrigated and Dryland Cropping
Cropland in the Hot Springs Creek watershed is primarily hay and pasture land (grass and alfalfa), with limited small grains production (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Much of the cropland in the watershed is located upstream of the Town of Norris, between monitoring sites M06HTSPC03 and M06HTSPC02. Improper fertilizer application can lead to nutrient loads coming from cropland, but the current data is not able to differentiate the cropland-related nutrient loads from other loading sources in the area.

Livestock Grazing
Grazing on rangeland and pastures is common in the Hot Springs Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of nutrients. Livestock manure from corrals must also be properly managed to avoid runoff into surface water.

In addition to private land grazing, there are 13 public land grazing allotments in the Hot Springs Creek watershed, 12 on BLM managed lands and one on USFS managed lands (**Figure 5-14**); the allotments are described as follows in **Table 5-22**. The 2009 Madison Watershed Assessment Report from the BLM (U.S. Department of the Interior, Bureau of Land Management (BLM) 2009a; BLM 2009b) indicated that the Billie Mine Isolated, Maltbys Mound, North Meadow Creek, Parent Isolated, Pony Gulch Isolated, and Red Bluff allotments are currently meeting BLM's healthy rangeland standards for upland, riparian wetland, air quality and biodiversity. The Elmer allotment is currently not meeting the BLM standard for riparian wetlands due to impacts from cattle, roads, and abandoned mine debris. The Preacher Creek and Wallace Peak AMP allotments are currently not meeting the BLM standard for riparian wetlands due to impacts from cattle. The Revenue Common AMP allotment is currently not meeting the BLM standard for riparian wetlands due to impacts from cattle and unauthorized Off Highway Vehicle (OHV) use. It was determined in the 2009 Madison Watershed Assessment Report that current livestock management is a significant factor in standards not being met for the Elmer, Preacher Creek, Wallace Peak AMP, and the Revenue Common AMP allotments. The Easter allotment is currently not meeting the BLM standard for water quality due to the Madison River being listed as impaired, but it was determined that BLM authorized activities, including livestock management are not a significant cause in failing to meet the standard. The Michel allotment is currently not meeting the BLM standard for uplands and riparian wetlands due to abandoned mine debris along Bradley Creek and spotted knapweed infestations in the uplands. It was determined by the BLM that livestock management was not a significant factor in the Michel allotment failing to meet these standards (BLM 2009a; BLM 2009b).

Livestock grazing is noted by the BLM as a significant causal factor for not meeting management objectives on 4 of the 13 grazing allotments in the Hot Springs Creek watershed, three of which are located in the upper portion of the Hot Springs Creek watershed upstream of the uppermost monitoring site (M06HTSPC04), and one is located in the lower portion of the Hot Springs Creek watershed upstream of monitoring site M06HTSPC02. It is likely that livestock grazing in these areas is contributing to elevated concentrations of TN, NO_3+NO_2, and TP in Hot Springs Creek as shown in **Figures 5-15, 5-16,** and **5-17**.

The Allotment Management Plan for the USFS managed North Meadow Creek allotment indicates that this allotment is currently meeting USFS standards and no major changes have occurred since the plan was last updated in 1996 (U.S. Department of Agriculture, Forest Service 1997a; Suzuki 2015). Since the livestock grazing activities in the North Meadow Creek allotment are meeting the USFS standards, it is not expected that this allotment is a significant source of nutrients to Hot Springs Creek.

Table 5-22. Public Land Grazing Leases in the Hot Springs Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Billie Mine Isolated	BLM	682	682	100%	69	Yes
Easter	BLM	259.1	1,012	25.6%	137	No[1]
Elmer	BLM	256	256	100%	76	No
Maltbys Mound	BLM	2,963.4	3,417	86.7%	25	Yes
Michel	BLM	284.7	370	76.9%	25	No[2]
North Meadow Creek	BLM	813.9	1,938	42%	136	Yes
North Meadow Creek	USFS	2,044.2	16,983.5	12%	1,653	Yes
Parent Isolated	BLM	617	617	100%	6	Yes
Pony Gulch Isolated	BLM	2,204.3	2,234	98.7%	28	Yes
Preacher Creek AMP	BLM	110.9	2,118	5.2%	124	No
Red Bluff	BLM	652.6	815	80%	220	Yes
Revenue Common AMP	BLM	3,947.9	4,446	88.8%	701	No
Wallace Peak AMP	BLM	2,367.4	2,802	84.5%	100	No

[1] The allotment is not meeting the standard for water quality, but it was determined that livestock management is not the cause

[2] The allotment is not meeting the standard for uplands and riparian wetlands, but it was determined that livestock management is not the cause

Residential Development and Subsurface Wastewater Treatment and Disposal

The town of Norris, although relatively small, contains some impervious surfaces to which stormwater may runoff into Hot Springs Creek, providing a pathway for nutrient transport. Septic systems in the Hot Springs Creek watershed are at relatively low densities, except for residences in and around the town of Norris. The town of Norris is located between water quality monitoring points M06HTSPC03 (upstream of Norris) and M06HTSPC02 (downstream of Norris) **(Figure 5-14)**, and no significant spike in nutrient concentrations is shown between these two sites, indicating that stormwater runoff and septic systems in the area, although contributing nutrients, are not likely a significant contributor of nutrients to Hot Springs Creek **(Figures 5-15, 5-16,** and **5-17)**. Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the Hot Springs Creek watershed can be found in **Table 5-23** below.

Table 5-23. Nutrient Loading Estimates from Septic Systems in the Hot Springs Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	51	43.92%	4.26	2.39
Total Phosphorus	51	85.49%	0.90	0.13

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Silviculture (timber harvest)
There has been one documented timber sale in the Hot Springs Creek watershed. The Chero Mountain timber sale was completed in 1985 and included approximately 41.1 acres in the Hot Springs Creek watershed near the headwaters of North Fork Hot Springs Creek **(Figure 5-14)**. This sale was classified as a stand clearcut, but due to the age of the cut, it is not expected that this timber sale is currently influencing nutrient concentrations in Hot Springs Creek.

Mining
The Hot Springs Creek watershed has a relatively high density of abandoned mines compared to neighboring watersheds. Sixty-one abandoned mines have been identified in the Hot Springs Creek watershed, with two of these mines, the Boaz Mine and the Grubstake Mine, designated as DEQ Abandoned Mine Lands priority sites (**Figure 5-14**).

In addition to the abandoned mines, there is one mine that has a current operating permit, the Revenue Mine. The Revenue Mine is currently owned by Majesty Mining, and although it maintains a current operating permit, the mine has not been in production since 1998 (Jepson 2015). While in active production, the Revenue Mine did not have a surface water discharge, but instead used evaporation ponds as a way of disposing of ore processing water. **Figure 5-14** shows the location of the Revenue Mine. Additional details on these mine sites can be found in **Section 7.6**.

Based on the high concentrations of nutrients at the uppermost water quality monitoring site **(Figures 5-15, 5-16,** and **5-17)**, it is possible that abandoned mines are a potential source of nutrients in the Hot Springs Creek watershed.

Natural Background
Several wildland fires have occurred in the lower portion of the Hot Springs Creek watershed, with the most recent being in 2012. **Figure 5-14** shows the location of wildland fires in the Hot Springs Creek watershed, and **Table 5-24** shows the details of each fire. Wildland fire can affect the nutrient concentrations in streams by contributing to increased sediment deposition due to lack of upland ground cover. The fires can cause a release of phosphorus and nitrogen which can bind to these soil particles and are transported to surface water via overland runoff (Hauer and Spencer 1998). The Bear Trap 2 fire occurred in June 2012 directly upstream of monitoring site M06HTSPC01, where nutrient sampling was conducted in August 2012. Pre-fire nutrient data was not collected, so the effect of this fire on nutrient concentrations in Hot Springs Creek is unknown.

Table 5-24. Wildland Fires in the Hot Springs Creek Watershed

Fire Name	Acres Burned	Year
Grubstake	510	1987
Norris	516	1994
Red Mountain	313	1994
Red Bluff	1,981	2000
Unknown	1,425	2000
Bar Z	298	2000
Red Bluff	100	2006
Bear Trap 2	1,5372	2012

Natural background concentrations of nutrients have been quantified for Hot Springs Creek as discussed above in **Section 5.6.1.6**.

5.6.5 Moore Creek Source Assessment

Nutrient inputs to Moore Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed), which are shown in **Figure 5-18**. There are currently no permitted point sources in the Moore Creek watershed. DEQ identified the following source categories that contribute nutrients in the Moore Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Silviculture (timber harvest)
- Mining
- Natural background

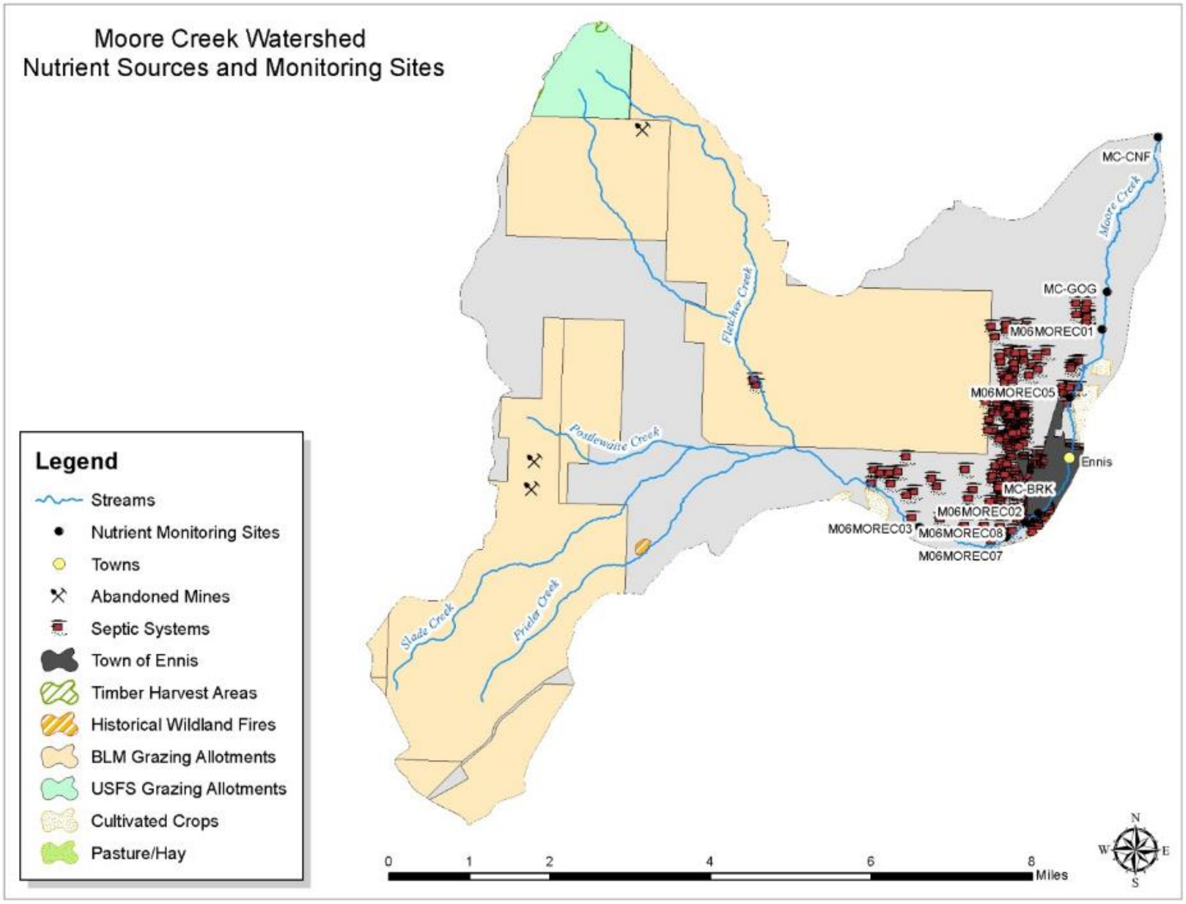

Figure 5-18. Map showing water quality monitoring sites and sources of nutrients in the Moore Creek watershed

This section contains nutrient source assessment information for the Moore Creek watershed. **Figures 5-19, 5-20**, and **5-21** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on Moore Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

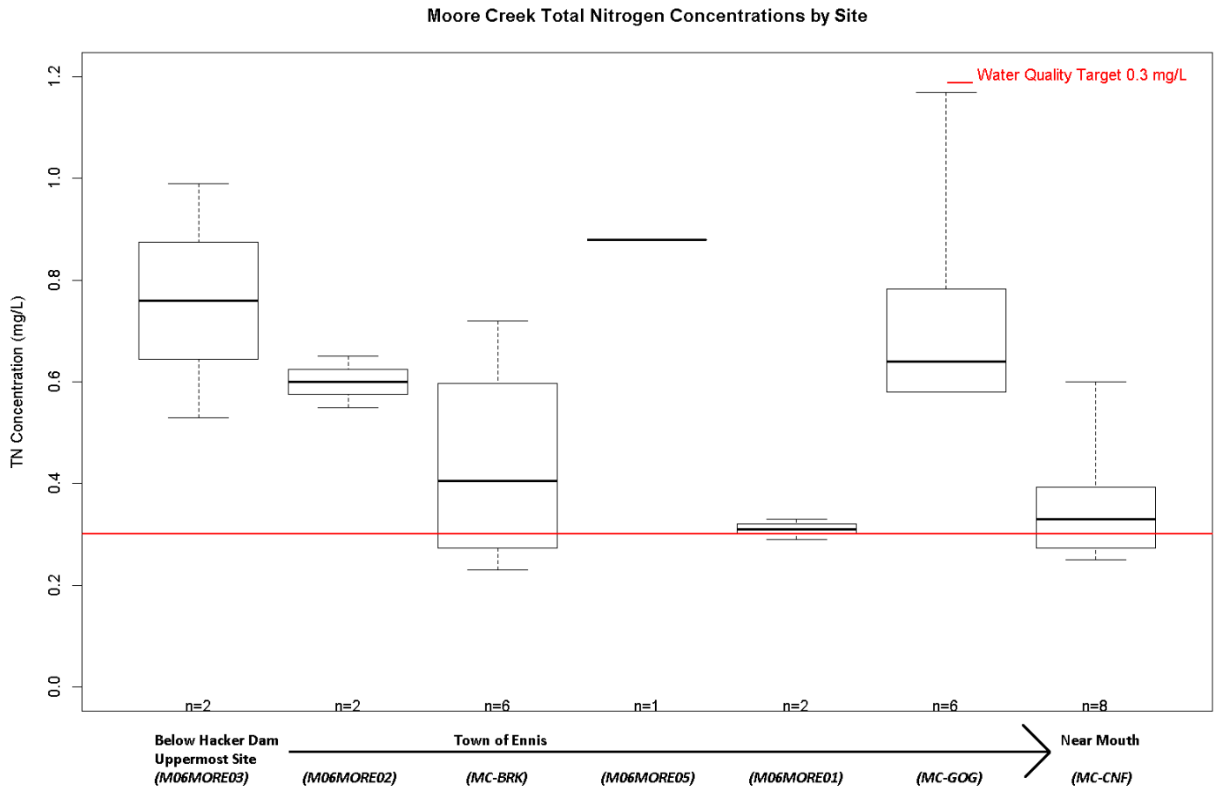

Figure 5-19. Box plot displaying the TN concentration data by monitoring site for Moore Creek

TN concentrations remain elevated above the TN target of 0.3 mg/L throughout Moore Creek. The uppermost monitoring site (M06MORE03, below Hacker Dam) shows TN concentrations which are twice the target concentration, indicating that there are TN sources in the upper part of the watershed. Unfortunately, DEQ was not able to obtain nutrient data upstream of this site, which makes it hard to determine if the elevated TN is coming from natural sources or human-caused sources. Additional data collection in the headwaters area may be able to better identify sources of elevated TN and the role that the Hacker Dam impoundment may have on seasonal TN loading. The fact that TN remains high throughout Moore Creek indicates that TN sources are present throughout the system. The spike in TN concentrations at monitoring site MC-GOG, suggests that there may be a localized source of TN loading directly upstream of that site.

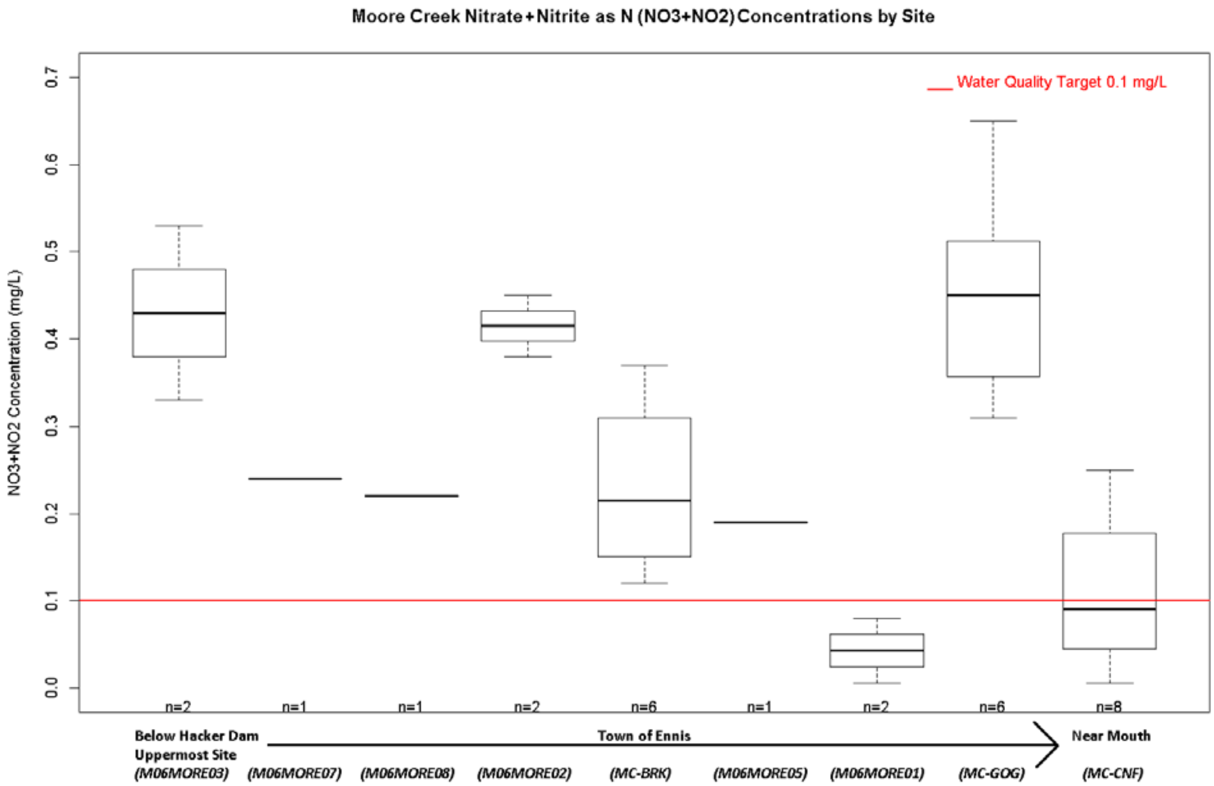

Figure 5-20. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for Moore Creek

Sources of elevated NO_3+NO_2 in the Moore Creek watershed are similar to the sources of TN. NO_3+NO_2 concentrations in Moore Creek display a similar pattern to TN and remain elevated throughout the system. There is a slight decreasing trend in NO_3+NO_2 concentrations near the mouth of Moore Creek, suggesting that there may be some dilution occurring, but concentration values still exceeded the NO_3+NO_2 target of 0.1 mg/L. The spike in NO_3+NO_2 concentrations at monitoring site MC-GOG, suggests that there may be a localized source of NO_3+NO_2 loading directly upstream of that site.

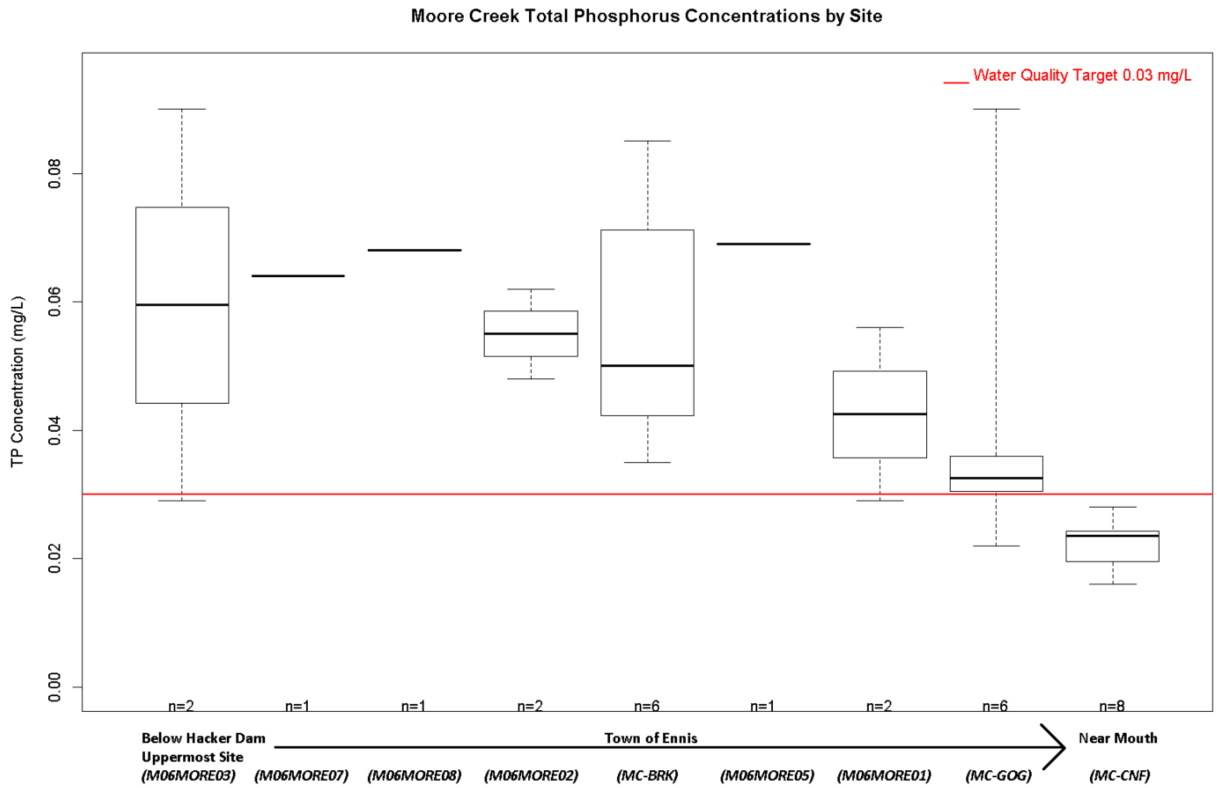

Figure 5-21. Box plot displaying the TP concentration data by monitoring site for Moore Creek

TP concentrations remain elevated above the TP target of 0.03 mg/L throughout much of Moore Creek, but show a decreasing trend towards the mouth, suggesting that there may be some dilution occurring where the stream picks up groundwater flow downstream of the Town of Ennis. The uppermost monitoring site (M06MORE03, below Hacker Dam) shows TP concentrations which are twice the target concentration, indicating that there are TP sources in the upper part of the watershed. Unfortunately, DEQ was not able to obtain nutrient data upstream of this site, which makes it hard to determine if the elevated TP is coming from natural sources or human-caused sources. Additional data collection in the headwaters area may be able to better identify sources of elevated TP and the role that the Hacker Dam impoundment may have on seasonal TP loading.

Additional source assessment sampling was conducted by the Madison Stream Team in December 2015 through March 2016. The purpose of this sampling was to describe the nutrient concentrations in Moore Creek with the absence of in-stream plant and algal growth, which would reduce in-stream nutrients via plant uptake. This sampling found that nutrient concentrations in the winter remain above the summer in-stream targets throughout the length of the stream, indicating that there are significant nutrient contributions to Moore Creek year-round. Even though these data fall outside of the dates to where the nutrient standards apply (July 1-September 30), the data are quite useful for source assessment purposes. The monitoring sites for this sampling effort correspond with previous nutrient monitoring sites chosen by DEQ and the Madison Stream Team.

5.6.5.1 Moore Creek Point Sources of Nutrients

There are currently no permitted point sources in the Moore Creek watershed. Ennis Hot Springs LLP previously held a Montana Pollutant Discharge Elimination System (MPDES) permit (MT0028843) to discharge unaltered groundwater to Moore Creek, but this permit expired on September 30, 2016, and the facility has chosen to not renew the permit. A permit is not required for discharges of unaltered groundwater; therefore, the facility may continue to discharge to Moore Creek without needing a permit. Water quality data collected is representative of the condition of Moore Creek including the Ennis Hot Springs LLP discharge.

Under the former MPDES permit for Ennis Hot Springs LLP, the facility was not required to monitor for nutrients in its effluent, so effluent nutrient data for Ennis Hot Springs LLP does not currently exist. In 2010, the Montana Bureau of Mines and Geology (MBMG) collected a sample at the Ennis Hot Springs LLP well, which has a TN concentration of 1.93 mg/L, which is greater than the TN standard of 0.3 mg/L. NO_3+NO_2 concentrations were below the reporting limit of < 0.2 mg/L, and TP concentrations were not analyzed. The flow rate from this well is approximately 35 gallons per minute or 0.08 cfs. The facility does not alter the water in a way that would add nutrients, although it is possible that the nutrient levels in groundwater are high enough to contribute elevated nutrient loads to Moore Creek, as may be the situation for other locations throughout Moore Creek and the Madison River watershed.

5.6.5.2 Moore Creek Nonpoint Sources of Nutrients

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-18** shows the location of agricultural land in the Moore Creek watershed in relation to water quality monitoring sites.

<u>Irrigated and Dryland Cropping</u>

Cropland in the Moore Creek watershed is primarily irrigated hay and pasture land (grass and alfalfa), with some irrigated small grains production (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Hay and pasture land in the Moore Creek valley bottom is irrigated using a combination of sprinkler, sub-irrigation and flood irrigation. Dryland cropping, if present, may have fallow periods, depending on site characteristics and landowner management.

Irrigated lands are supplied with water being diverted from the Madison River via the West Madison Canal. Upstream of the town of Ennis, the West Madison Canal crosses Moore Creek. Water quality sampling above and below this crossing was conducted by DEQ in September 2014. Further investigation indicated that this is a bypass structure, with check-boards to control the amount of any discharge from the canal into Moore Creek, with Moore Creek passing underneath the canal. It was discovered that some water from the West Madison Canal was mixing with Moore Creek via a headgate upstream of the intersection and some minor leakage through the check boards; see **Figure 5-22**. NO_3+NO_2 concentrations in the canal were lower than those in Moore Creek; therefore, the mixing is having a dilution effect for NO_3+NO_2. TP concentrations however were slightly higher in the canal than in Moore Creek, possibly due to a higher concentration of TSS in the canal, and therefore the West Madison Canal is acting as a source of TP to Moore Creek. These samples were analyzed for TN, but due to possible TN blank contamination, the TN values were not used for assessment purposes. These data are shown in **Figures 5-20** and **5-21** at monitoring sites M06MORE07 (upstream of intersection with canal) and M06MORE08 (downstream of intersection with canal).

Figure 5-22. Photo showing West Madison Canal crossing Moore Creek and mixing through leaky check-boards in the center of the photo. Headgate releases water into Moore Creek to the left of photo (off photo).

Livestock Grazing

Grazing on rangeland and pastures is common in the Moore Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of nutrients. Livestock manure from corrals must also be properly managed to avoid runoff into surface water. Livestock grazing downstream of the town of Ennis is likely a significant contributor to the nitrogen concentration spike at monitoring site MC-GOG **Figures 5-19** and **5-20**.

In addition to private land grazing, there are seven public land grazing allotments in the Moore Creek watershed, six on BLM managed lands and one on USFS managed lands (**Figure 5-18**); the allotments are described as follows in **Table 5-25**. The BLM managed grazing allotments in the Moore Creek watershed fall within the "South Tobacco Roots Watershed Assessment" report completed in 2007 (U.S. Department of the Interior, Bureau of Land Management (BLM) 2007a; BLM 2007b). Since the 2007 assessment report, the boundaries and names of some grazing allotments have changed. In the 2007 assessment report, the Cal Creek allotment includes the current Alder Gulch allotment, and the Virginia City Hill allotment includes the current Madison Overlook allotment. The report indicated that the Cal Creek (including the Alder Gulch allotment) is not currently meeting BLM's healthy rangeland standards for riparian wetlands, water quality, and bio-diversity. The primary resource concerns for not meeting these standards are conifer encroachment in uplands and riparian areas, forest health (insects and/or disease), excessive fuel loads, streambank impacts from livestock grazing, invasive weeds, and impacts to Idaho sedge habitat, which is a sensitive plant species. It was determined that livestock management is a significant factor in these standards not being met. The Fletcher-Moore, Granite-Moore, and Virginia City Hill (including the Madison Overlook allotment) allotments are not currently meeting the standards for riparian wetlands and bio-diversity due to conifer encroachment, forest health (insects and/or disease), excessive fuel loads, and streambank impacts from livestock grazing. It was determined that livestock management is a significant factor in these standards not being met. The Dry Lakes allotment is not currently meeting the standard for bio-diversity due to conifer encroachment in uplands and riparian areas, forest health (insects and/or disease), excessive fuel loads. Livestock management was not determined to be a significant factor in the standard not being met on the Dry Lakes allotment (BLM 2007a; BLM 2007b).

The Allotment Management Plan for the USFS managed South Meadow Creek allotment indicates that this allotment is currently meeting USFS standards and no major changes have occurred since the plan was last updated in 1996 (U.S. Department of Agriculture, Forest Service 1997b; Suzuki 2015).

Table 5-25. Public Land Grazing Leases in the Moore Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Alder Gulch [1]	BLM	156.6	10,293	1.5%	623	No
Dry Lakes	BLM	83.2	6,258	1.3%	152	No [2]
Fletcher-Moore	BLM	6,378.8	8,681	73.4%	213	No
Granite-Moore	BLM	1,709	1,709	100%	198	No
Madison Overlook	BLM	710.6	3,439	20.7%	284	No
South Meadow Creek	USFS	694.8	11,227.9	6.2%	911	Yes
Virginia City Hill [1]	BLM	4,484.7	8,159	55.0%	565	No

[1] The allotment names and boundaries have changed since the 2007 BLM South Tobacco Roots Watershed Assessment report

[2] The allotment is not meeting the standard for biodiversity, but it was determined that livestock management is not the cause

Livestock grazing is noted by the BLM as a significant causal factor for not meeting management objectives on 5 of the 6 grazing allotments in the Moore Creek watershed, all of which are located in the upper portion of the Moore Creek watershed above the uppermost monitoring site (M06MORE03), it is likely that livestock grazing in the upper portions of the Moore Creek watershed is contributing to elevated concentrations of TN, NO_3+NO_2, and TP in Moore Creek as shown in **Figures 5-19, 5-20,** and **5-21**.

Residential Development and Subsurface Wastewater Treatment and Disposal
Residential landscaping and parks in the town of Ennis have the potential to be nutrient sources to Moore Creek, which flows through town. The Moore Creek watershed also contains one golf course, the Madison Meadows golf course. To keep the grass green throughout the year, golf courses typically use large amounts of commercial fertilizer, which can be a source of nutrients to surface water via overland runoff, or to groundwater via leaching. Although Moore Creek does not pass through the course, it may be a potential source of nutrients to Moore Creek through groundwater pathways. Stormwater discharges from impervious surfaces in town can also be a pathway for nutrients to enter Moore Creek. Upon further investigation by DEQ in 2015, there appears to be only one stormwater drain in town that has the potential to significantly contribute pollutants to Moore Creek. The road crossing on West Main Street appears to discharge under a stormwater event (**Figure 5-23)**. Although there are other points of stormwater discharge in town, they appear to have minimal potential to discharge a significant amount of pollutants to Moore Creek.

Figure 5-23. Photo showing stormwater discharge point to Moore Creek in the Town of Ennis at the West Main Street crossing (Moore Creek on right)

The town of Ennis is under municipal sewer within city limits, but discharges to the Madison River, not Moore Creek. Residential sources of wastewater outside of the Ennis city limits are treated via septic systems. Septic systems in the Moore Creek watershed are at very low densities in the upper portion of the watershed, but densities are relatively high around the town of Ennis. Since Moore Creek receives a significant amount of groundwater in its lower reaches, it is likely that nutrient loading from septic systems is having an impact on nutrient concentrations in Moore Creek. Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the Moore Creek watershed can be found in **Table 5-26** below.

Table 5-26. Nutrient Loading Estimates from Septic Systems in the Moore Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	192	50.68%	16.04	7.91
Total Phosphorus	192	93.70%	3.39	0.21

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Silviculture (timber harvest)

There has been one documented timber sale in the Moore Creek watershed. The Granite Creek timber sale was completed in 1985 and included approximately 9.4 acres in the Moore Creek watershed near the headwaters of Fletcher Creek **(Figure 5-18)**. This sale was classified as a shelterwood cut, but due to the age of the cut, it is not expected that the effects of this timber sale are currently influencing nutrient concentrations in Moore Creek.

Mining

The density of abandoned mines in the Moore Creek watershed is relatively low. Three abandoned mines have been identified in the Moore Creek watershed, one near the headwaters of Fletcher Creek, and the other two mines near the headwaters of Postlewaite Creek (**Figure 5-18**). These mines have not been designated as priority sites by the DEQ Abandoned Mine Lands program, and therefore are not anticipated to be a significant contributor of nutrients in the Moore Creek watershed.

Natural Background

One small wildland fire has occurred in the Moore Creek watershed near Frieler Creek in 1999. **Figure 5-18** shows the location of the wildland fire in the Moore Creek watershed, and **Table 5-27** shows the details of the fire. Wildland fire can affect the nutrient concentrations in streams by contributing to increased sediment deposition due to lack of upland ground cover. The fires can cause a release of phosphorus and nitrogen which can bind to these soil particles and are transported to surface water via overland runoff (Hauer and Spencer 1998). Due to the age of this fire, it is not expected to have a significant impact on nutrient loads to Moore Creek.

Table 5-27. Wildland Fire in the Moore Creek Watershed

Fire Name	Acres Burned	Year
Bobcat	15	1999

Natural background concentrations of nutrients have been quantified for Moore Creek as discussed above in **Section 5.6.1.6**.

5.6.6 O'Dell Spring Creek Source Assessment

Nutrient inputs to O'Dell Spring Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 5-24**. There are no permitted point sources located in the O'Dell Spring Creek watershed. DEQ identified the following source categories that contribute nutrients in the O'Dell Spring Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Mining
- Natural background

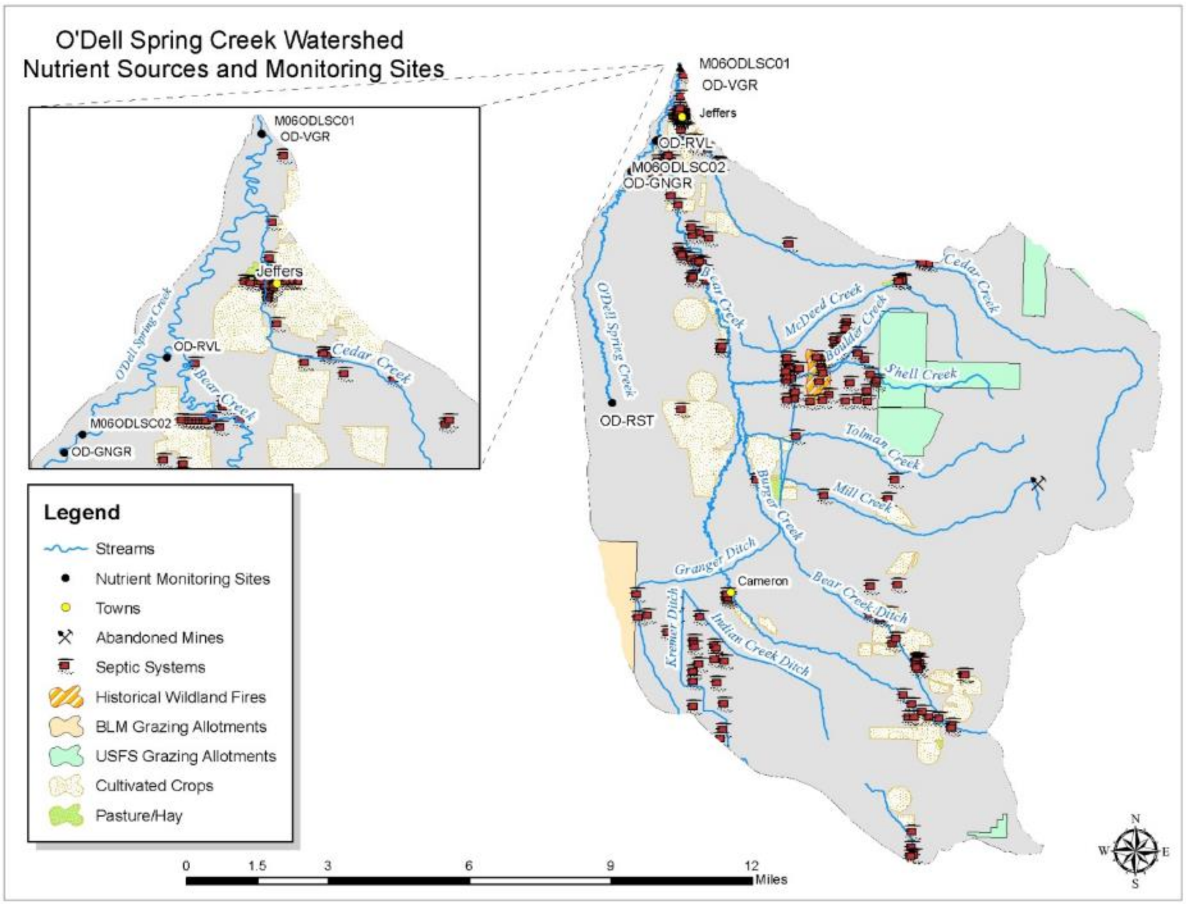

Figure 5-24. Map showing water quality monitoring sites and sources of nutrients in the O'Dell Spring Creek watershed

This section contains nutrient source assessment information for the O'Dell Spring Creek watershed. **Figures 5-25, 5-26**, and **5-27** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on O'Dell Spring Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

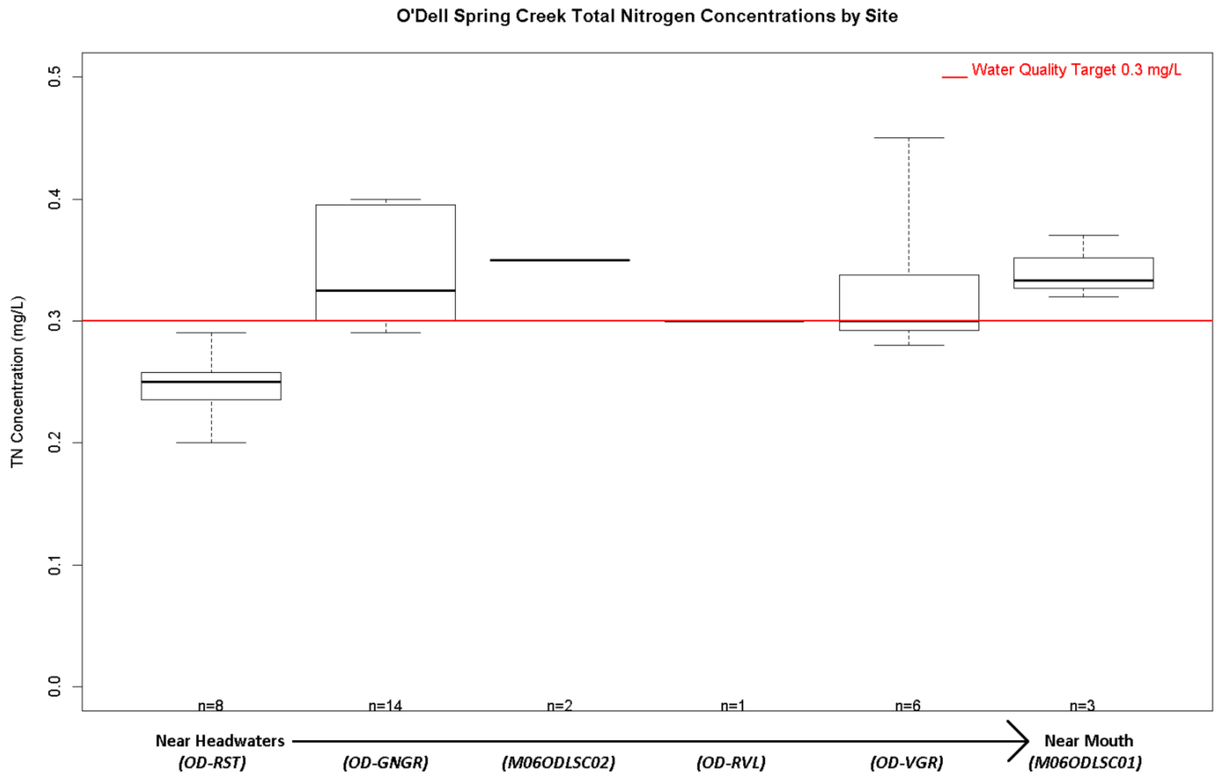

Figure 5-25. Box plot displaying the TN concentration data by monitoring site for O'Dell Spring Creek

TN concentrations in O'Dell Spring Creek are elevated near the headwaters, but below the TN concentration target of 0.3 mg/L. Further downstream, TN concentrations increase to levels above the TN target and remain consistently above the target, indicating that there are sources of TN throughout O'Dell Spring Creek. Monitoring sites OD-RST, OD-GNGR, M06ODLSC02, and OD-RVL are all located upstream of the confluence with Bear Creek, the largest tributary to O'Dell Spring Creek, while sites OD-VGR and M06ODLSC01 are located downstream of the confluence with Bear Creek. TN sources upstream of the Bear Creek confluence are most likely a combination of natural background sources and agriculture, while the sources in the Bear Creek watershed include natural background, agriculture, residential development and septic systems, in addition to an inter-basin transfer of Madison River water to Bear Creek.

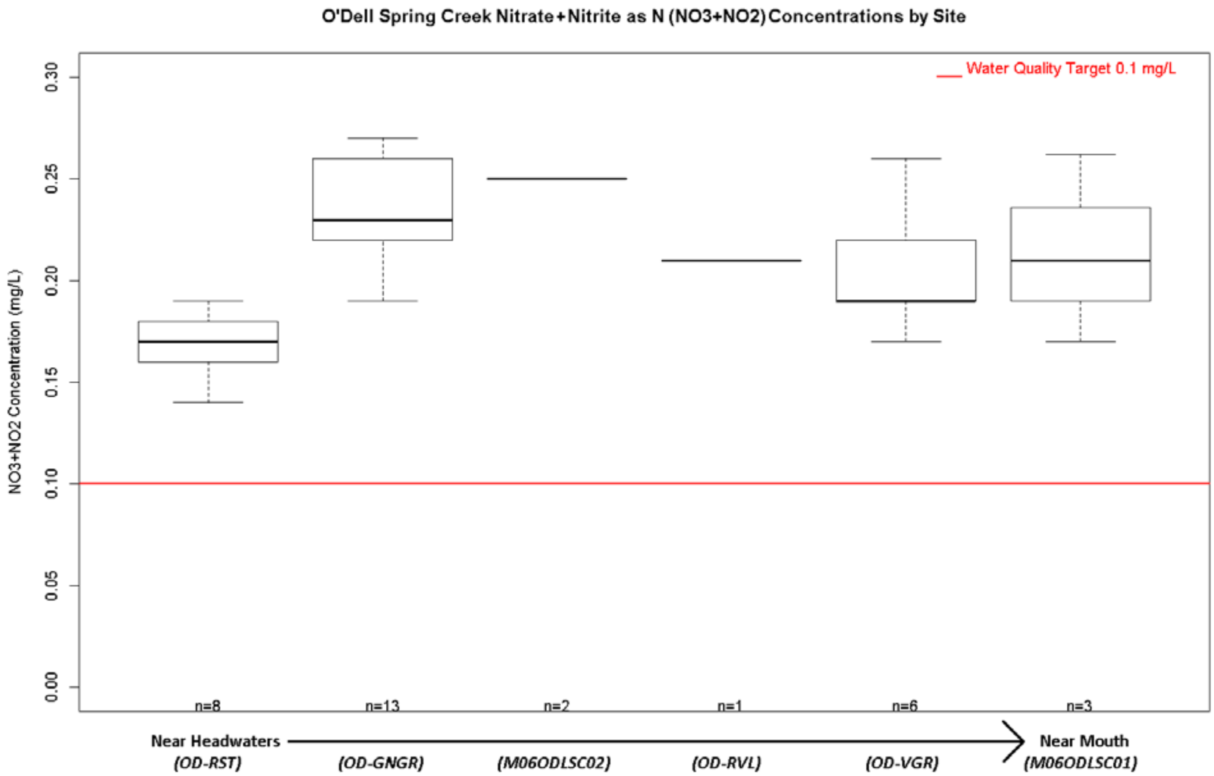

Figure 5-26. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for O'Dell Spring Creek

NO_3+NO_2 concentrations in O'Dell Spring Creek follow a similar pattern to TN concentrations, and remain above the NO_3+NO_2 concentration target of 0.01 mg/L throughout O'Dell Spring Creek. The elevated NO_3+NO_2 concentrations in the headwaters of O'Dell Spring Creek may indicate that the source of NO_3+NO_2 near the headwaters spring sources may be natural. This is further discussed in **Section 5.6.6.2**.

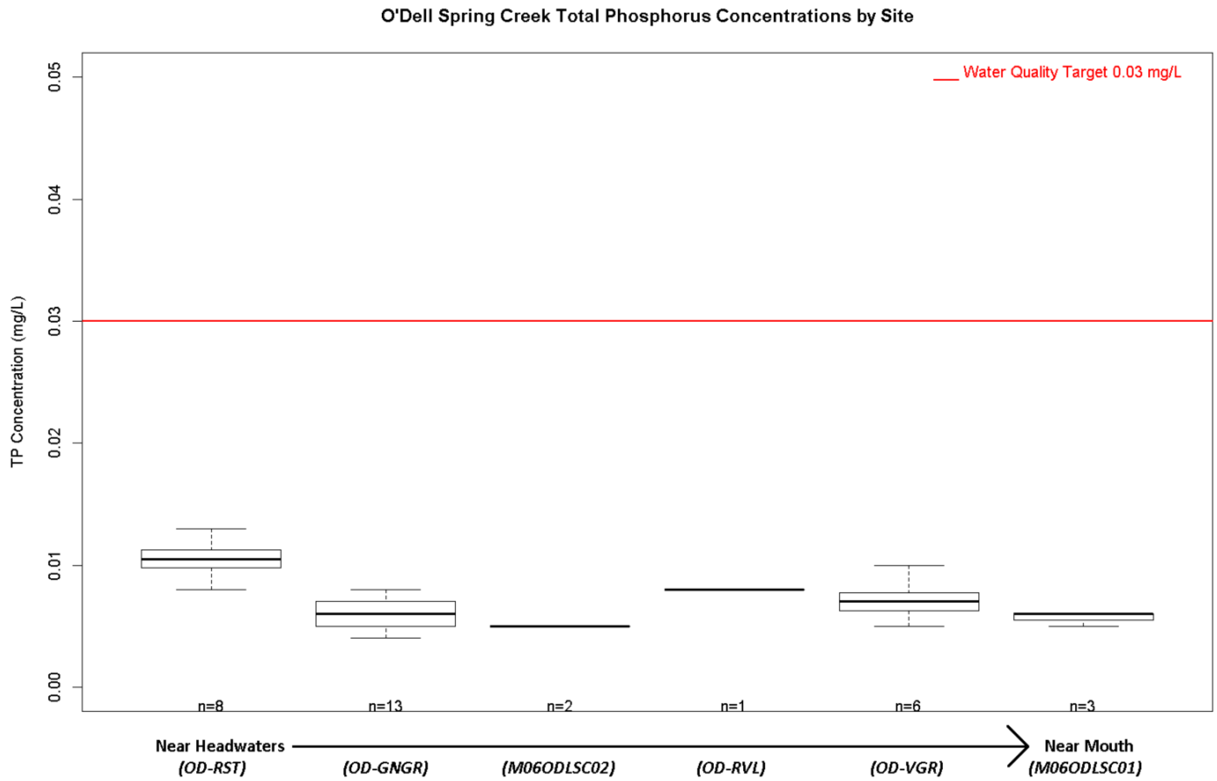

Figure 5-27. Box plot displaying the TP concentration data by monitoring site for O'Dell Spring Creek

TP concentrations in O'Dell Spring Creek remain below the TP concentration target of 0.03 mg/L, and it was determined that O'Dell Spring Creek is not impaired by TP.

5.6.6.1 O'Dell Spring Creek Point Sources of Nutrients

No permitted point source discharges have been identified in the O'Dell Spring Creek watershed.

5.6.6.2 O'Dell Spring Creek Nonpoint Sources of Nutrients

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-24** shows the location of agricultural land in the O'Dell Spring Creek watershed in relation to water quality monitoring sites.

Irrigated and Dryland Cropping

Cropland in the O'Dell Spring Creek watershed is primarily irrigated hay and pasture land (grass and alfalfa), with limited small grains production (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Irrigated lands on the Cameron Bench are supplied with water being diverted from Bear Creek via the Bear Creek Ditch, Indian Creek via the Indian Creek Ditch, and the Madison River via the Granger Ditch. Hay and pasture land in the O'Dell Spring Creek valley bottom is irrigated using a combination of sub-irrigation and flood irrigation. Dryland cropping, if present, may have fallow periods, depending on site characteristics and landowner management.

<u>Livestock Grazing</u>

Grazing on rangeland and pastures is common in the O'Dell Spring Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of nutrients. Livestock manure from corrals must also be properly managed to avoid runoff into surface water. In addition to the privately-owned grazing land, there are seven public land grazing allotments that are located either partially or entirely in the O'Dell Spring Creek watershed, including two allotments on BLM managed lands, and five allotments on USFS managed lands. The allotments are described as follows in **Table 5-28**.

The 2009 Madison Watershed Assessment Report from the BLM indicated that the Mill Creek-Gustin and North Indian Creek allotments are currently meeting BLM's healthy rangeland standards for upland, riparian wetland, air quality, and biodiversity (U.S. Department of the Interior, Bureau of Land Management 2009b). The Allotment Management Plans for the USFS managed Bear Creek On & Off, Jeffers On & Off, and Cedar Creek On & Off allotments indicate that these allotments are currently meeting USFS standards and no major changes have occurred since the plans were last updated in 2008 (U.S. Department of Agriculture, Forest Service (USFS) 2008a; USFS 2008b; USFS 2008c; Suzuki 2015). On & Off allotments contain small amounts of USFS land that are adjacent to larger tracts of private land. The Jack Creek and Shell Creek USFS allotments are currently closed to livestock grazing.

Table 5-28. Public Land Grazing Leases in the O'Dell Spring Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Bear Creek On & Off	USFS	668	668	100%	238	Yes
Cedar Creek On & Off	USFS	1,176.3	8,165	61.3%	900	Yes
Jack Creek (closed)	USFS	50.2	1,478.4	3.4%	0	N/A
Jeffers On & Off	USFS	1,415	1,415	100%	200	Yes
Mill Creek-Gustin	BLM	835.9	1,512	55.3%	23	Yes
North Indian Creek	BLM	9.8	493	2.0%	29	Yes
Shell Creek (closed)	USFS	1,287.3	1,287.3	100%	0	N/A

Residential Development and Subsurface Wastewater Treatment and Disposal

Septic systems in the O'Dell Spring Creek watershed tend to be clustered around the town of Cameron, near the Ennis Airport, and in the lower portion of the watershed near the towns of Ennis and Jeffers (**Figure 5-24)**. Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the O'Dell Spring Creek watershed can be found in **Table 5-29** below.

Table 5-29. Nutrient Loading Estimates from Septic Systems in the O'Dell Spring Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	178	37.87%	14.87	9.24
Total Phosphorus	178	87.47%	3.14	0.39

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Mining

The density of abandoned mines in the O'Dell Spring Creek watershed is very low. One abandoned mine has been identified in the O'Dell Spring Creek watershed near the headwaters of Mill Creek, a tributary to Bear Creek (**Figure 5-24**). This mine has not been designated as a priority site by the DEQ Abandoned Mine Lands program, and therefore is not anticipated to be a significant contributor of nutrients in the O'Dell Spring Creek watershed.

Natural Background

Water quality data collected at the furthest upstream monitoring site on O'Dell Spring Creek indicates elevated concentrations of TN that do not exceed, but are close to exceeding, the current nutrient standard of 0.30 mg/L, with a large proportion of that being inorganic nitrogen (nitrate + nitrite as N). The concentrations of NO_3+NO_2 ranged from 0.14 mg/L to 0.19 mg/L and exceed the recommended water quality target of 0.10 mg/L at this site. Water quality data collected by the Montana Bureau of Mines and Geology (MBMG) was obtained from two spring sources near the headwaters of O'Dell Spring Creek on 7/26/2012, and had NO_3+NO_2 concentrations of 0.39 mg/L at both samples, which is roughly four times the recommended water quality target for NO_3+NO_2 and more importantly, results in TN values greater than the numeric water quality criteria. It is unknown at this time if the elevated NO_3+NO_2 concentrations are coming from naturally occurring sources or anthropogenically influenced sources, therefore, further investigation is needed as to whether site-specific nutrient standards will need to be developed for O'Dell Spring Creek. TN concentrations in O'Dell Spring Creek generally increase downstream and are in exceedance of the nutrient target for TN at all sites downstream of the headwaters, indicating that sources of TN other than natural background exist.

One wildland fire has occurred in the O'Dell Spring Creek watershed near the Ennis Airport in 1998. **Figure 5-24** shows the location of wildland fires in the O'Dell Spring Creek watershed, and **Table 5-30** shows the details of the fire. Wildland fire can affect the nutrient concentrations in streams by contributing to increased sediment deposition due to lack of upland ground cover. The fires can cause a release of phosphorus and nitrogen which can bind to these soil particles and are transported to surface water via overland runoff (Hauer and Spencer 1998). Due to the age of this fire, it is not expected to have a significant impact on current nutrient loads in O'Dell Spring Creek.

Table 5-30. Wildland Fire in the O'Dell Spring Creek Watershed

Fire Name	Acres Burned	Year
Big Sky	299	1998

Natural background concentrations of nutrients have been quantified for O'Dell Spring Creek as discussed above in **Section 5.6.1.6**.

5.6.7 South Meadow Creek Source Assessment

Nutrient inputs to South Meadow Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 5-28**. There are no permitted point sources located in the South Meadow Creek watershed. DEQ identified the following source categories that contribute nutrients in the South Meadow Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Silviculture (timber harvest)
- Mining
- Natural background

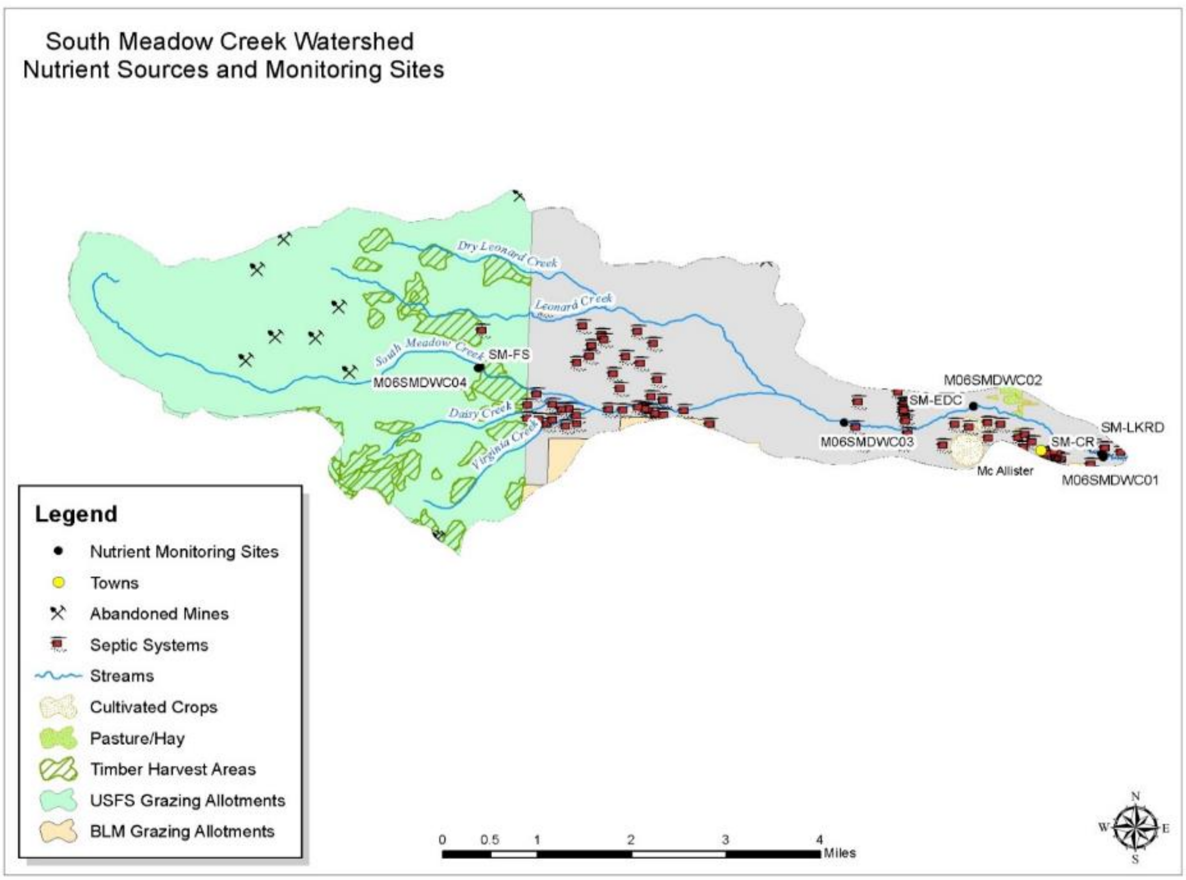

Figure 5-28. Map showing water quality monitoring sites and sources of nutrients in the South Meadow Creek watershed

This section contains nutrient source assessment information for the South Meadow Creek watershed. **Figures 5-29, 5-30,** and **5-31** display box plots of nutrient data (TN, NO_3+NO_2, and TP respectively) collected on South Meadow Creek. Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

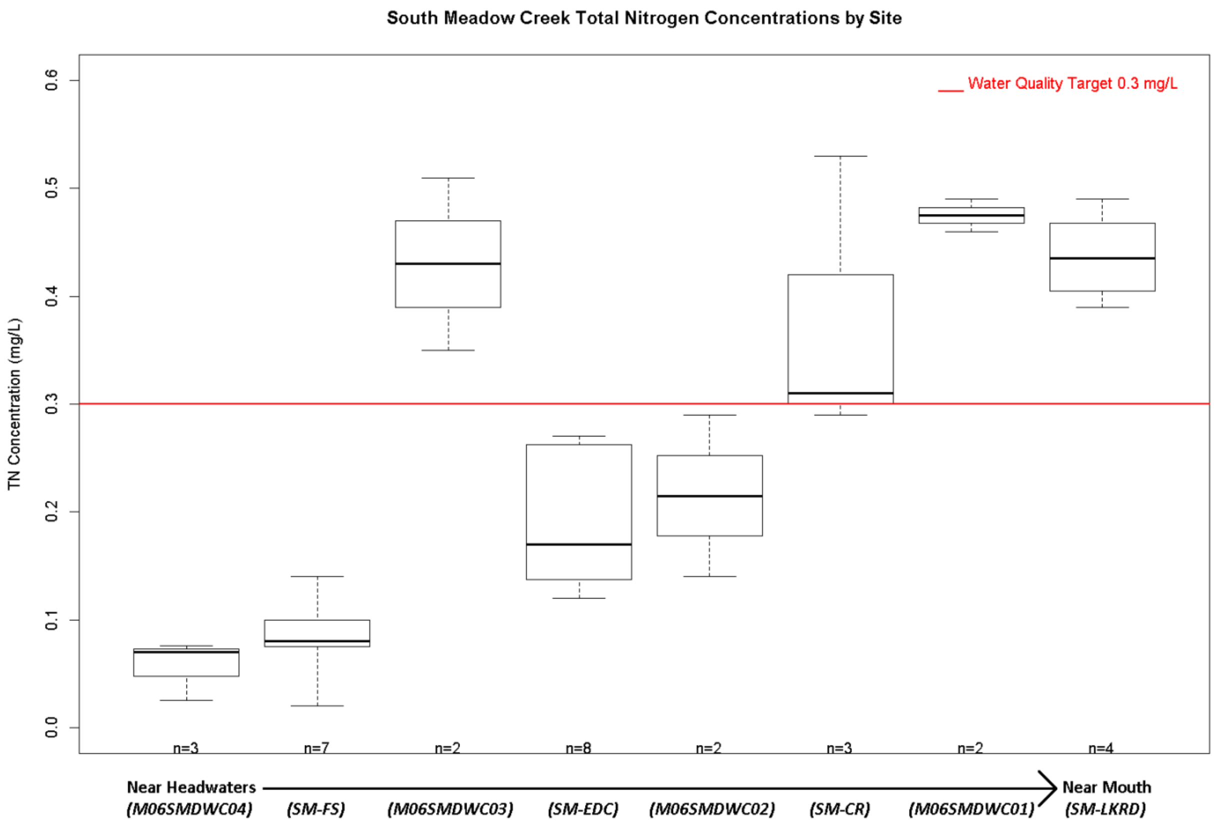

Figure 5-29. Box plot displaying the TN concentration data by monitoring site for South Meadow Creek

TN concentrations in South Meadow Creek are generally low near the headwaters and increase further downstream to levels above the TN target concentration of 0.3 mg/L. Monitoring sites M06SMDWC04 and SM-FS are located on USFS land and are upstream of many significant nutrient sources. Monitoring site M06SMDWC03 is located downstream of an area which has a relatively high concentration of septic systems, past timber harvest, and livestock grazing. These nutrient sources are reflected in high TN concentrations at site M06SMDWC03. Downstream of site M06SMDWC03, the land use is predominately agricultural land (cultivated crops and pasture/hay), with a moderate concentration of septic systems. TN loads from these nutrient sources are reflected in sites SM-CR, M06SMDWC01, and SM-LKRD, which show TN concentrations above the TN target.

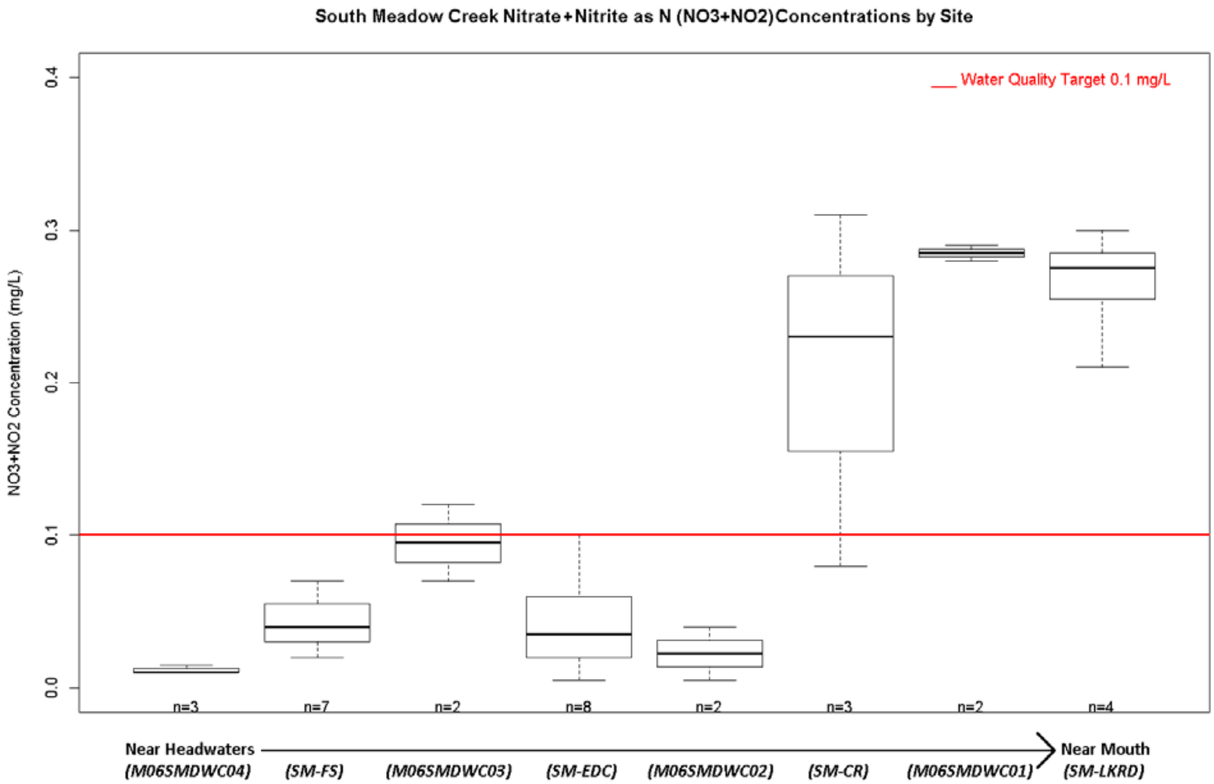

Figure 5-30. Box plot displaying the NO_3+NO_2 concentration data by monitoring site for South Meadow Creek

NO_3+NO_2 concentration data for South Meadow Creek follows a similar pattern to the TN concentrations in South Meadow Creek, with the concentrations near the headwaters being generally low and increasing downstream. Sources of NO_3+NO_2 in the watershed are similar to the sources of TN described above.

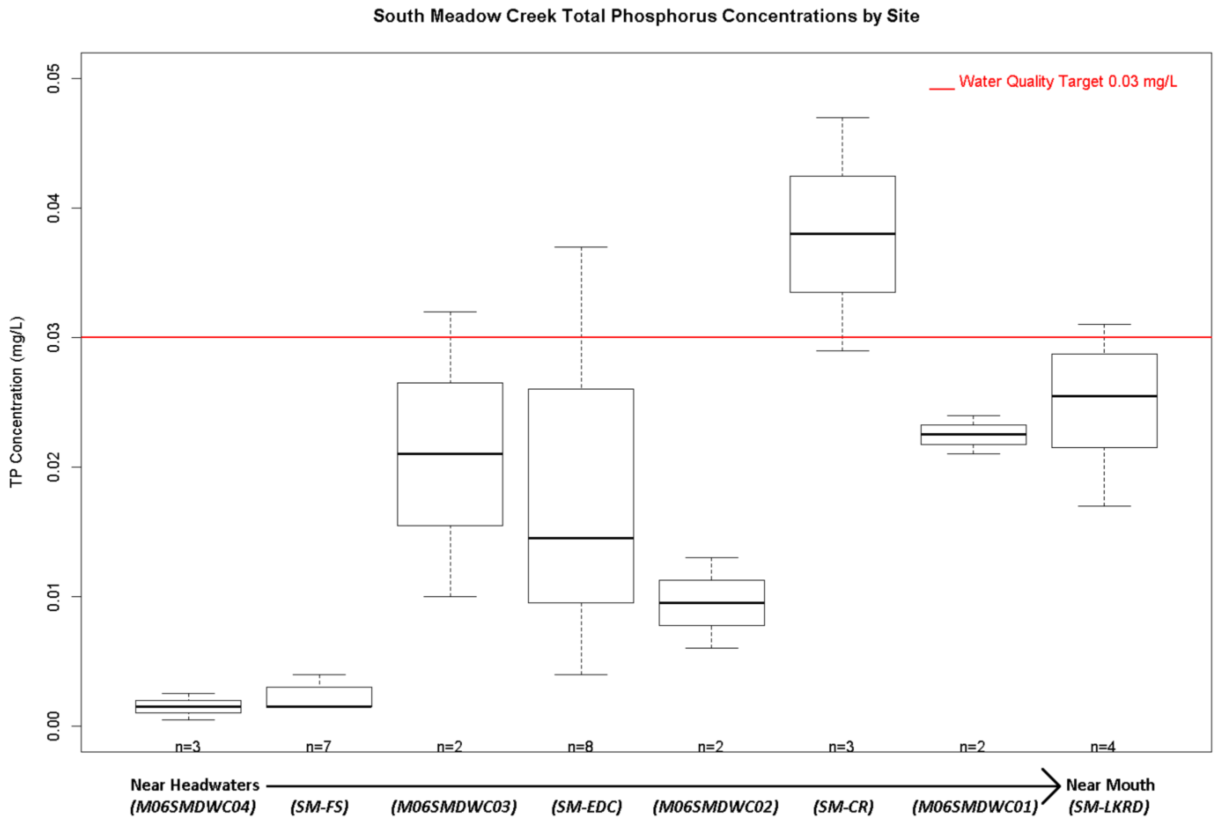

Figure 5-31. Box plot displaying the TP concentration data by monitoring site for South Meadow Creek

TP concentration data for South Meadow Creek follows a similar pattern to the TN and NO_3+NO_2 concentrations in South Meadow Creek, with the concentrations near the headwaters being generally low and increasing downstream. Sources of TP in the watershed are similar to the sources of TN and NO_3+NO_2. Monitoring sites near the mouth (M06SMDWC01 and SM-LKRD) decrease in concentration, indicating that there may be a dilution effect occurring. This area receives a significant amount of groundwater, and phosphorus is not able to travel through groundwater as easily as nitrogen, which would explain the high TN and NO_3+NO_2 concentrations at these sites and why TP concentrations are below the target.

5.6.7.1 South Meadow Creek Point Sources of Nutrients
No permitted point source discharges have been identified in the South Meadow Creek watershed.

5.6.7.2 South Meadow Creek Nonpoint Sources of Nutrients
Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season as described in **Section 5.6.1.2** above. **Figure 5-28** shows the location of agricultural land in the South Meadow Creek watershed in relation to water quality monitoring sites.

Irrigated and Dryland Cropping

Cropland in the South Meadow Creek watershed is primarily hay and pasture land (grass and alfalfa) (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Irrigated lands in the watershed are a combination of flood, sprinkler irrigation via diversions on South Meadow Creek, and sub-irrigation. The highest nutrient concentrations are generally found in the furthest downstream monitoring sites in the watershed (**Figures 5-29, 5-30,** and **5-31**), which is also where the majority of the agricultural lands are found.

Livestock Grazing

Grazing on rangeland and pastures is common in the South Meadow Creek watershed and occurs in a manner as described in **Section 5.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of nutrients. Livestock manure from corrals must also be properly managed to avoid runoff into surface water. In addition to private land grazing, there are three public land grazing allotments in the South Meadow Creek watershed, two on BLM managed lands and one on USFS managed lands (**Figure 5-28**); the allotments are described as follows in **Table 5-31**.

The BLM managed grazing allotments in the South Meadow Creek watershed fall within the "South Tobacco Roots Watershed Assessment" report completed in 2007 (U.S. Department of the Interior, Bureau of Land Management (BLM) 2007a; BLM 2007b). The 2007 report indicated that the Miller and South Daisy Creek allotments are meeting BLM's healthy rangeland standards for uplands, riparian wetlands, water quality, and air quality, but failing to meet the standard for bio-diversity due to conifer encroachment in uplands and riparian areas, forest health (insects and/or disease), and excessive fuel loads. Livestock management was not determined to be a significant factor in the standard not being met on these allotments (BLM 2007b).

The Allotment Management Plan for the USFS managed South Meadow Creek allotment indicates that this allotment is currently meeting USFS standards and no major changes have occurred since the plan was last updated in 1996 (U.S. Department of Agriculture, Forest Service 1997b; Suzuki 2015).

Table 5-31. Public Land Grazing Leases in the South Meadow Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Miller	BLM	32.7	162	20.2%	4	No [1]
South Daisy Creek	BLM	93.0	1,624	5.7%	89	No [1]
South Meadow Creek	USFS	7,282.1	11,227.9	64.9%	911	Yes

[1] The allotment is not meeting the standard for biodiversity, but it was determined that livestock management is not the cause

Residential Development and Subsurface Wastewater Treatment and Disposal

Septic systems in the South Meadow Creek watershed are at relatively low densities throughout the watershed, but are clustered in higher density groups in areas directly downstream of the USFS Beaverhead-Deerlodge National Forest boundary and near the mouth by the town of McAllister **(Figure 5-28)**. Nutrient concentrations are fairly low at the uppermost water quality monitoring sites, M06SMDWC04 and SM-FS, but increase further downstream as South Meadow Creek passes through private lands **(Figures 5-29, 5-30,** and **5-31)**. It is likely that septic systems in combination with land uses in this area are a source of nutrients to South Meadow Creek.

Potential loading from septic systems can be quantified by using the MEANSS model described in **Section 5.6.1.3** and **Appendix B**. While the MEANSS model estimates the total load of any particular nutrient entering a waterbody, it does not account for nutrient uptake by vegetation and aquatic organisms in that waterbody; therefore, the loading numbers may be higher than what water quality data suggests nutrient loads are. The results of this analysis for the South Meadow Creek watershed can be found in **Table 5-32** below.

Table 5-32. Nutrient Loading Estimates from Septic Systems in the South Meadow Creek Watershed Using the MEANSS Model

Pollutant	Number of Septic Systems	% of Pollutant Removed Prior to Stream	Total Load from Septic Systems (lbs/day)[1]	Total Load Entering Streams (lbs/day)
Total Nitrogen	74	42.70%	6.18	3.54
Total Phosphorus	74	91.76%	1.31	0.11

[1] Nitrogen loading from each septic system is estimated at 30.5 lbs/year. Phosphorus loading from each septic system is estimated at 6.44 lbs/year.

Silviculture (timber harvest)

There have been six documented timber sales in the South Meadow Creek watershed, which are shown in **Figure 5-28** and described in **Table 5-33** below. Due to age of the Granite Creek, Kings Mill, Virginia Creek, and Washington Creek timber sales, it is unlikely that these harvests are currently impacting nutrient concentrations in South Meadow Creek. It is possible however, that any effects of the Daisy Creek timber sale that was completed in 2010 were seen in water quality data collected from 2011-2013, as any increase in nutrient levels from timber harvest activities generally only lasts up to 2 or 3 years before returning to pre-harvest (Feller and Kimmins 1984; Likens et al. 1978) (Martin and Harr 1989). The Daisy Creek timber sale was located in the headwaters of Daisy Creek, a tributary to South Meadow Creek, but its location in the watershed in comparison to water quality monitoring sites makes it hard to isolate in the data from other sources of nutrients. The Daisy Creek timber sale is relatively small in size compared to other harvest activities and therefore is likely not a significant source of nutrients to South Meadow Creek. The Meadow Creek Fuels Reduction timber sale was planned in 2015 and currently ongoing, and therefore would not be represented in the water quality data collected from 2011-2014.

Table 5-33. Timber Sale Activities in the South Meadow Creek Watershed

Timber Sale Name	Acres Harvested in Watershed	Type of Harvest	Year Completed
Daisy Creek	20.9	Commercial thinning	2010
Granite Creek	118.1	Stand clearcut, seed-tree seed cut, shelterwood cut	1985
Kings Mill	69	Commercial thinning	1998
Meadow Creek Fuels Reduction	320	Commercial thinning	Ongoing
Virginia Creek	175	Biomass removal, Shelterwood cut, seed-tree seed cut	1990

Table 5-33. Timber Sale Activities in the South Meadow Creek Watershed

Timber Sale Name	Acres Harvested in Watershed	Type of Harvest	Year Completed
Washington Creek	35	Shelterwood cut	1984

Mining

Ten abandoned mines have been identified in the South Meadow Creek watershed, with two of these mines, the Missouri Mine and an unnamed abandoned mine, being designated as DEQ Abandoned Mine Lands priority sites by DEQ's Abandoned Mine Lands Program (**Figure 5-28**). Details of these two priority mine sites can be found in **Section 7.6**.

Although abandoned mines may be a source of nutrients in the South Meadow Creek watershed, because the furthest upstream water quality monitoring sites (which are downstream of the influence of many of the abandoned mines) are showing relatively low concentrations of nutrients, it is unlikely that abandoned mines are a significant contributor of nutrients to South Meadow Creek.

Natural Background

Natural background concentrations of nutrients have been quantified for South Meadow Creek as discussed above in **Section 5.6.1.6**.

5.7 Approach to TMDL Allocations

As discussed in **Section 4.0**, the TN and TP TMDLs for applicable impaired waterbodies consist of the sum of load allocations (LAs) to individual sources and source categories (**Tables 5-34** and **5-35**). The TMDLs for each stream are broken into a load allocation to natural background and a composite load allocation to all human-caused nonpoint sources (**Equation 5-2**). An implicit margin of safety (MOS) is applied such that the MOS in the TMDL equation is equal to zero as discussed in **Section 4.0**. In the absence of an explicit margin of safety, the TMDLs for TN and TP in each waterbody are calculated as follows:

Equation 5-2: $TMDL = LA_{NB} + LA_{H}$

TMDL = Total maximum daily load in lbs/day
LA_{NB} *= Load Allocation to natural background sources in lbs/day*
LA_{H} *= Load Allocation to human-caused nonpoint sources in lbs/day*

Table 5-34. Total Nitrogen and Nitrate + Nitrite Source Categories and Descriptions for the Madison TMDL Planning Area

Source Category	Source Descriptions
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

Table 5-34. Total Nitrogen and Nitrate + Nitrite Source Categories and Descriptions for the Madison TMDL Planning Area

Source Category	Source Descriptions
Nonpoint Sources (Agriculture, residential development and subsurface wastewater disposal and treatment, silviculture, and mining)	• septic • domestic animal waste • fertilizer • loss of riparian and wetland vegetation along streambanks • reduced nutrient uptake due to loss of overstory • anthropogenic activities contributing to runoff from exposed rock or soil containing natural background nitrate • residual chemicals left over from mining practices • residential development

Table 5-35. Total Phosphorus Source Categories and Descriptions for the Madison TMDL Planning Area

Source Category	Load Allocation Descriptions
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute phosphorus to nearby waterbodies
Nonpoint Sources (Agriculture, residential development and subsurface wastewater disposal and treatment, silviculture, and mining)	• septic • domestic animal waste • fertilizer • loss of riparian and wetland vegetation along streambanks • reduced nutrient uptake due to loss of overstory • anthropogenic activities contributing to runoff from exposed rock or soil containing natural background phosphorus

5.7.1 Natural Background Allocation

LAs for natural background sources in all applicable impaired segments are based on median concentration values from reference sites in the Middle Rockies Level III Ecoregion during the growing season (**Table 5-36**) as described in Suplee et al., (2008) and Suplee and Watson (2013) (Suplee et al. 2008; Suplee and Schmidt 2013). Reference sites were chosen to represent stream conditions where human activities may be present but do not negatively harm stream uses. The effects of natural events such as forest pests and disease, flooding, and fire may be captured at these sites.

Table 5-36. Median Nutrient Concentration Values from DEQ Reference Sites

Level III Ecoregion	Growing Season	Nitrate + Nitrite (mg/L)	TN (mg/L)	TP (mg/L)
Middle Rockies	July 1 to September 30	0.020	0.095	0.010

Natural background load allocations are calculated by multiplying the median reference concentration by the streamflow. The natural background load allocation is calculated as follows (**Equation 5-3**):

Equation 5-3: LA_{NB} = (X) (Y) (5.4)

LA_{NB} = Load Allocation to natural background sources in lbs/day
*X = natural background concentration in mg/L (**Table 5-36**)*
Y = streamflow in cubic feet per second (cfs)
5.4 = conversion factor

5.7.2 Allocations for Human-Caused Sources

The LA to human-caused nonpoint sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load allocation (**Equation 5-4**):

Equation 5-4: LA_H = TMDL – LA_{NB}

LA_H = Load Allocation to human-caused nonpoint sources in lbs/day
TMDL = Total maximum daily load in lbs/day
LA_{NB} = Load Allocation to natural background sources in lbs/day

This equation will be used for nutrient TMDLs on all streams in the Madison TMDL Planning Area.

5.7.3 Total Existing (Above Target) Load

To estimate a total existing load for estimating a required load reduction, the following equation will be used:

Equation 5-5: Total Existing Load (lbs/day) = (X) (Y) (5.4)

X = measured concentration in mg/L (median of exceedances from the applicable stream)
Y = streamflow in cubic feet per second (cfs)
5.4 = conversion factor

Only the median of the concentrations that exceeded the target will be used to determine the total existing load since concentrations greater than the target indicate that the TMDL is being exceeded and load reductions are necessary. Concentrations that are below the target are meeting the TMDL and do not require load reductions.

5.7.4 Load Reductions

Loads greater than the TMDL require load reductions to meet the TMDL; because the TMDL changes in direct proportion to flow multiplied by concentration, percent reductions in nutrient loads are the same as percent reductions in nutrient concentrations. **Equation 5-6** was used to calculate load reductions for all streams in the Madison TMDL Planning Area:

Equation 5-6: Load Reduction = (1 - (TMDL/Total Existing Load))*100

TMDL = Total maximum daily load in lbs/day
*Total Existing Load = calculated total existing load in lbs/day (**Equation 5-5**)*

5.8 TMDLs and Allocations by Stream

The below sections establish TMDLs, natural background LAs, and composite LAs to identified sources. These sections additionally provide nutrient loading estimates for natural and human-caused source categories to nutrient-impaired stream segments, and estimate reductions necessary to meet water quality targets for the following streams:

- Elk Creek
- Hot Springs Creek
- Moore Creek
- O'Dell Spring Creek
- South Meadow Creek

As noted above in **Section 5.5**, a nutrient TMDL was not developed for Blaine Spring Creek at this time because of elevated concentrations of TN at the spring source, which may be naturally occurring. The total existing loads, based on concentrations as discussed above in **Section 5.7.3**, are used to estimate load reductions by comparing them to the allowable (TMDL) load and computing a required percent reduction to meet the TMDL. These load reduction estimates can be complicated by nutrient uptake within the stream. The number of TN and/or TP target exceedances, or the extent by which they exceed a target, can be masked by this nutrient uptake. No load reductions are given for natural background allocations; therefore, all necessary load reductions apply to the nonpoint sources within each watershed.

5.8.1 Elk Creek TMDLs and Allocations

This section describes the TN and TP TMDLs, as well as the NO_3 + NO_2 TMDL surrogate for Elk Creek.

5.8.1.1 Elk Creek TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-32** presents the TN TMDL for Elk Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

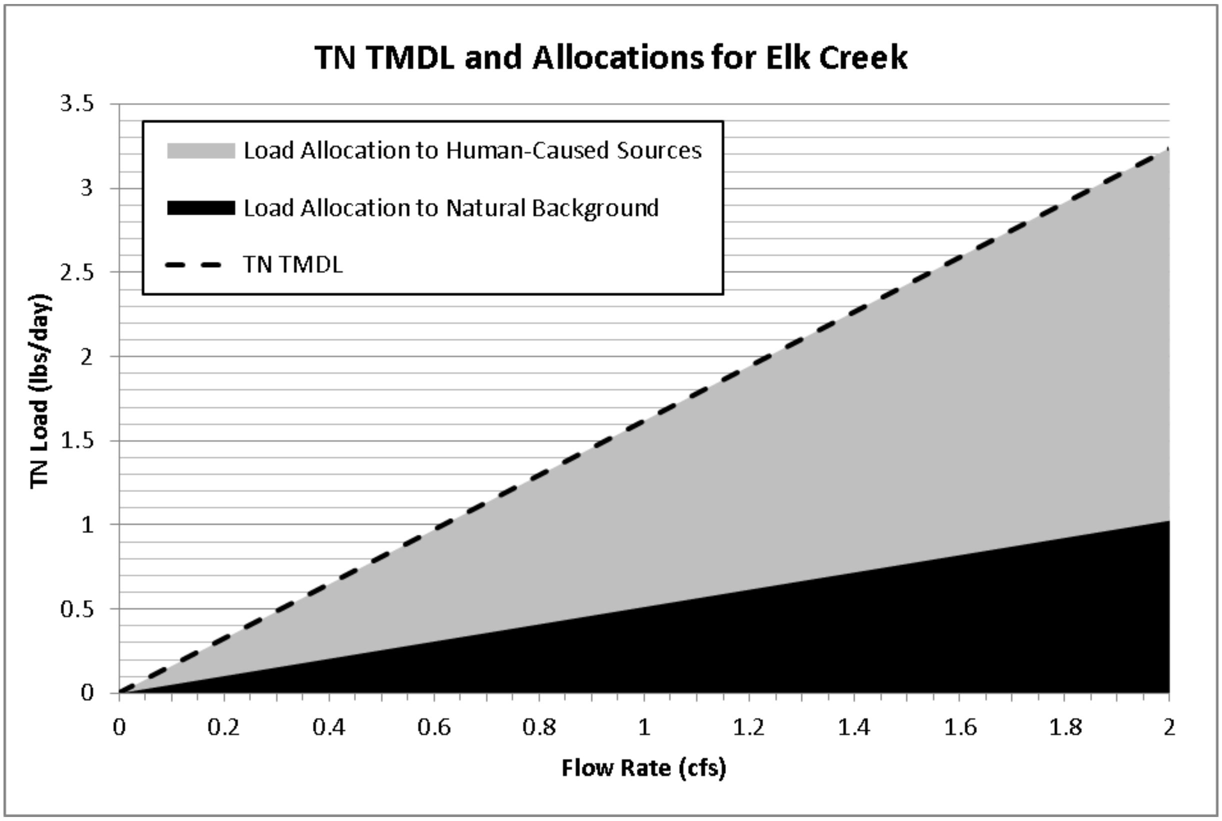

Figure 5-32. TN TMDL and source allocations for Elk Creek

The following is the Elk Creek TN TMDL for a median flow rate of 0.14 cfs. This median flow rate was derived from measured flow values on all sites during the 2007-2013 sampling:

TMDL = (0.30 mg/L) (0.14 cfs) (5.4) = 0.23 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TN. To continue with the calculation at a flow rate of 0.14 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (0.14 cfs) (5.4) = 0.070 lbs/day

Using **Equation 5-4**, the human-caused TN load allocation at a flow rate of 0.14 cfs can be calculated:

LA_{H} = (0.23 lbs/day) – (0.070 lbs/day) = 0.16 lbs/day

The total existing load at a flow rate of 0.14 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TN target exceedance values measured from Elk Creek from 2007-2013 (0.71 mg/L):

Total Existing Load = (0.71 mg/L) (0.14 cfs) (5.4) = 0.54 lbs/day

The portion of the total existing load attributed to human-caused sources is 0.47 lbs/day, which is determined by subtracting out the 0.070 lbs/day background load. This 0.47 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-37 contains the results for the TN TMDL expressed at a median flow rate of 0.14 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 0.14 cfs, and the median of measured TN target exceedance values, the current loading in Elk Creek is greater than the TMDL. Under these conditions, a 66% reduction of human-caused TN loads, which results in an overall 57% reduction of TN in Elk Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TN concentration targets under all conditions will equate to meeting the TMDL.

Table 5-37. Elk Creek TN TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	0.070	0.070	0%
Human-caused	0.16	0.47	66%
	TMDL = 0.23	**Total = 0.54**	**Total = 57%**

[1] Based on a median growing season flow rate of 0.14 cfs

The source assessment of the Elk Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, and agriculture are the most likely sources of TN in Elk Creek; load reductions should focus on limiting and controlling TN loading from those sources. Meeting LAs for Elk Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.1.2 Elk Creek $NO_3 + NO_2$ TMDL Surrogate

Because nitrate and nitrite are components of TN, and because the loading sources and methods to reduce loading sources of $NO_3 + NO_2$ and TN are essentially the same, the above TMDL for TN is a surrogate TMDL for $NO_3 + NO_2$ in Elk Creek. As a result, existing $NO_3 + NO_2$ loading requires reductions consistent with the TN TMDL and the composite load allocation for $NO_3 + NO_2$ would apply to the same source categories as the TN composite load allocation.

5.8.1.3 Elk Creek TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-33** presents the TP TMDL for Elk Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

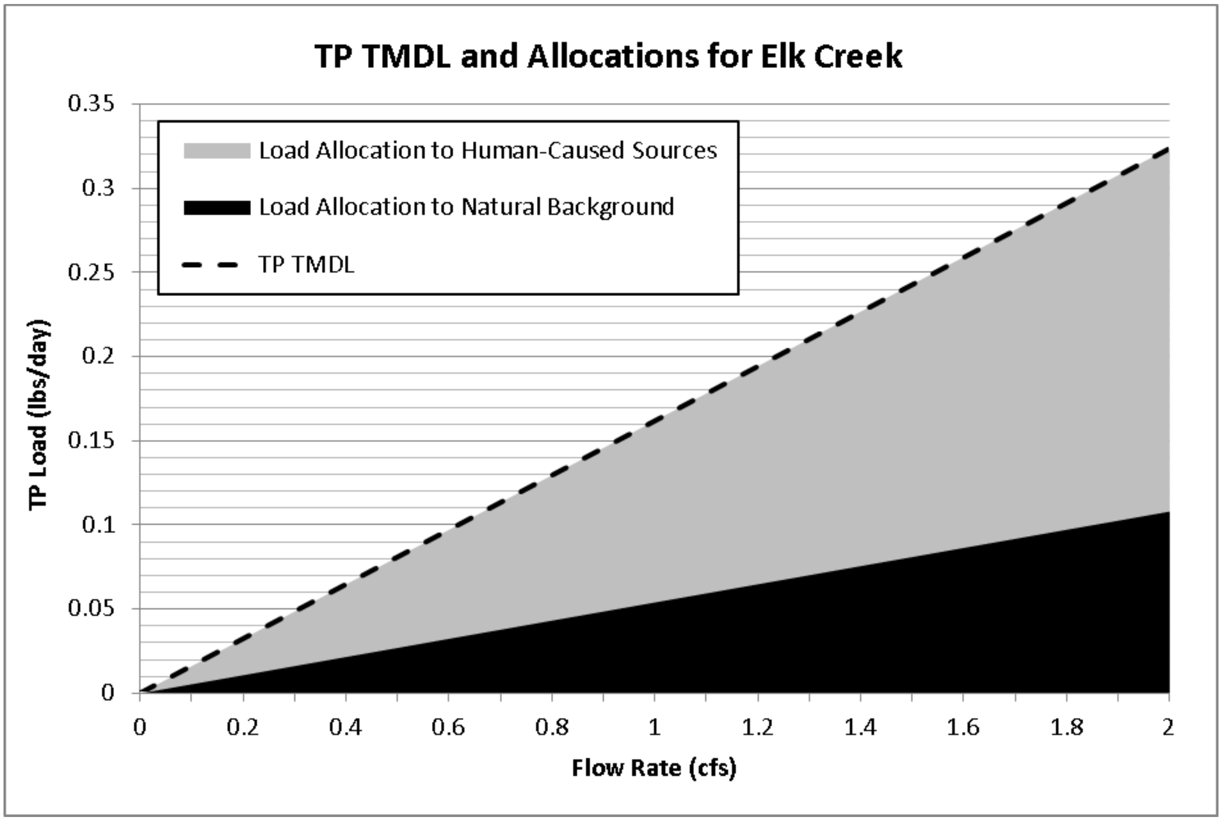

Figure 5-33. TP TMDL and source allocations for Elk Creek

The following is the Elk Creek TP TMDL for a median flow rate of 0.14 cfs. This median flow rate was derived from measured flow values on all sites during the 2007-2013 sampling:

TMDL = (0.030 mg/L) (0.14 cfs) (5.4) = 0.023 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TP. To continue with the calculation at a flow rate of 0.14 cfs, this allocation is as follows:

LA_{NB} = (0.010 mg/L) (0.14 cfs) (5.4) = 0.0080 lbs/day

Using **Equation 5-4**, the human-caused TP load allocation at a flow rate of 0.14 cfs can be calculated:

LA_{H} = (0.023 lbs/day) – (0.0080 lbs/day) = 0.015 lbs/day

The total existing load at a flow rate of 0.14 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TP target exceedance values measured from Elk Creek from 2007-2013 (0.097 mg/L):

Total Existing Load = (0.097 mg/L) (0.14 cfs) (5.4) = 0.073 lbs/day

The portion of the total existing load attributed to human-caused sources is 0.065 lbs/day, which is determined by subtracting out the 0.0080 lbs/day background load. This 0.065 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-38 contains the results for the TP TMDL expressed at a median flow rate of 0.14 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 0.14 cfs, and the median of measured TP target exceedance values, the current loading in Elk Creek is greater than the TMDL. Under these conditions, a 77% reduction of human-caused TP loads, which results in an overall 68% reduction of TP in Elk Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TP concentration targets under all conditions will equate to meeting the TMDL.

Table 5-38. Elk Creek TP TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	**Allocation and TMDL (lbs/day)**[1]	**Existing Load (lbs/day)**[1]	**Percent Reduction Needed to Meet the TMDL**
Natural Background	0.0080	0.0080	0%
Human-caused	0.015	0.065	77%
	TMDL = 0.023	**Total = 0.073**	**Total = 68%**

[1] Based on a median growing season flow rate of 0.14 cfs

The source assessment of the Elk Creek watershed indicates that agriculture is the most likely source of TP in Elk Creek; load reductions should focus on limiting and controlling TP loading from this source. Meeting LAs for Elk Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.2 Hot Springs Creek TMDLs and Allocations

This section describes the TN and TP TMDLs for Hot Springs Creek.

5.8.2.1 Hot Springs Creek TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-34** presents the TN TMDL for Hot Springs Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

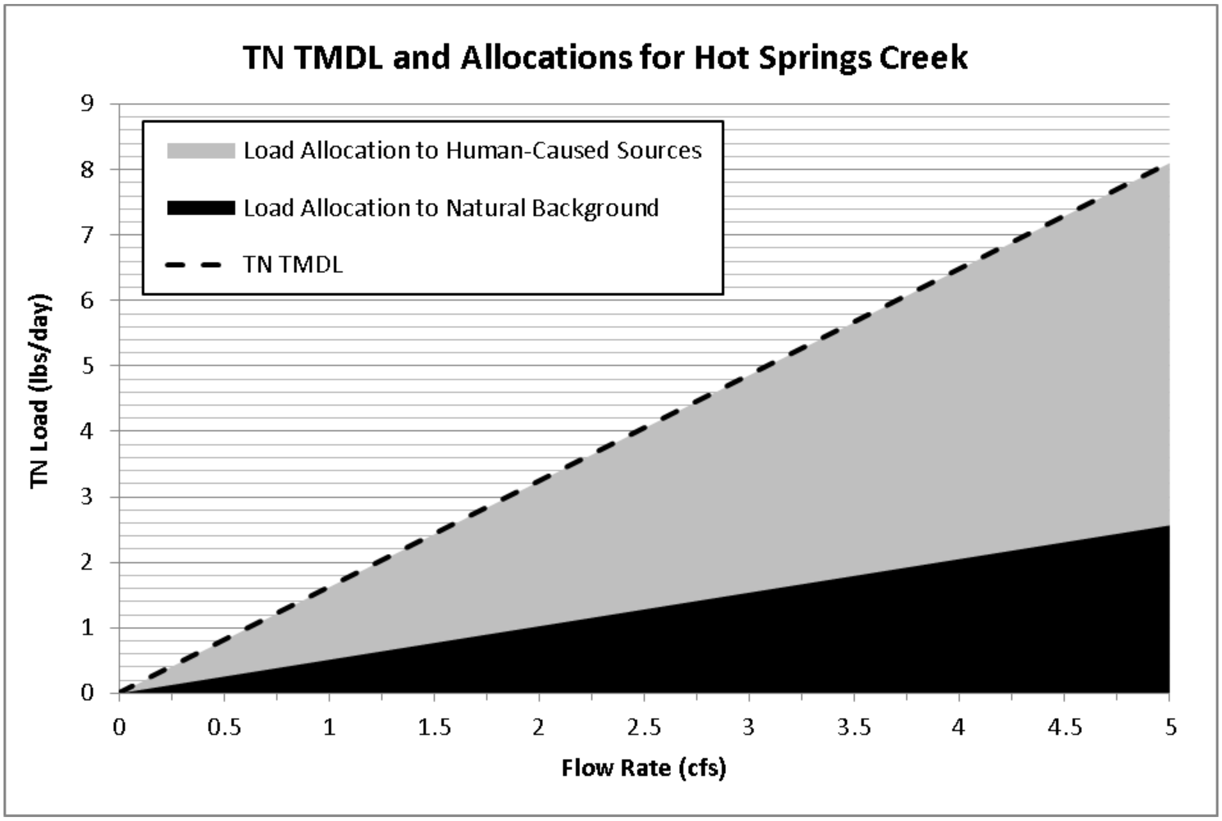

Figure 5-34. TN TMDL and source allocations for Hot Springs Creek

The following is the Hot Springs Creek TN TMDL for a median flow rate of 2.4 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2013 sampling:

TMDL = (0.30 mg/L) (2.4 cfs) (5.4) = 3.9 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TN. To continue with the calculation at a flow rate of 2.4 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (2.4 cfs) (5.4) = 1.2 lbs/day

Using **Equation 5-4**, the human-caused TN load allocation at a flow rate of 2.4 cfs can be calculated:

LA_{H} = (3.9 lbs/day) – (1.2 lbs/day) = 2.7 lbs/day

The total existing load at a flow rate of 2.4 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TN target exceedance values measured from Hot Springs Creek from 2012-2013 (0.50 mg/L):

Total Existing Load = (0.50 mg/L) (2.4 cfs) (5.4) = 6.5 lbs/day

The portion of the total existing load attributed to human-caused sources is 5.3 lbs/day, which is determined by subtracting out the 1.2 lbs/day background load. This 5.3 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-39 contains the results for the TN TMDL expressed at a median flow rate of 2.4 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 2.4 cfs, and the median of measured TN target exceedance values, the current loading in Hot Springs Creek is greater than the TMDL. Under these conditions, a 49% reduction of human-caused TN loads, which results in an overall 40% reduction of TN in Hot Springs Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TN concentration targets under all conditions will equate to meeting the TMDL.

Table 5-39. Hot Springs Creek TN TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	1.2	1.2	0%
Human-caused	2.7	5.3	49%
	TMDL = 3.9	**Total = 6.5**	**Total = 40%**

[1] Based on a median growing season flow rate of 2.4 cfs

The source assessment of the Hot Springs Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, agriculture, and mining are the most likely sources of TN in Hot Springs Creek; load reductions should focus on limiting and controlling TN loading from those sources. Meeting LAs for Hot Springs Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.2.1 Hot Springs Creek TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-35** presents the TP TMDL for Hot Springs Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

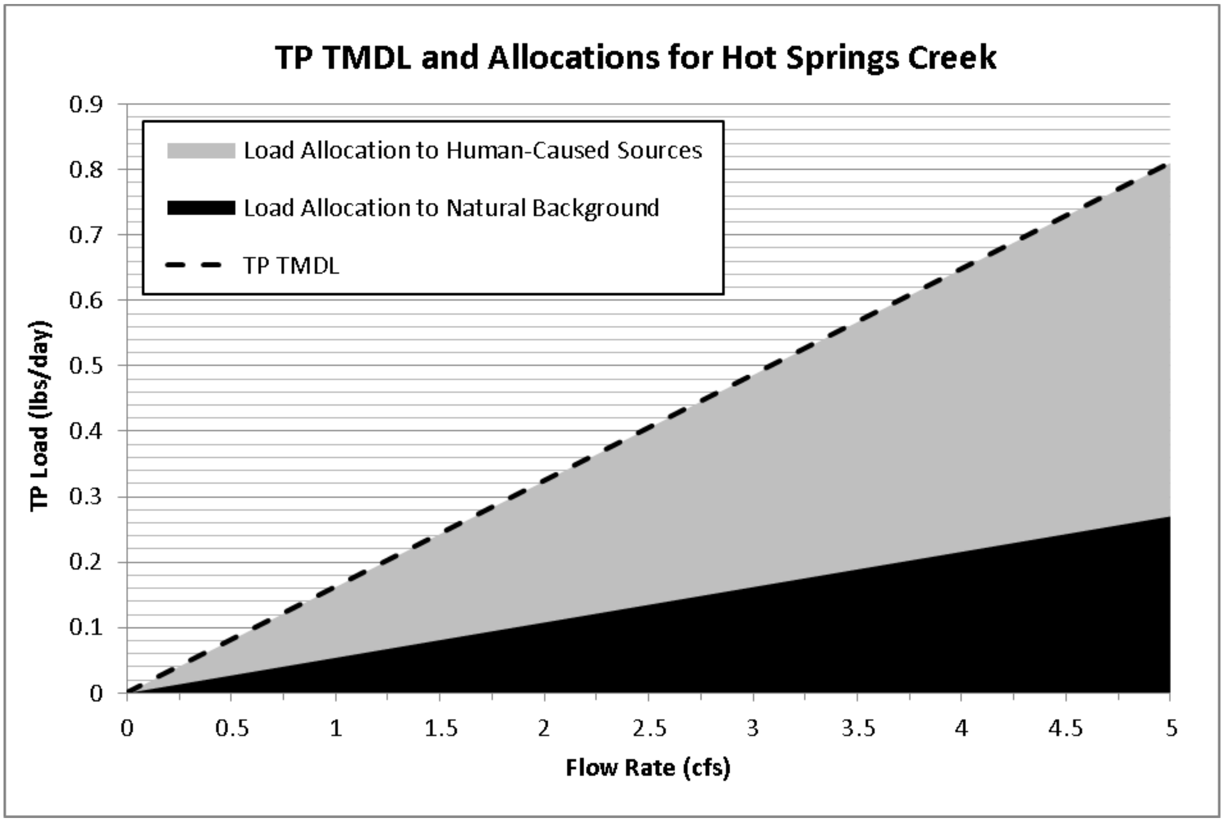

Figure 5-35. TP TMDL and source allocations for Hot Springs Creek

The following is the Hot Springs Creek TP TMDL for a median flow rate of 2.4 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2013 sampling:

TMDL = (0.030 mg/L) (2.4 cfs) (5.4) = 0.39 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TP. To continue with the calculation at a flow rate of 2.4 cfs, this allocation is as follows:

LA_{NB} = (0.010 mg/L) (2.4 cfs) (5.4) = 0.13 lbs/day

Using **Equation 5-4**, the human-caused TP load allocation at a flow rate of 2.4 cfs can be calculated:

LA_{H} = (0.39 lbs/day) – (0.13 lbs/day) = 0.26 lbs/day

The total existing load at a flow rate of 2.4 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TP target exceedance values measured from Hot Springs Creek from 2012-2013 (0.11 mg/L):

Total Existing Load = (0.11 mg/L) (2.4 cfs) (5.4) = 1.4 lbs/day

The portion of the total existing load attributed to human-caused sources is 1.3 lbs/day, which is determined by subtracting out the 0.13 lbs/day background load. This 1.3 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-40 contains the results for the TP TMDL expressed at a median flow rate of 2.4 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 2.4 cfs, and the median of measured TP target exceedance values, the current loading in Hot Springs Creek is greater than the TMDL. Under these conditions, an 80% reduction of human-caused TP loads, which results in an overall 72% reduction of TP in Hot Springs Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TP concentration targets under all conditions will equate to meeting the TMDL.

Table 5-40. Hot Springs Creek TP TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	0.13	0.13	0%
Human-caused	0.26	1.3	80%
	TMDL = 0.39	**Total = 1.4**	**Total = 72%**

[1] Based on a median growing season flow rate of 2.4 cfs

The source assessment of the Hot Springs Creek watershed indicates that agriculture is the most likely source of TP in Hot Springs Creek; load reductions should focus on limiting and controlling TP loading from this source. Meeting LAs for Hot Springs Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.3 Moore Creek TMDLs and Allocations

This section describes the TN and TP TMDLs for Moore Creek.

5.8.3.1 Moore Creek TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-36** presents the TN TMDL for Moore Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

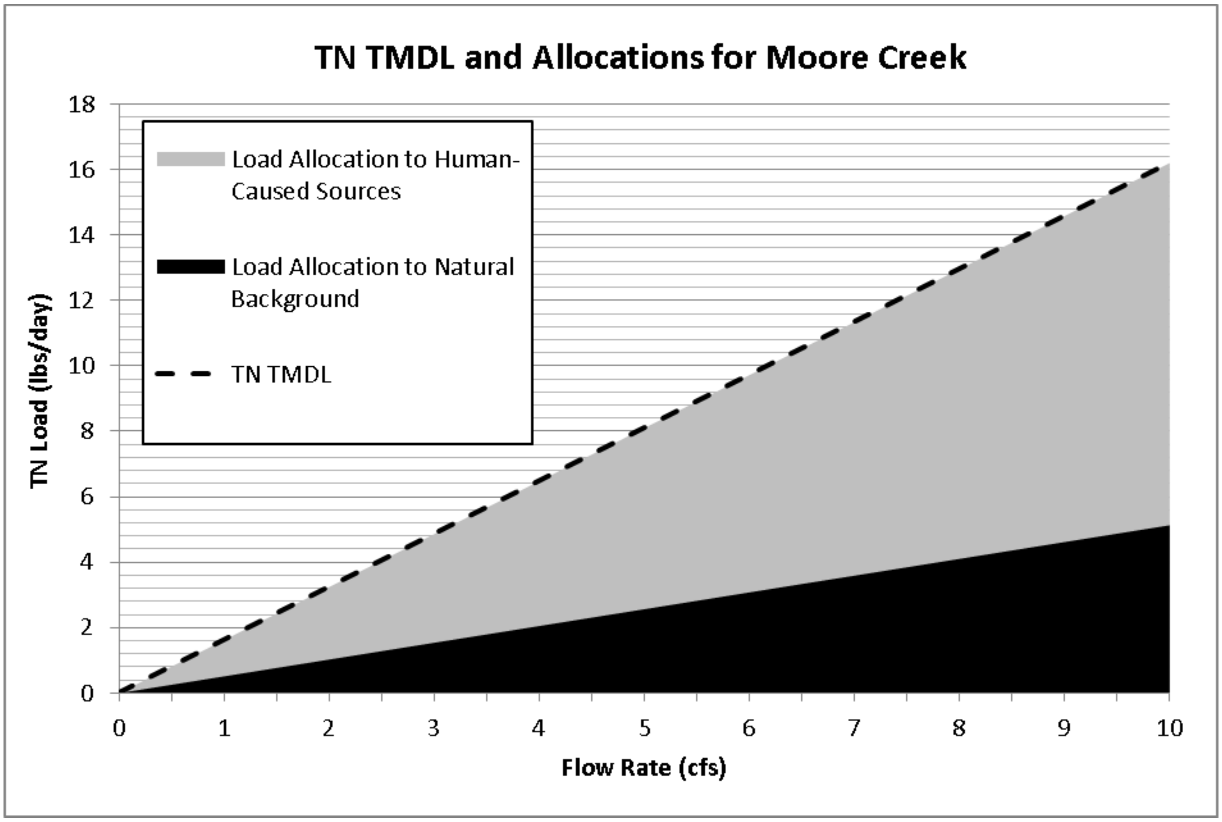

Figure 5-36. TN TMDL and source allocations for Moore Creek

The following is the Moore Creek TN TMDL for a median flow rate of 2.0 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2014 sampling:

TMDL = (0.30 mg/L) (2.0 cfs) (5.4) = 3.2 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TN. To continue with the calculation at a flow rate of 2.0 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (2.0 cfs) (5.4) = 1.0 lbs/day

Using **Equation 5-4**, the human-caused TN load allocation at a flow rate of 2.0 cfs can be calculated:

LA_{H} = (3.2 lbs/day) – (1.0 lbs/day) = 2.2 lbs/day

The total existing load at a flow rate of 2.0 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TN target exceedance values measured from Moore Creek from 2012-2014 (0.58 mg/L):

Total Existing Load = (0.58 mg/L) (2.0 cfs) (5.4) = 6.2 lbs/day

The portion of the total existing load attributed to human-caused sources is 5.2 lbs/day, which is determined by subtracting out the 1.0 lbs/day background load. This 5.2 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-41 contains the results for the TN TMDL expressed at a median flow rate of 2.0 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 2.0 cfs, and the median of measured TN target exceedance values, the current loading in Moore Creek is greater than the TMDL. Under these conditions, a 58% reduction of human-caused TN loads, which results in an overall 48% reduction of TN in Moore Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TN concentration targets under all conditions will equate to meeting the TMDL.

Table 5-41. Moore Creek TN TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	1.0	1.0	0%
Human-caused	2.2	5.2	58%
	TMDL = 3.2	**Total = 6.2**	**Total = 48%**

[1] Based on a median growing season flow rate of 2.0 cfs

The source assessment of the Moore Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, and agriculture are the most likely sources of TN in Moore Creek; load reductions should focus on limiting and controlling TN loading from those sources. Meeting LAs for Moore Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.3.2 Moore Creek TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-37** presents the TP TMDL for Moore Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

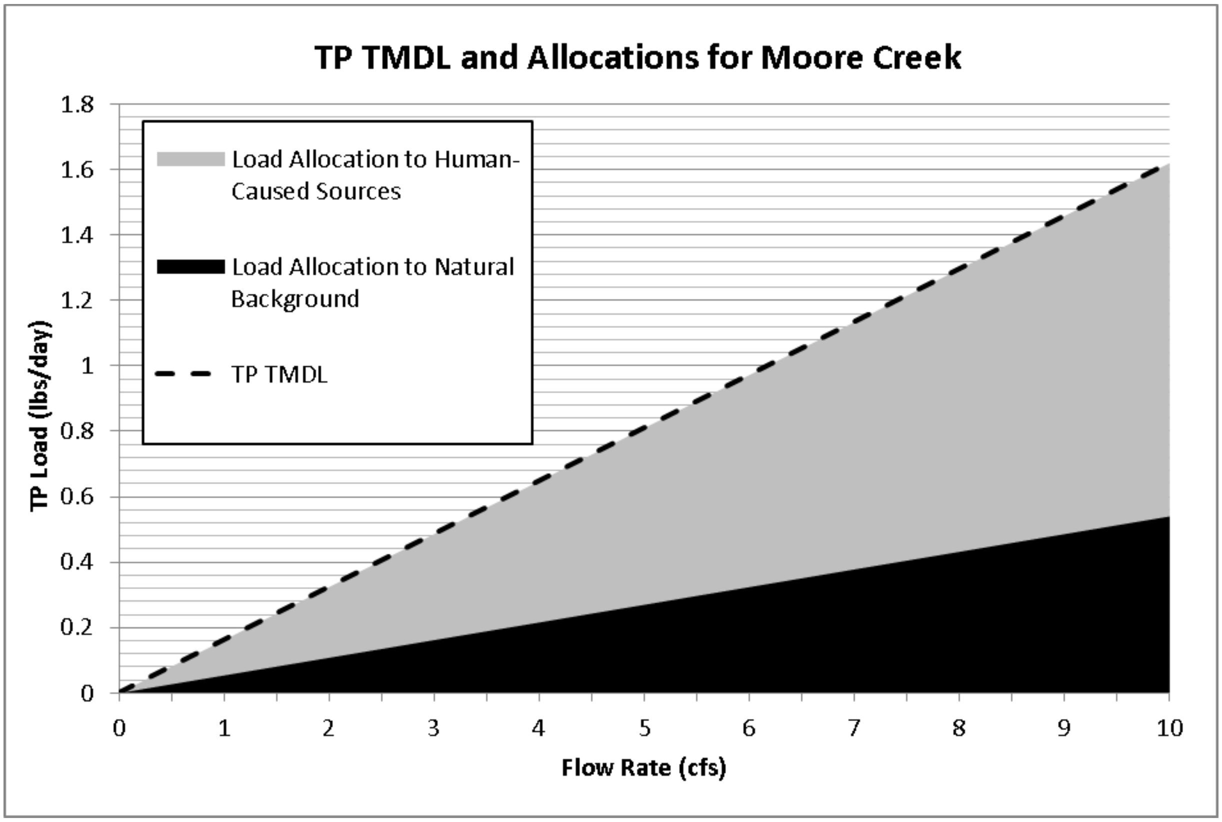

Figure 5-37. TP TMDL and source allocations for Moore Creek

The following is the Moore Creek TP TMDL for a median flow rate of 2.0 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2014 sampling:

TMDL = (0.030 mg/L) (2.0 cfs) (5.4) = 0.32 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TP. To continue with the calculation at a flow rate of 2.0 cfs, this allocation is as follows:

LA_{NB} = (0.010 mg/L) (2.0 cfs) (5.4) = 0.11 lbs/day

Using **Equation 5-4**, the human-caused TP load allocation at a flow rate of 2.0 cfs can be calculated:

LA_H = (0.32 lbs/day) – (0.11 lbs/day) = 0.21 lbs/day

The total existing load at a flow rate of 2.0 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TP target exceedance values measured from Moore Creek from 2012-2014 (0.056 mg/L):

Total Existing Load = (0.056 mg/L) (2.0 cfs) (5.4) = 0.60 lbs/day

The portion of the total existing load attributed to human-caused sources is 0.49 lbs/day, which is determined by subtracting out the 0.11 lbs/day background load. This 0.49 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-42 contains the results for the TP TMDL expressed at a median flow rate of 2.0 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 2.0 cfs, and the median of measured TP target exceedance values, the current loading in Moore Creek is greater than the TMDL. Under these conditions, a 55% reduction of human-caused TP loads, which results in an overall 47% reduction of TP in Moore Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TP concentration targets under all conditions will equate to meeting the TMDL.

Table 5-42. Moore Creek TP TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	0.11	0.11	0%
Human-caused	0.22	0.49	55%
	TMDL = 0.32	**Total = 0.60**	**Total = 47%**

[1] Based on a median growing season flow rate of 2.0 cfs

The source assessment of the Moore Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, and agriculture are the most likely sources of TP in Moore Creek; load reductions should focus on limiting and controlling TP loading from those sources. Meeting LAs for Moore Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.4 O'Dell Spring Creek TMDL and Allocations

This section describes the TN TMDL for O'Dell Spring Creek.

5.8.4.1 O'Dell Spring Creek TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-38** presents the TN TMDL for O'Dell Spring Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

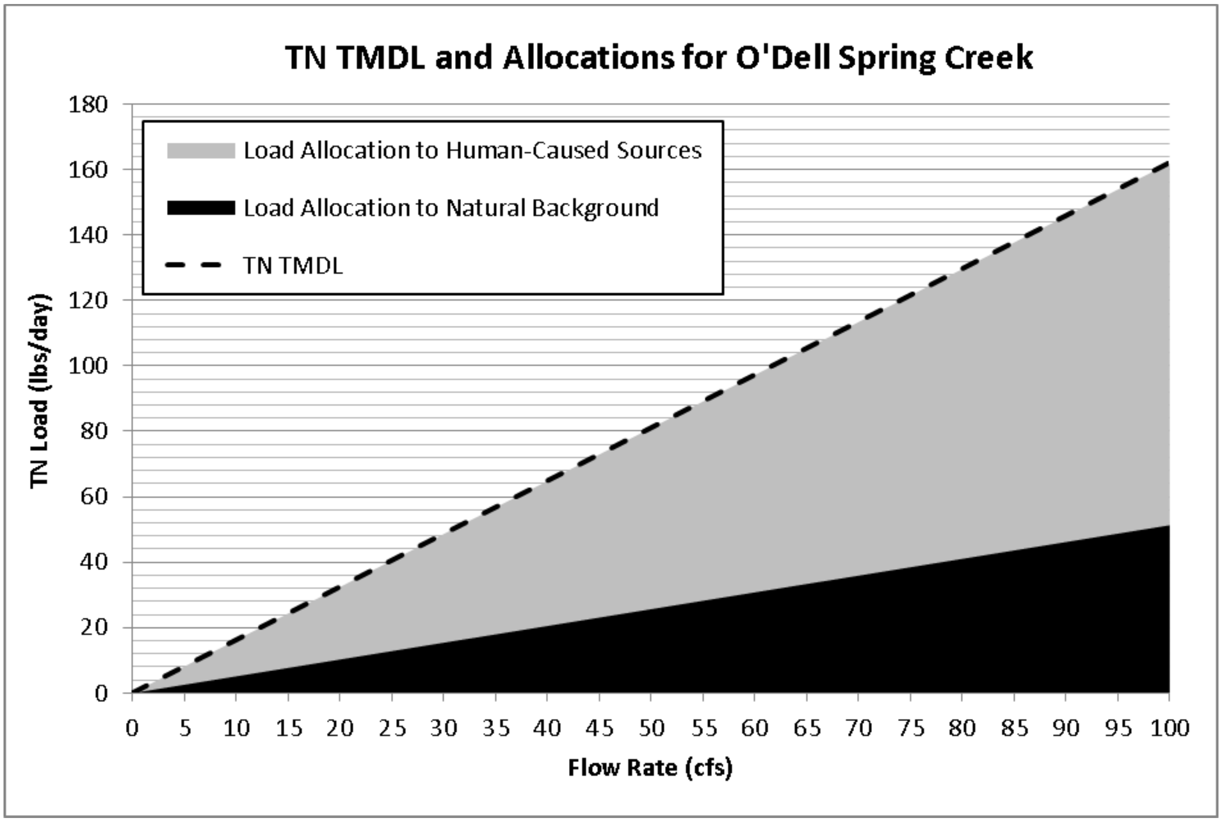

Figure 5-38. TN TMDL and source allocations for O'Dell Spring Creek

The following is the O'Dell Spring Creek TN TMDL for a median flow rate of 67 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2014 sampling:

TMDL = (0.30 mg/L) (67 cfs) (5.4) = 109 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TN. To continue with the calculation at a flow rate of 67 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (67 cfs) (5.4) = 34 lbs/day

Using **Equation 5-4**, the human-caused TN load allocation at a flow rate of 67 cfs can be calculated:

LA_{H} = (109 lbs/day) – (34 lbs/day) = 75 lbs/day

The total existing load at a flow rate of 67 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TN target exceedance values measured from O'Dell Spring Creek from 2012-2014 (0.37 mg/L):

Total Existing Load = (0.37 mg/L) (67 cfs) (5.4) = 134 lbs/day

The portion of the total existing load attributed to human-caused sources is 100 lbs/day, which is determined by subtracting out the 34 lbs/day background load. This 100 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-43 contains the results for the TN TMDL expressed at a median flow rate of 67 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 67 cfs, and the median of measured TN target exceedance values, the current loading in O'Dell Spring Creek is greater than the TMDL. Under these conditions, a 25% reduction of human-caused TN loads, which results in an overall 19% reduction of TN in O'Dell Spring Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TN concentration targets under all conditions will equate to meeting the TMDL.

Table 5-43. O'Dell Spring Creek TN TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	34	34	0%
Human-caused	75	100	25%
	TMDL = 109	**Total = 134**	**Total = 19%**

[1] Based on a median growing season flow rate of 67 cfs

The source assessment of the O'Dell Spring Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, and agriculture are the most likely sources of TN in O'Dell Spring Creek; load reductions should focus on limiting and controlling TN loading from those sources. Meeting LAs for O'Dell Spring Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.5 South Meadow Creek TMDLs and Allocations

This section describes the TN and TP TMDLs for South Meadow Creek.

5.8.5.1 South Meadow Creek TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-39** presents the TN TMDL for South Meadow Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

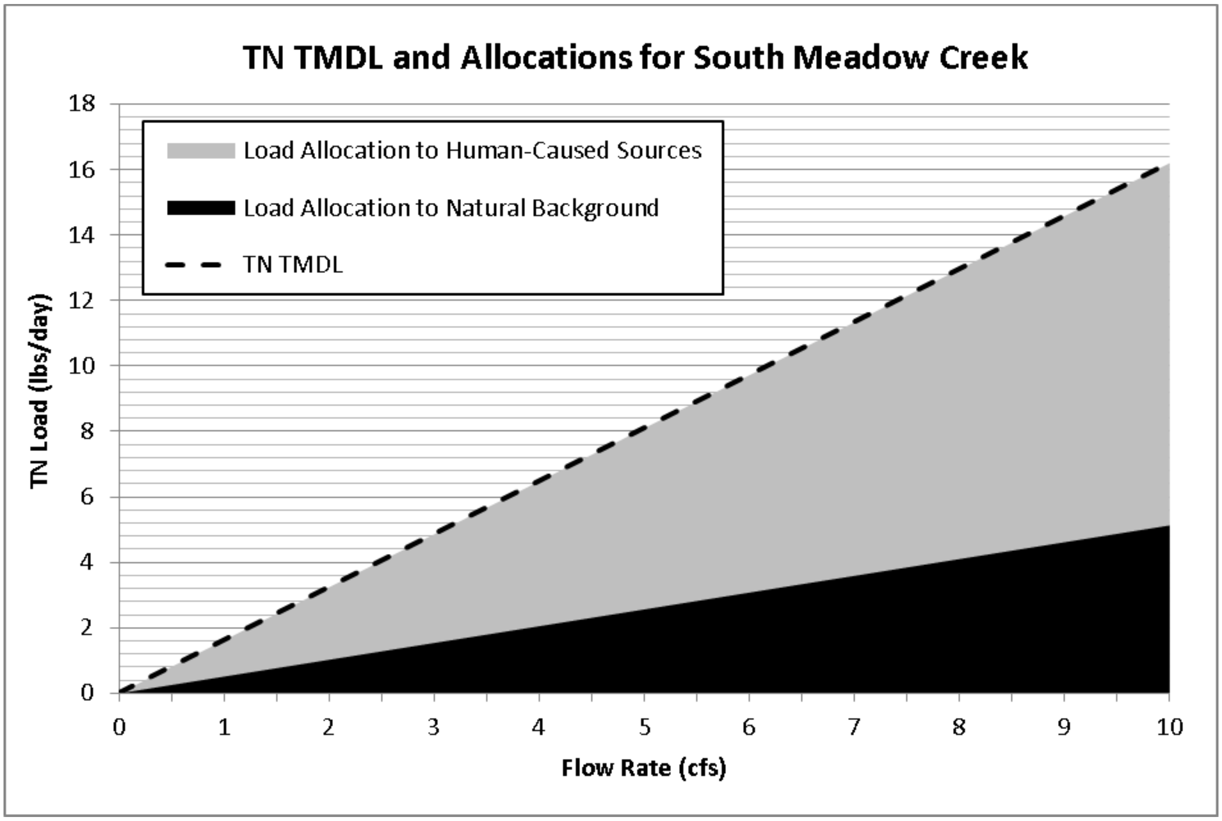

Figure 5-39. TN TMDL and source allocations for South Meadow Creek

The following is the South Meadow Creek TN TMDL for a median flow rate of 4.7 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2014 sampling:

TMDL = (0.30 mg/L) (4.7 cfs) (5.4) = 7.6 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TN. To continue with the calculation at a flow rate of 4.7 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (4.7 cfs) (5.4) = 2.4 lbs/day

Using **Equation 5-4**, the human-caused TN load allocation at a flow rate of 4.7 cfs can be calculated:

LA_{H} = (7.6 lbs/day) – (2.4 lbs/day) = 5.2 lbs/day

The total existing load at a flow rate of 4.7 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TN target exceedance values measured from South Meadow Creek from 2012-2014 (0.46 mg/L):

Total Existing Load = (0.46 mg/L) (4.7 cfs) (5.4) = 11.7 lbs/day

The portion of the total existing load attributed to human-caused sources is 9.3 lbs/day, which is determined by subtracting out the 2.4 lbs/day background load. This 9.3 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-44 contains the results for the TN TMDL expressed at a median flow rate of 4.7 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 4.7 cfs, and the median of measured TN target exceedance values, the current loading in South Meadow Creek is greater than the TMDL. Under these conditions, a 44% reduction of human-caused TN loads, which results in an overall 35% reduction of TN in South Meadow Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TN concentration targets under all conditions will equate to meeting the TMDL.

Table 5-44. South Meadow Creek TN TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	2.4	2.4	0%
Human-caused	5.2	9.3	44%
	TMDL = 7.6	**Total = 11.7**	**Total = 35%**

[1] Based on a median growing season flow rate of 4.7 cfs

The source assessment of the South Meadow Creek watershed indicates that residential development, subsurface wastewater treatment and disposal, and agriculture are the most likely sources of TN in South Meadow Creek; load reductions should focus on limiting and controlling TN loading from those sources. Meeting LAs for South Meadow Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**.

5.8.5.1 South Meadow Creek TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5-1** and the TMDL allocations are based on **Equation 5-2.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figure 5-40** presents the TP TMDL for South Meadow Creek, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

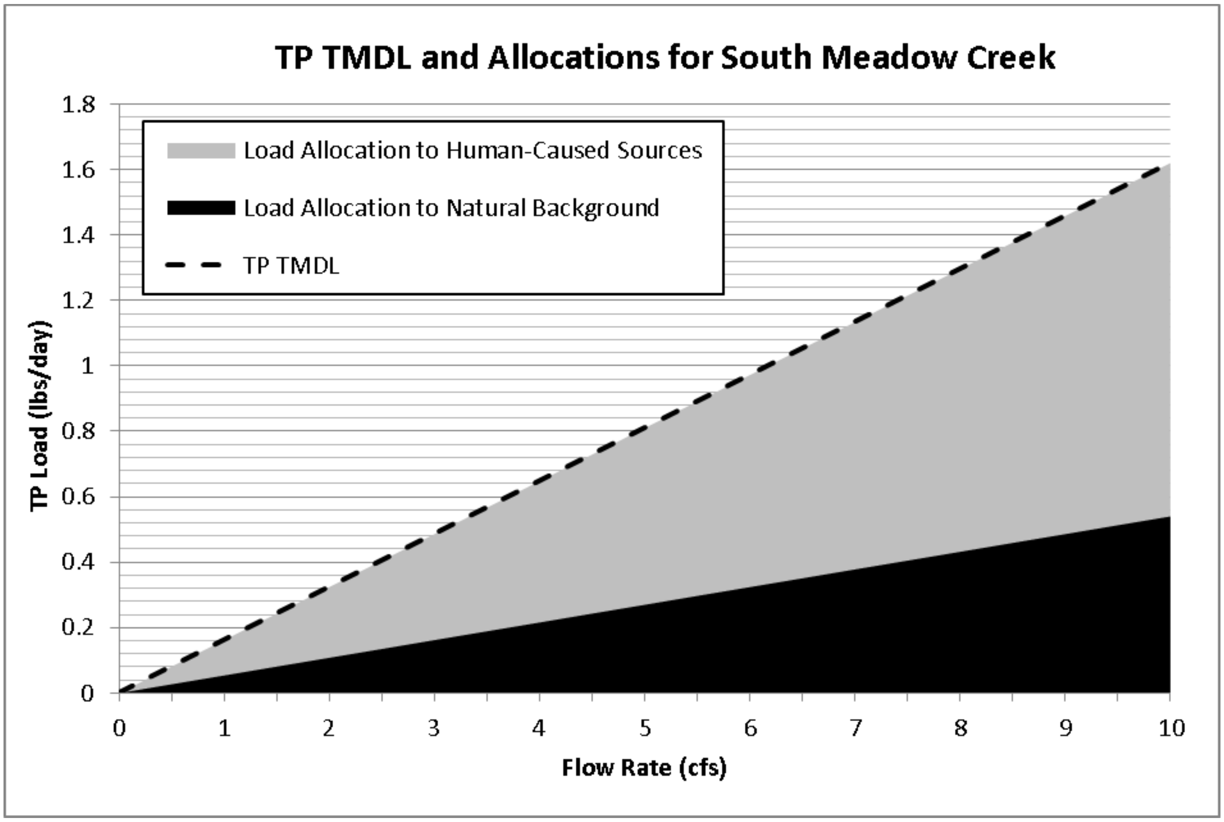

Figure 5-40. TP TMDL and source allocations for South Meadow Creek

The following is the South Meadow Creek TP TMDL for a median flow rate of 4.7 cfs. This median flow rate was derived from measured flow values on all sites during the 2012-2014 sampling:

TMDL = (0.030 mg/L) (4.7 cfs) (5.4) = 0.76 lbs/day

Equation 5-3 is the basis for the natural background load allocation for TP. To continue with the calculation at a flow rate of 4.7 cfs, this allocation is as follows:

LA_{NB} = (0.010 mg/L) (4.7 cfs) (5.4) = 0.25 lbs/day

Using **Equation 5-4**, the human-caused TP load allocation at a flow rate of 4.7 cfs can be calculated:

LA_{H} = (0.76 lbs/day) – (0.25 lbs/day) = 0.51 lbs/day

The total existing load at a flow rate of 4.7 cfs is based on **Equation 5-5**, and is calculated as follows using the median of TP target exceedance values measured from South Meadow Creek from 2012-2014 (0.035 mg/L):

Total Existing Load = (0.035 mg/L) (4.7 cfs) (5.4) = 0.89 lbs/day

The portion of the total existing load attributed to human-caused sources is 0.64 lbs/day, which is determined by subtracting out the 0.25 lbs/day background load. This 0.64 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-45 contains the results for the TP TMDL expressed at a median flow rate of 4.7 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 4.7 cfs, and the median of measured TP target exceedance values, the current loading in South Meadow Creek is greater than the TMDL. Under these example conditions, a 20% reduction of human-caused TP loads, which results in an overall 15% reduction of TP in South Meadow Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream TP concentration targets under all conditions will equate to meeting the TMDL.

Table 5-45. South Meadow Creek TP TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Natural Background	0.25	0.25	0%
Human-caused	0.51	0.64	20%
	TMDL = 0.76	**Total = 0.89**	**Total = 15%**

[1] Based on a median growing season flow rate of 4.7 cfs

The source assessment of the South Meadow Creek watershed indicates that agriculture is the most likely source of TP in South Meadow Creek; load reductions should focus on limiting and controlling TP loading from this source. Meeting LAs for South Meadow Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**

5.8.6 Summary of Load Reduction Requirements

The nutrient TMDLs developed for streams in the Madison TMDL Planning Area, the current loading based on the median of measured target exceedance values at a median flow rate, and the percent reduction needed to meet these TMDLs are summarized below in **Table 5-46**.

Table 5-46. Summary of the Madison TMDL Planning Area Nutrient TMDLs Expressed at a Median Growing Season Flow Rate, and Percent Reductions from Existing Loading Needed to Meet Each TMDL

Waterbody (Assessment Unit)	Median Growing Season Flow Rate (cfs)	Pollutant	TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction Needed to Meet the TMDL
Elk Creek	0.14	TN	0.23	0.54	57%
		TP	0.023	0.073	68%
Hot Springs Creek	2.4	TN	3.9	6.5	40%
		TP	0.39	1.4	72%
Moore Creek	2.0	TN	3.2	6.2	48%
		TP	0.32	0.60	47%
O'Dell Spring Creek	67	TN	109	134	19%
South Meadow Creek	4.7	TN	7.6	11.7	35%
		TP	0.76	0.89	15%

[1] Based on a median growing season flow rate

5.9 Seasonality and Margin of Safety

TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), Wasteload Allocations (WLAs) and Load Allocations (LAs). TMDL development must also incorporate a margin of safety (MOS) 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 are sufficiently protective of water quality and beneficial uses. This section describes seasonality and MOS in the Madison TMDL Planning Area nutrient TMDL development process.

5.9.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan, seasonality is an integral consideration. Water quality and particularly nitrogen concentrations are recognized to have seasonal cycles. Specific examples of how seasonality has been addressed within this document include:

- Water quality targets and subsequent allocations are applicable for the summer growing season (July 1 to September 30), to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads were collected during the summertime period to coincide with applicable nutrient targets.
- Flow values used in calculating the nutrient TMDLs and allocations contained in **Section 5.8** were collected during the summer growing season (July 1 to September 30) and are considered representative of conditions during which nutrient concentration and seasonal algal growth targets apply.

5.9.2 Margin of Safety

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

- Static nutrient target values (0.30 mg/L for TN, 0.10 mg/L for NO_3+NO_2, and 0.030 mg/L for TP for the Middle Rockies level III ecoregion) were used to calculate allowable loads (TMDLs). Allowable exceedances of nutrient targets were not incorporated into the calculation of allowable loads, thereby adding a MOS to established allocations.
- Target values were developed to err on the conservative side of protecting beneficial uses. DEQ's nutrient assessment decision matrix for wadeable streams in mountainous regions of Western Montana considers impacts to both aquatic life and primary contact recreation, the two most sensitive beneficial uses affected by nutrient impairments. The assessment incorporates parameters representing physical (nutrient water chemistry), biological (e.g., periphyton and macroinvertebrates), and aesthetic (benthic algal growth concentrations) properties of these stream systems in a multi-tiered data analysis framework. Further, the nutrient assessment process considers both magnitude and frequency of nutrient target exceedances through the use of two statistical tests to help address nutrient uptake. Also, the number of allowable exceedances varies dependent on previous impairment status, taking a "guilty until proven innocent" approach for streams already considered to have water quality

problems and to attempt to balance type I (alpha) and type II (beta) errors (Suplee and Sada de Suplee 2011).
- Seasonality (discussed above) and variability in nutrient loading is considered in target development, monitoring design, and source assessment.
- An adaptive management approach (discussed below) is recommended to evaluate target attainment and allow for refinement of load allocations, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development over time.

5.10 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, nutrient targets, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. However, mitigation and reduction of uncertainties through adaptive management approaches is a key component of ongoing TMDL implementation and evaluation. The process of adaptive management is predicated on the premise that TMDL targets, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. Uncertainty is inherent in both the water quality-based and model-based methods of assessing nutrient sources and needed reductions. The main sources of uncertainty are summarized below.

5.10.1 Water Quality Conditions

It was assumed that sampling data for each waterbody segment are representative of conditions in each segment. Future monitoring as discussed in **Section 9.0** should help reduce the uncertainty regarding data representativeness, clarify for streams with TMDLs for both nutrient forms (i.e., TN and TP) whether both forms have a role in causing excess algal growth, improve the understanding of the effectiveness of Best Management Practice (BMP) implementation, and increase the understanding of the load reductions needed to meet the TMDLs.

It was also assumed that background concentrations are less than the target values, and based on sample data upstream of suspected sources and from other streams within the Madison TMDL Planning Area that are not impaired for nutrients, this appears to be true in most cases. However, it is possible that target values are naturally exceeded during certain times or at certain locations in the watershed. Blaine Spring Creek and O’Dell Spring Creek have elevated concentrations of NO_3+NO_2 at their respective sources and it is unknown at this time what proportion of that NO_3+NO_2 is naturally occurring. Future monitoring should help reduce uncertainty regarding background nutrient concentrations.

5.10.2 Source Assessment

Source characterization and assessment to determine the major sources in each of the nutrient impaired waterbodies was conducted by using monitoring data collected from the Madison TMDL Planning Area from 2007-2016, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Uncertainties in source assessment can occur by using data that does not reflect the current condition of the waterbody, the misinterpretation of aerial photos, using outdated GIS data, using field data that may not be representative of the overall condition of the waterbody, and referencing literature that was developed for areas outside of the Madison TMDL Planning Area.

Water quality monitoring data used for source assessment includes the time period from 2007-2016. Sources of pollutants or the level of contribution from those sources may have changed since data collection, and therefore there is some uncertainty that the data used is reflective of the current conditions of a particular waterbody. An assumption was made that the data used are representative of current conditions. Data collected on a waterbody accurately characterizes that particular site, but there is some uncertainty as to whether or not that site is representative of the overall waterbody conditions. To address this, monitoring site locations were selected to generate the most representative samples.

When using aerial photography and GIS data, uncertainty may occur through the misinterpretation of aerial photos and using GIS data that may either be inaccurate or outdated. To reduce uncertainty, multiple years of aerial photos were analyzed and only GIS data containing complete metadata and generated from reliable sources were used for source assessment.

Literature referenced in this study helped to identify potential sources of nutrients and their level of contribution. For sources that we did not have data for (timber harvest operations, wildland fires, mining contributions, animal feeding operations, etc.) assumptions were made, based on literature values, to the potential nutrient contribution of these sources. There is inherent uncertainty in applying literature values derived outside of the Madison TMDL Planning Area, but these values are assumed to be applicable to this area and helped to fill gaps where data do not exist.

5.10.3 Loading Estimates

Loading estimates are based on currently available data, and are only representative of the pollutant load at the time of data analysis. It is important to recognize that pollutant loads are not static and can therefore be different than the loads reported in this document. This brings some uncertainty into load reductions, as achieving the load reductions stated in this document may or may not result in meeting in-stream water quality targets based on current conditions. For the purpose of determining existing nutrient loads, the median of target exceedances was used, which only reflects the existing load when the exceedances are occurring. Future additional water quality monitoring may be able to identify when the TMDL is being met and when the TMDL is being exceeded, which can help guide BMP implementation efforts by identifying the most significant nutrient sources. Adaptive management can address uncertainties related to loading estimates through the re-evaluation of water quality conditions as BMPs are installed, land uses change, or pollutant sources and their contribution levels change.

6.0 *Escherichia coli (E. coli)* TMDL Components

This portion of the document focuses on *Escherichia coli* (*E. coli*) as an indicator of pathogen water quality impairment in the Madison TMDL Planning Area. It describes: (1) how excess *E. coli* is an indicator of impaired beneficial uses, (2) the affected stream segment (waterbody), (3) the currently available data pertaining to *E. coli* impairment in the watershed, (4) the identification of *E. coli* targets and the comparison of those targets to the affected stream segment, (5) the *E. coli* TMDL, (6) the sources of *E. coli* based on recent studies, (7) the source allocations for the TMDL, and (8) the seasonality and margin of safety for the TMDL.

6.1 Effects of Excess *E. coli* on Beneficial Uses

E. coli is a nonpathogenic indicator bacterium that is usually associated with pathogens transmitted by fecal contamination. While its presence does not always prove or disprove the presence of pathogenic bacteria, viruses, or protozoans, *E. coli* correlates highly with the presence of fecal contamination and is an indicator that other pathogenic bacteria are likely present (U.S. Environmental Protection Agency 2001). The Environmental Protection Agency (EPA) recommends the use of *E. coli* as the preferred indicator organism for pathogenic bacteria forms due to its strong correlation with swimming-related gastroenteritis. Elevated instream concentrations of pathogenic pollutants put humans at risk for contracting water-borne illnesses and can lead to impairments of a waterbody's recreation beneficial use. In 2006 Montana DEQ adopted *E. coli* water quality criteria for the protection of recreational beneficial uses, replacing the previous Fecal Coliform water quality criteria.

6.2 Stream Segment of Concern

The stream segment of concern for *E. coli* in the Madison TMDL Planning Area is Moore Creek, which is listed as impaired for *E. coli* in the 2016 Water Quality Integrated Report (**Table 6-1**) (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau 2016). Moore Creek flows approximately 15.8 miles from its headwaters in the Tobacco Root Mountains to its confluence with the Madison River. Moore Creek was first listed as impaired by Fecal Coliform on the 2000 303(d) List of impaired waterbodies. In the 2012 Water Quality Integrated Report, that impairment listing was changed to *E. coli* due to the 2006 adoption of the new *E. coli* standard. In 2012, additional data were collected on Moore Creek to reassess and support the *E. coli* impairment listing for the 2016 Water Quality Integrated Report. **Figure 6-1** contains a map shows the location of the Moore Creek watershed in the Madison TMDL Planning Area.

Table 6-1. Stream Segment of Concern for *E. coli* Impairment Based on the 2016 Integrated Report

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Pathogen Related Pollutant Impairment Identified in the 2016 Integrated Report
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	*E. coli*

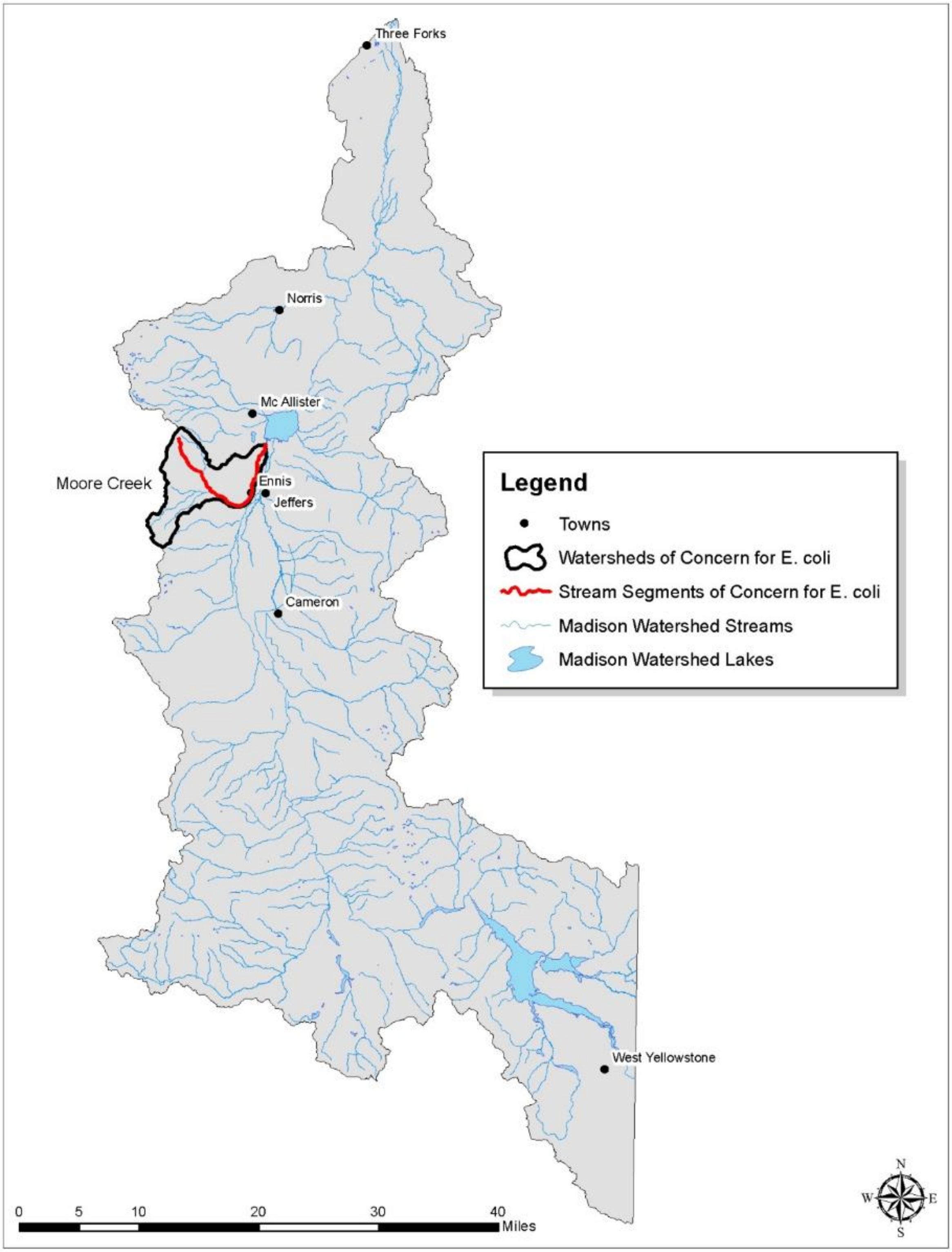

Figure 6-1. Map of the Stream Segment of Concern for E. coli in the Madison Watershed

6.3 Information Sources

The information sources used to develop the TMDL components include data used to determine impairments (**See Section 3.0**), in addition to data obtained during the TMDL development process. The data collected by DEQ, its contractors, other agencies, and volunteer monitoring groups, was catalogued within DEQ's centralized water quality database, and can be found in **Appendix A**. Data and information used for impairment determination, source assessment, and TMDL development consisted of:

- Water biological and streamflow data collected by DEQ and the Madison Stream Team
- Streamflow data collected by the United States Geological Survey (USGS)
- Grazing management plans developed by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS)
- Cropland data collected by the USDA
- Aerial photography and Geographic Information System (GIS) data and analysis
- Literature reviews

6.4 Water Quality Targets

Water quality targets are numeric indicators used to evaluate attainment of water quality standards, and are discussed in further detail in **Section 4.0**. This section presents *E. coli* water quality targets, and compares those target values to recently collected *E. coli* data.

6.4.1 *E. coli* Target Values and Assessment Methodology

6.4.1.1 E. coli Target Values

The Montana instream numeric water quality standards for *E. coli* are adopted as the *E. coli* target for streams in the Madison TMDL Planning Area. Because the numeric values within the standard and the TMDL target values are equal, the term "standard" and "target" are used interchangeably throughout the remainder of **Section 6.0**. Moore Creek is classified as a B-1 stream and therefore, the Montana *E. coli* standard for B-1 waterbodies (**Table 6-2**) applies [ARM 17.30.620(2)] and [ARM 17.30.602(11)]. The *E. coli* targets are seasonal and based on bacterial colony growth rates (e.g. colonies multiply and grow faster in warmer temperatures), thus creating a more stringent target for the summer period (April 1 through October 31) than the winter period (November 1 through March 31).

Table 6-2. *E. coli* Targets for B-1 classified waterbodies in the Madison TMDL Planning Area

Applicable Period	**Target Concentration** (cfu[1]/100 mL)	**Measurement Type**	**Allowable Exceedance Frequency**	**Dataset Requirement**
Summer *(April 1 – October 31)*	126	Geometric mean	Not to be exceeded	Minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period
	252	Single sample	< 10% exceedance rate allowed	
Winter *(November 1 – March 31)*	630	Geometric mean	Not to be exceeded	
	1,260	Single sample	< 10% exceedance rate allowed	

[1] Colony forming units

6.4.1.2 E. coli Assessment Methodology

Each waterbody assessed is compared to target values based on the above stated *E. coli* targets **(Table 6-2)** using the impairment assessment criteria as stated in the Administrative Rules of Montana [ARM 17.30.620(2)] and [ARM 17.30.602(11)]. The *E. coli* standard is based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period that are analyzed by the most probable number or equivalent membrane filter method. The geometric mean number of *E. coli* may not exceed 126 cfu/100 mL and 10% of the total samples may not exceed 252 cfu/100 mL during any 30-day period from April 1 through October 31. From November 1 through March 31, the geometric mean number of *E. coli* may not exceed 630 cfu/100 mL and 10% of the samples may not exceed 1,260 cfu/100 mL during any 30-day period. A geometric mean is the value obtained by taking the nth root of the product of the measured values, where n equals the number of samples collected. Values below the detection limit are taken to be the detection limit. If a waterbody does not meet the above-mentioned targets, then it is deemed to be impaired by *E. coli* and identified as such in Montana's Water Quality Integrated Report.

6.4.2 Existing Conditions and Comparison to Targets

DEQ evaluated attainment of *E. coli* water quality targets for Moore Creek by comparing existing water quality conditions with the water quality targets presented in **Table 6-2** and applied the assessment methodology described above in **Section 6.4.1.2**. A data summary is presented in **Table 6-3** along with a comparison of existing data with targets, using the assessment methodology, and a TMDL development determination was made. TMDL development determinations depend on results of the data evaluation, and these updated impairment determinations are found in the 2016 Water Quality Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau 2016).

A total of 22 *E. coli* samples were collected by DEQ in the summer of 2012 with 14 samples (64%) of the samples exceeding the individual sample target of 252 cfu/100 mL. *E. coli* concentration values ranged from 12 cfu/100 mL to 2,419.6 cfu/100 mL. The geometric mean for *E. coli* samples exceeded the target of 126 cfu/100 mL at four of the five sample sites, with the geometric means of each site ranging from 24.6 cfu/100 mL to 1,173.8 cfu/100 mL (**Table 6-3**). Due to the exceedance of the geometric mean target and the total sample exceedance target at four of the five sample sites, Moore Creek was determined to be impaired by *E. coli* and a TMDL will be developed.

Table 6-3. Moore Creek *E. coli* Data and Target Comparison Summary

Site ID	Data Collection Date	Result Value (cfu[1]/100 mL)	Geometric Mean (cfu[1]/100 mL)	Water Quality Targets[2]		Assessment Rationale Per Site
				Geometric Mean < 126 cfu[1]/100 mL	10% of E.coli samples <252 cfu[1]/ 100 mL	
Moore Creek upper site (M06MOREC03)	7/18/2012	21.5	24.6	**Yes (Pass)**	**Yes (Pass)**	**Site meets targets**
	7/19/2012	12				
	7/20/2012	18.3				
	7/21/2012	52.9				
	7/22/2012	35.9				

Table 6-3. Moore Creek *E. coli* Data and Target Comparison Summary

Site ID	Data Collection Date	Result Value (cfu[1]/100 mL)	Geometric Mean (cfu[1]/100 mL)	Water Quality Targets[2]		Assessment Rationale Per Site
				Geometric Mean < 126 cfu[1]/100 mL	10% of E.coli samples <252 cfu[1]/ 100 mL	
Moore Creek at Hwy 287 crossing (M06MOREC02)	7/18/2012	228.2	286.4	**No (Fail)**	**No (Fail)**	**Site does not meet targets**
	7/19/2012	167				
	7/20/2012	325.5				
	7/21/2012	378.4				
	7/22/2012	410.6				
Moore Creek just north of Ennis (M06MOREC04)	7/18/2012	435.2	290.2[3]	**No (Fail)**	**No (Fail)**	**Site does not meet targets**
	7/19/2012	193.5				
Moore Creek at Feeds-N-Needs (M06MOREC05)	7/18/2012	547.5	995.9	**No (Fail)**	**No (Fail)**	**Site does not meet targets**
	7/19/2012	517.2				
	7/20/2012	1553.1				
	7/21/2012	2419.6				
	7/22/2012	920.8				
Moore Creek north of Ennis (M06MOREC01)	7/18/2012	866.4	1173.8	**No (Fail)**	**No (Fail)**	**Site does not meet targets**
	7/19/2012	980.4				
	7/20/2012	1553.1				
	7/21/2012	1299.7				
	7/22/2012	1299.7				

[1] Colony forming units
[2] Water quality targets presented are for the summer period (April 1 through October 31)
[3] Site M06MOREC05 only had two samples, which was not enough to calculate the 5-sample geometric mean for that site

6.5 Total Maximum Daily Load (TMDL)

This section summarizes the approach used for TMDL development, and then presents the TMDL, allocations, and estimated reductions necessary to meet water quality targets for Moore Creek. **Table 6-4** shows the waterbody, assessment unit, and the TMDL developed. Loading estimates and load allocations are based on observed water quality data and representative flow conditions.

Table 6-4. *E. coli* TMDL Developed in the Madison TMDL Planning Area

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Pathogen Related Pollutant Impairment Identified in the 2016 Integrated Report	TMDL Developed
Moore Creek – springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	*E. coli*	*E. coli*

Because streamflow varies seasonally, TMDLs are not expressed as a static value, but as an equation of the appropriate target multiplied by flow as shown in **Equation 6-1**:

Equation 6-1: TMDL = (X) (Y) (24.4)

TMDL= Total Maximum Daily Load in (million cfu) Mcfu/day
X = E. coli water quality target in cfu/100 mL
Y = streamflow in cubic feet per second (cfs)
24.4 = conversion factor

The *E. coli* TMDLs displayed in **Figure 6-2** display the TMDL based on using the geometric mean targets, which are the lowest applicable target for *E. coli*. It is assumed that if the geometric mean target of 126 cfu/100 mL is being met on a waterbody, the 10% exceedance target of 252 cfu/100 mL will also be met. **Figure 6-2** also displays the relationship that the TMDL has in regard to flow; as flow increases, the allowable load (TMDL) increases. The TMDL is not expressed as a load or mass, but instead expressed as the number of colony forming units per day due to the nature of the pollutant. This approach is consistent with EPA's recommended analytical method for measuring *E. coli* in ambient waters and the flexibility offered in [40 CFR §130.3(i)] to express TMDLs in other appropriate, non-mass based, measures. For example, at a flow rate of 5 cfs, the application of **Equation 6-1** would result in a. *E. coli* TMDL of 15,372 Mcfu/day for the summer period and 76,860 Mcfu/day for the winter period. Like the water quality targets, the TMDLs change seasonally between the winter season (November 1 through March 31) and the summer season (April 1 through October 31).

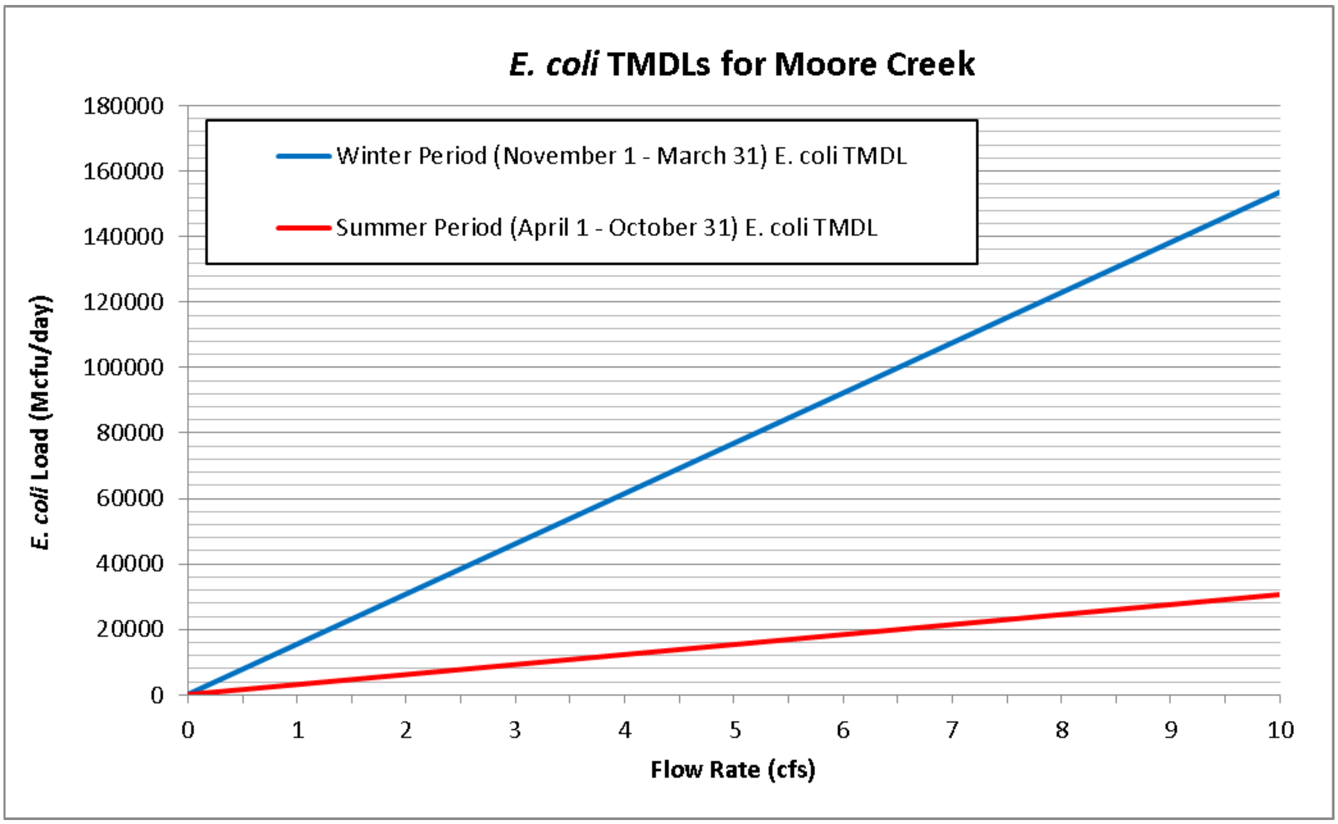

Figure 6-2. TMDLs for E. coli at streamflows ranging from 0 to 10 cfs

6.6 Source Assessment

This section provides the *E. coli* source assessment, which characterizes the type, magnitude, and distribution of sources contributing to *E. coli* loading to Moore Creek, and establishes the approach used to develop the TMDL for Moore Creek and allocations to specific source categories in Moore Creek. Source characterization and assessment to determine the major sources in Moore Creek was conducted by using monitoring data collected from Moore Creek in 2012-2013, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Assessment of existing *E. coli* sources is needed to understand Load Allocations (LAs) and load reductions for different source categories. Source characterization links *E. coli* sources, *E. coli* loading to streams, water quality response, and supports the formulation of the allocation portion of the TMDL.

E. coli inputs to Moore Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 6-3**. There are currently no permitted point sources in the Moore Creek watershed. DEQ identified the following source categories that can potentially contribute *E. coli* in the Moore Creek watershed:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Residential development and subsurface wastewater disposal and treatment (individual and community septic systems)
- Recreation and domestic animals
- Natural background

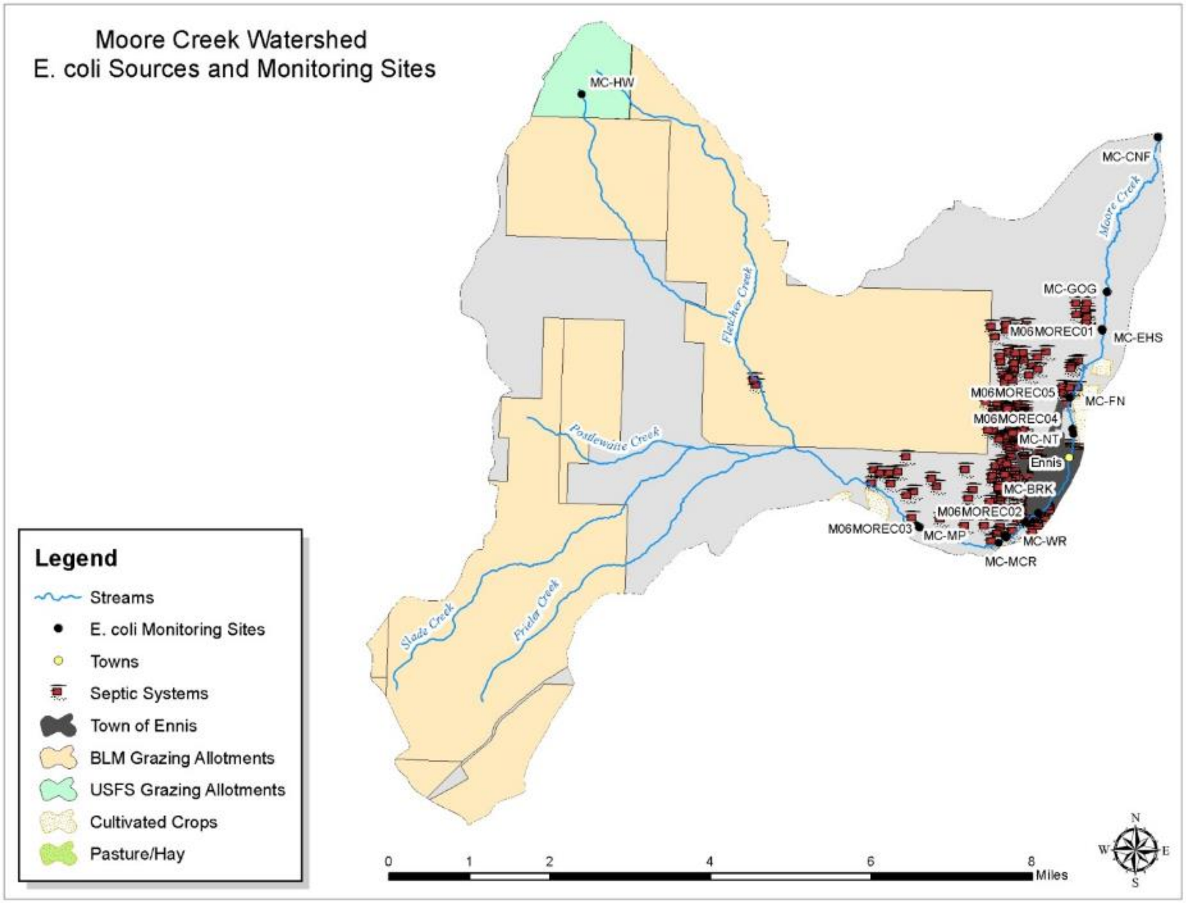

Figure 6-3. Map showing water quality monitoring sites and sources of *E. coli* in the Moore Creek watershed

Figures 6-4, 6-5, and **6-6** display the distribution of *E. coli* data collected on Moore Creek. **Figure 6-4** shows the distribution of the *E. coli* data collected by DEQ in the summer of 2012, while **Figure 6-5** displays the geometric means of that data. **Figure 6-6** shows the distribution of the *E. coli* data collected by the Madison Stream Team in the summers of 2012 and 2013. Although the data collected by the Madison Stream Team was not collected in a manner such that a 30-day geometric mean can be calculated, this data can still provide useful information for source assessment. These figures display the data by monitoring site in an upstream (left) to downstream (right) orientation, and can show water quality trends to assist with source assessment.

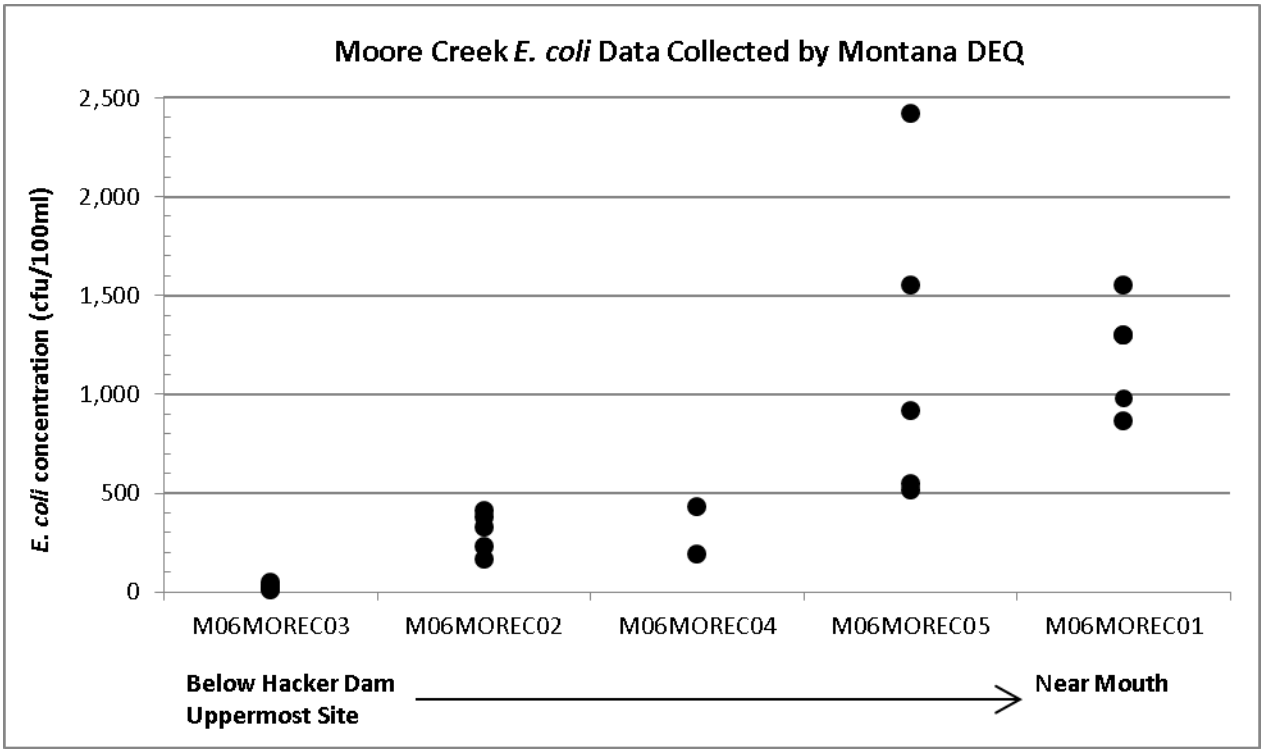

Figure 6-4. *E. coli* data collected on Moore Creek by Montana DEQ

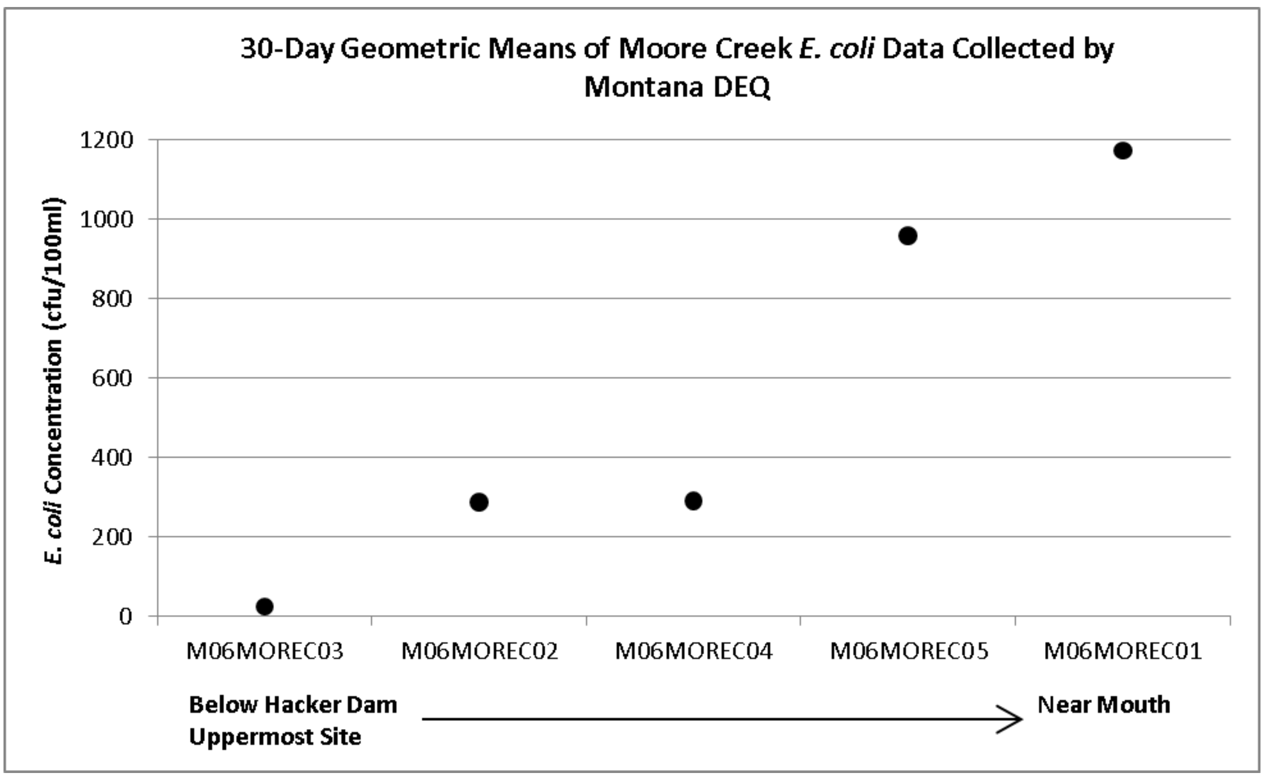

Figure 6-5. 30-Day geometric means of E. coli data collected on Moore Creek by Montana DEQ

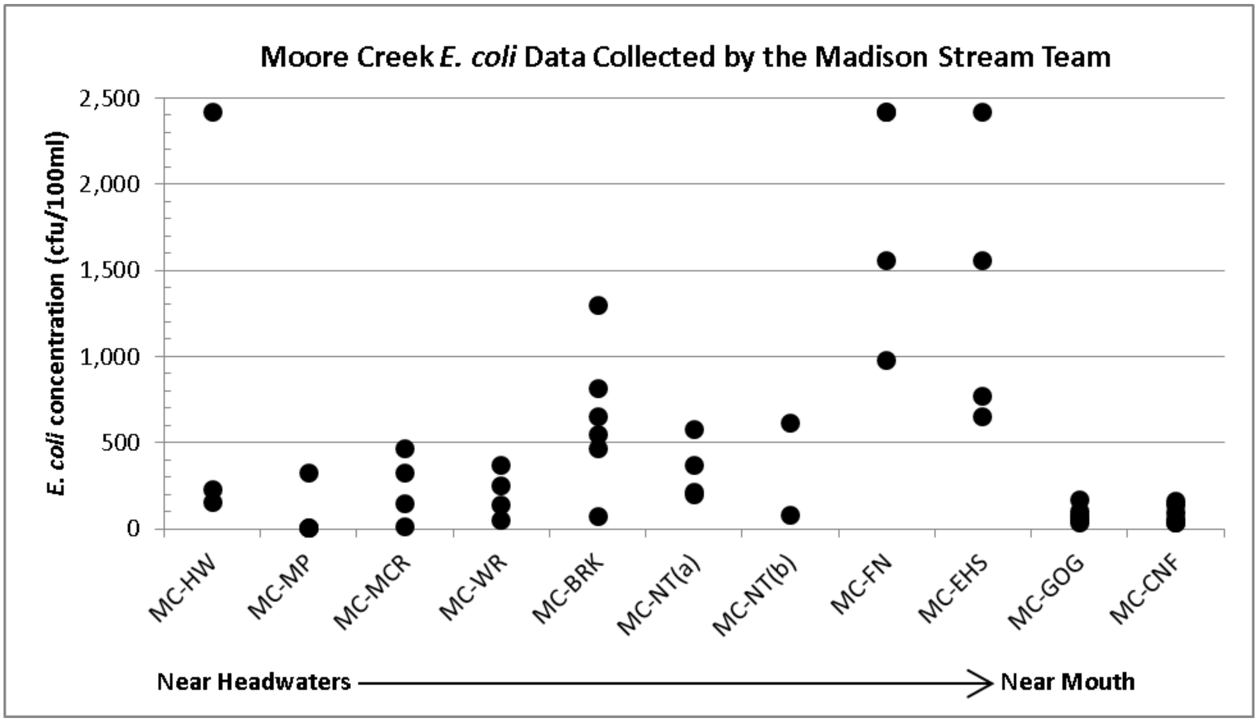

Figure 6-6. *E. coli* data collected on Moore Creek by the Madison Stream Team

E. coli concentrations, as shown above in **Figure 6-4** increase from upstream to downstream with all monitoring sites except the uppermost site (M06MOREC03) exceeding the *E. coli* targets. The geometric means of this data, shown in **Figure 6-5**, also show an increasing trend in *E. coli* concentrations from upstream to downstream. Site M06MOREC03, which is the uppermost DEQ monitoring site on Moore Creek, is located below Hacker Dam, and the potential exists that the reservoir may be affecting *E. coli* concentrations. Additional paired *E. coli* sampling above and below the reservoir could help gain a better understanding as to how this reservoir is affecting the in-stream *E. coli* dynamics.

Significant *E. coli* loads exist between monitoring sites M06MOREC03 and M06MOREC02, which are both located upstream of the town of Ennis. The sources of *E. coli* in this area are likely related to agricultural grazing practices and manure management from livestock corrals, in addition to exurban residential development. The town of Ennis lies between monitoring sites M06MOREC02 and M06MOREC04, and because there is not a significant spike in *E. coli* concentration between these two sites, it is assumed that residential development in Ennis is a relatively minor source of *E. coli* to Moore Creek. It is unknown if *E. coli* data was collected during a stormwater discharge event, but an assumption was made based on field observations of the stormwater discharge points in the town of Ennis that the potential for *E. coli* loading from stormwater is likely minor. Further discussion of stormwater can be found below in **Section 6.6.2.2**. At site MC-NT, there were two sample locations, MC-NT(a) and MC-NT(b), which were set up to bracket a potential *E. coli* source. Based on the limited data collected at site MC-NT, there does not appear to be a significant difference between the *E. coli* concentrations at MC-NT(a) and MC-NT(b). Downstream of the town of Ennis, there is a large spike in *E. coli* concentration for both the data collected by DEQ (between monitoring sites M06MOREC04 and M06MOREC05) and the data collected by the Madison Stream Team (monitoring sites MC-NT and MC-FN), and that spike is likely due to livestock grazing and manure management in that area. Near the mouth of Moore Creek (monitoring sites MC-GOG and MC-CNF), *E. coli* concentrations drop, and this is likely due to dilution from groundwater entering Moore Creek.

The data collected by the Madison Stream Team provided a robust dataset to use for source assessment purposes, and helped augment the *E. coli* assessment data collected by DEQ. By combining the data from both of these sampling efforts, DEQ was able to validate monitoring data that was collected for assessment purposes and fill data gaps to gain a further understanding of *E. coli* source assessment.

6.6.1 Point Sources of *E. coli*

There are currently no permitted point sources in the Moore Creek watershed. Ennis Hot Springs LLP previously held a Montana Pollutant Discharge Elimination System (MPDES) permit (MT0028843) to discharge unaltered groundwater to Moore Creek, but this permit expired on September 30, 2016, and the facility has chosen to not renew the permit. A permit is not required for discharges of unaltered groundwater; therefore, the facility may continue to discharge to Moore Creek without needing a permit. Water quality data collected is representative of the condition of Moore Creek including the Ennis Hot Springs LLP discharge. Under the former MPDES permit for Ennis Hot Springs LLP, the facility was not required to monitor for *E. coli* in its effluent because it was not expected to be an *E. coli* source, therefore *E. coli* data for the Ennis Hot Springs LLP discharge was not available.

6.6.2 Nonpoint Sources of *E. coli*

Nonpoint sources of *E. coli* in the Moore Creek watershed primarily consist of agriculture (pasture, rangeland, and manure applied on cropland), residential development, including subsurface wastewater disposal and treatment, and natural background sources. Ideally sampling is conducted in a way that allows identification of these sources and their potential level of *E. coli* contribution to Moore Creek.

6.6.2.1 Agriculture

The transport of *E. coli* from agricultural land to surface water can happen from the grazing of riparian areas by livestock, which provides a pathway for excrement to be deposited in and near the waterbody, and through the field application of manure on crops, which can travel to surface water via overland runoff. **Figure 6-3** shows areas of cropland, pasture, and public land grazing leases in the Moore Creek watershed in relation to water quality monitoring sites. Livestock grazing on private rangeland occurs throughout the watershed, but is not specifically identified in **Figure 6-3**.

Irrigated and Dryland Cropping

Cropland in the Moore Creek watershed is primarily and irrigated hay and pasture land (grass and alfalfa), with some irrigated small grains production (U.S. Department of Agriculture, National Agricultural Statistics Service 2016). Manure applied to cropland can be a source of *E. coli* to surface water if it is not applied at agronomic rates or not incorporated into the soil correctly and in a timely manner. When properly applied, manure can provide an excellent source of fertilizer for crops, but improper application can leave excess manure on the soil surface, which makes it susceptible to being transported off-site via overland runoff from precipitation or irrigation. Prior to field application, manure must be properly stored in areas where the risk for surface and groundwater contamination is low. Improper manure storage in areas with a high water table or areas adjacent to surface water pose the greatest risk for off-site *E. coli* transport. The extent of manure application on cropland in the Moore Creek watershed is unknown, but likely minimal in comparison to the application of commercial fertilizers.

Livestock Grazing

Livestock grazing in the Moore Creek watershed occurs on both large tracts of private and public rangeland and pastureland, as well as on small "ranchettes" around the town of Ennis. Livestock grazing on rangeland are allowed to roam and graze and in some areas along the valley bottoms during the growing season. Rangeland is typically grazed during the summer months (June-October) in the watershed. Pastures are typically managed for hay production during the summer and for grazing during the fall and spring. Hay pastures are typically thickly vegetated in the summer and less so in the fall through spring. During the winter grazing period (October through May) trampling and winter feeding further reduces biomass when it is already low. Livestock manure occurs in higher quantities on pasture ground from October through May because of higher cattle density than that found on range and forested areas. Rangeland differs from pasture in that rangeland has much less biomass. However, grazing impacts do factor in and manure deposition can result in significant *E. coli* contribution to surface water via riparian grazing.

Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can be significant sources of *E. coli*. Livestock manure from corrals must also be properly managed to avoid runoff into surface water. Livestock grazing downstream of the town of Ennis is likely a significant contributor to the *E. coli* concentration spike at monitoring site M06MOREC05 and MC-FN (**Figures 6-4** and **6-6**). Livestock grazing on small parcels or "ranchettes" occurs around the town of Ennis, and can be a significant source of *E. coli* to surface water because these parcels are smaller than typical pastures, which leads to reduced ground cover and more concentrated manure deposition, increasing the risk of off-site *E. coli* transport.

In addition to private land grazing, there are seven public land grazing allotments in the Moore Creek watershed, six on BLM managed lands and one on USFS managed lands (**Figure 6-3**); the allotments are described as follows in **Table 6-5**. The BLM managed grazing allotments in the Moore Creek watershed fall within the "South Tobacco Roots Watershed Assessment" report completed in 2007 (U.S. Department of Interior, Bureau of Land Management (BLM) 2007a; BLM 2007b). Since the 2007 assessment report, the boundaries and names of some grazing allotments have changed. In the 2007 assessment report, the Cal Creek allotment includes the current Alder Gulch allotment, and the Virginia City Hill allotment includes the current Madison Overlook allotment. The report indicated that the Cal Creek (including the Alder Gulch allotment) is not currently meeting BLM's healthy rangeland standards for riparian wetlands, water quality, and bio-diversity. The primary resource concerns for not meeting these standards are conifer encroachment in uplands and riparian areas, forest health (insects and/or disease), excessive fuel loads, streambank impacts from livestock grazing, invasive weeds, and impacts to Idaho sedge habitat, which is a sensitive plant species. It was determined that livestock management is a significant factor in these standards not being met. The Fletcher-Moore, Granite-Moore, and Virginia City Hill (including the Madison Overlook allotment) allotments are not currently meeting the standards for riparian wetlands and bio-diversity due to conifer encroachment, forest health (insects and/or disease), excessive fuel loads, and streambank impacts from livestock grazing. It was determined that livestock management is a significant factor in these standards not being met. The Dry Lakes allotment is not currently meeting the standard for bio-diversity due to conifer encroachment in uplands and riparian areas, forest health (insects and/or disease), excessive fuel loads. Livestock management was not determined to be a significant factor in the standard not being met on the Dry Lakes allotment (BLM 2007a; BLM 2007b).

The Allotment Management Plan for the USFS managed South Meadow Creek allotment indicates that this allotment is currently meeting USFS standards and no major changes have occurred since the plan was last updated in 1996 (U.S. Department of Agriculture, Forest Service 1997b; Suzuki 2015).

Table 6-5. Public Land Grazing Leases in the Moore Creek Watershed

Allotment Name	Land Management Agency	Allotment Acres in Watershed	Total Allotment Acres	Percentage of Allotment in Watershed	Total Allotment AUMs	Meeting Management Objectives
Alder Gulch [1]	BLM	156.6	10,293	1.5%	623	No
Dry Lakes	BLM	83.2	6,258	1.3%	152	No [2]
Fletcher-Moore	BLM	6,378.8	8,681	73.4%	213	No
Granite-Moore	BLM	1,709	1,709	100%	198	No
Madison Overlook	BLM	710.6	3,439	20.7%	284	No
South Meadow Creek	USFS	694.8	11,227.9	6.2%	911	Yes
Virginia City Hill [1]	BLM	4,484.7	8,159	55.0%	565	No

[1] The allotment names and boundaries have changed since the 2007 BLM South Tobacco Roots Watershed Assessment report.
[2] The allotment is not meeting the standard for biodiversity, but it was determined that livestock management is not the cause.

Livestock grazing is noted by the BLM as a significant causal factor for not meeting management objectives on 5 of the 6 grazing allotments in the Moore Creek watershed, all of which are located in the upper portion of the Moore Creek watershed above the uppermost DEQ monitoring site (M06MORE03). It is likely that livestock grazing in the upper portions of the Moore Creek watershed is contributing to *E. coli* loading in Moore Creek, but the magnitude of this loading is unknown due to the lack of monitoring sites upstream of Hacker Dam. Additional *E. coli* source assessment sampling between monitoring sites MC-HW and Hacker Dam could help determine the effect that livestock grazing has on *E. coli* concentrations in the upper Moore Creek watershed.

6.6.2.2 Residential Development, Recreation, Domestic Pets, and Subsurface Wastewater Treatment and Disposal

Developed areas contribute *E. coli* to the watershed by runoff from impervious surfaces, re-suspension of sediment in streams by recreational use, deposition of fecal material in or near surface water by domestic pets, and from improperly treated wastewater. As development increases, so does the use of underground sewer, and subsurface wastewater and treatment disposal. Possible wastewater sources with the potential to contribute *E. coli* loads to surface waters include individual septic systems, sewer system main lines, and residential service connections. Properly designed, installed and maintained, these systems pose no significant loading threat to surface waters. Failing systems or leaking pipes have the potential to contribute *E. coli* loads where they are in close proximity to surface waters.

Stormwater runoff

Stormwater discharges from impervious surfaces can be a pathway for *E. coli* to enter surface water. Upon further investigation by DEQ in 2015, there appears to be only one stormwater drain in the town of Ennis that has the potential to significantly contribute pollutants to Moore Creek. The road crossing on West Main Street appears to discharge under a stormwater event (**Figure 6-7)**. Although there are other points of stormwater discharge in town, they appear to have minimal potential to discharge a significant amount of pollutants to Moore Creek. Since it is unknown if there was a stormwater discharge event at the time of sampling, the actual contributions of *E. coli* from the Town of Ennis are unknown.

Figure 6-7. Photo showing stormwater discharge point to Moore Creek in the Town of Ennis at the West Main Street crossing (Moore Creek on right)

Domestic pets and recreational use

Domestic pets such as dogs are common in the residential areas of the Moore Creek watershed, and recreational stock (commercial trail and hobby horses) are also present in the watershed. Excrement from domestic pets and recreational stock that is deposited near surface water has the potential to contribute *E. coli* to that waterbody via surface water runoff. Re-suspension of *E. coli* in substrate sediments as a result of recreational usage (fishing, swimming, domestic pets, etc.) or disturbance may contribute to instream *E. coli* loads during the summer usage season.

Failing or malfunctioning septic systems

Failing or malfunctioning septic systems include individual wastewater systems that are not providing adequate treatment of bacterial contaminants before they reach surface waters. Typically, such systems exhibit evidence of failure by surface ponding or routing of effluent, and these symptoms are easily identifiable by the owner of the system in most circumstances. Because a failing or malfunctioning septic system is easily identifiable by the owner, repairs are likely done in a timely manner, limiting the risk of *E. coli* contamination to nearby surface or groundwater. Malfunctioning systems may also include improperly installed systems, those that intercept groundwater, or those that are susceptible to flooding. The MEANSS model, further described in **Appendix B**, identified 192 septic systems in the Moore Creek watershed. Although used for nutrient TMDL development, this tool helped identify septic systems in the watershed and their proximity to the nearest surface water source, which is useful for *E. coli* source assessment. Septic systems in the Moore Creek watershed are at very low densities in the upper portion of the watershed, but densities are relatively high around the town of Ennis (**Figure 6-3**). While no information is available regarding failing septic systems in the Moore Creek watershed, the number of failing septic systems is likely very low and is not expected to be a significant contributor of *E. coli* to Moore Creek.

Broken sewer lines or domestic service lines

Compromised underground sewer and service lines are not uncommon to sewer systems, and have the potential to contribute *E. coli* loads to nearby waterbodies. The significance of this source is unknown, but maintenance of sewer and service lines is conducted routinely by the Town of Ennis, and broken lines are usually repaired in a timely manner, minimizing risk of *E. coli* contamination to Moore Creek. **Figure 6-8** shows a map of the area within the Town of Ennis that is under sewer coverage, and those areas which are located in the Moore Creek watershed.

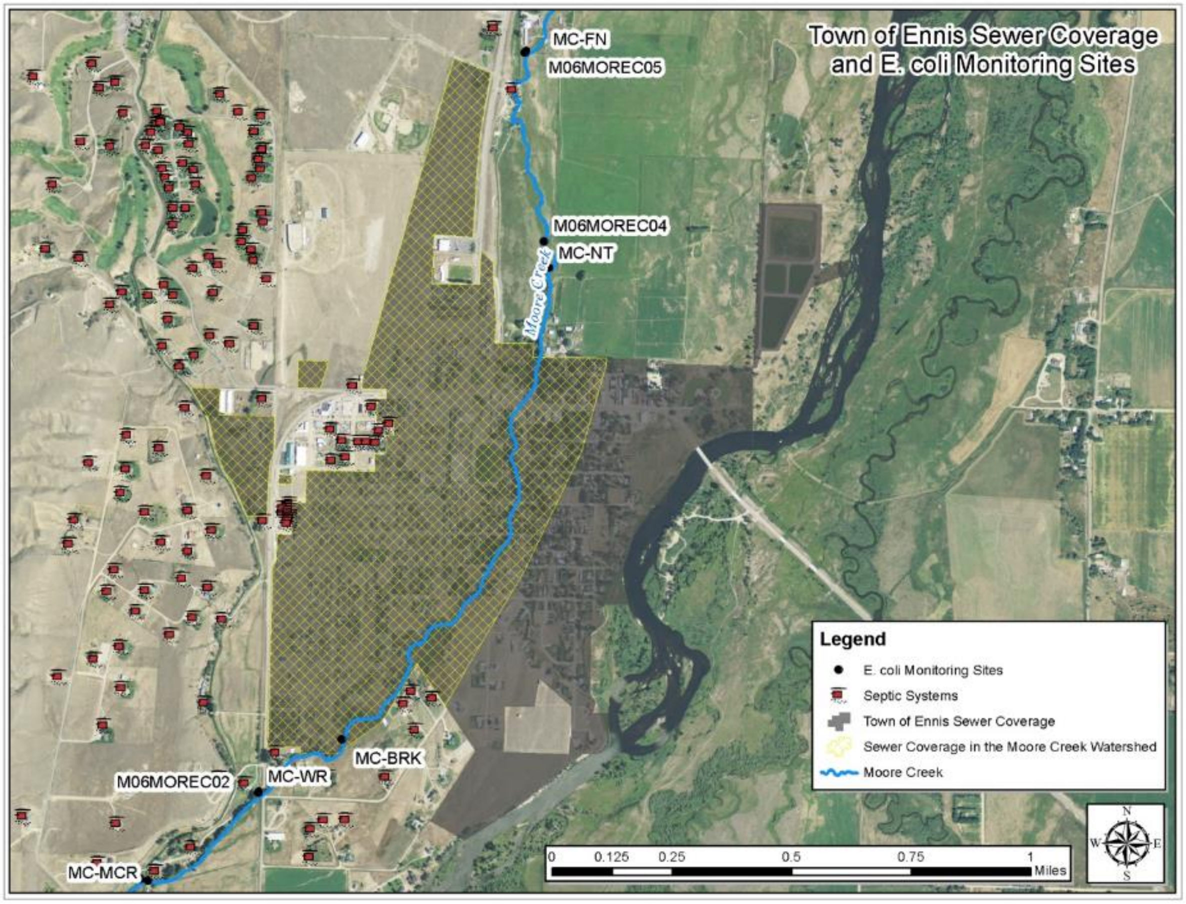

Figure 6-8. Sewer coverage area for the Town of Ennis in relation to E. coli monitoring sites

6.6.2.3 Natural Background

Natural background sources of *E. coli* are primarily from wildlife excrement, mainly from species that utilize riparian and stream corridors. Estimates of natural background conditions for *E. coli* rely on reference data collected in areas with limited or no anthropogenic sources of *E. coli*. Historical/pre-development *E. coli* data with which to estimate natural background levels is limited for the Moore Creek watershed, therefore data from the nearby West Fork Gallatin watershed was used to estimate natural background *E. coli* concentrations.

During the development of the West Fork Gallatin TMDLs (Montana Department of Environmental Quality, 2010), *E. coli* data were collected from 2006-2008 at several sampling sites identified as 'reference' condition for the purposes of quantifying a natural background load for *E. coli*. These sites include undeveloped areas of Swan Creek, Hellroaring Creek, Beehive Creek, the North Fork West Fork Gallatin River, and the South Fork West Fork Gallatin River. Late summer/fall *E. coli* concentrations averaged 24 cfu/100 mL (**Table 6-6**). These West Fork Gallatin streams likely have natural background loading similar to streams in the Madison, and thus are applicable as reference streams for this watershed. For purposes of estimating natural background concentrations for Moore Creek TMDL development, the 90th percentile reference value of 48 cfu/100 mL is used as an estimate of natural background sources for the calculation of load allocations in **Section 6.7**. Using the high end of the reference data percentile (90th) accounts for the potential for a higher natural background loading of *E. coli* in Moore Creek.

Table 6-6. *E. Coli* Reference Data and Summary Statistics

Waterbody Name	Site ID	Data Collection Date	Result Value (cfu/100 mL)
Beehive Creek	BEHV01	08/18/06	29
Beehive Creek	BEHV01	11/17/06	6
Beehive Creek	BEHV01	08/27/08	19
North Fork West Fork Gallatin River	NFWF01	08/18/06	91
North Fork West Fork Gallatin River	NFWF01	11/17/06	20
South Fork West Fork Gallatin River	SFTR01	08/27/08	5
Hellroaring Creek	HLRG01	08/27/08	3
Swan Creek	SWAN03	08/27/08	23
			Minimum = 3
			Mean = 24
			90th Percentile = 48
			Maximum = 91

6.7 Approach to TMDL Allocations

As discussed in **Section 4.0**, the *E. coli* TMDL for Moore Creek consists of the sum of allocations to individual sources and source categories. The TMDL is broken into a load allocation to natural background and a composite load allocation to all human-caused nonpoint sources (**Table 6-7**).

Table 6-7. *E. coli* Source Categories and Descriptions for the Moore Creek Watershed

Source Category	Source Descriptions
Natural Background	• Wild animal excrement
Nonpoint Sources (Agriculture, Residential Development, Recreation, Domestic Pets, and Subsurface Wastewater Treatment and Disposal)	• Livestock manure • Domestic animal excrement • Leaking septic and sewer systems • Broken sewer lines or domestic service lines

In the absence of individual wasteload allocations and an explicit margin of safety, the TMDLs for *E. coli* are calculated as follows (**Equation 6-2**):

Equation 6-2: $TMDL = LA_{NB} + LA_{H}$

TMDL = Total maximum daily load in (million cfu) Mcfu/day
LA_{NB} = Load Allocation to natural background sources in (million cfu) Mcfu/day
LA_{H} = Load Allocation to human-caused nonpoint sources in (million cfu) Mcfu/day

6.7.1 Natural Background Allocation

LAs for natural background sources in Moore Creek are based on 90th percentile concentration values from reference sites in the nearby West Fork Gallatin watershed (**Table 6-6**). Reference sites were chosen to represent stream conditions where human activities may be present but do not negatively harm stream uses.

Natural background loads are calculated by multiplying the 90th percentile reference concentration by the streamflow. The natural background load allocation is calculated as follows (**Equation 6-3**):

Equation 6-3: LA_{NB} = (X) (Y) (24.4)

LA_{NB} = Load Allocation to natural background sources in (million cfu) Mcfu/day
X = natural background concentration in cfu/100 mL
Y = streamflow in cubic feet per second (cfs)
24.4 = conversion factor

6.7.2 Allocations for Human-Caused Sources

The LA to human-caused nonpoint sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load allocation (**Equation 6-4**):

Equation 6-4: LA_H = TMDL – LA_{NB}

TMDL = Total maximum daily load in (million cfu) Mcfu/day
LA_H = Load Allocation to human-caused nonpoint sources in (million cfu) Mcfu/day
LA_{NB} = Load Allocation to natural background sources in (million cfu) Mcfu/day

6.7.3 Total Existing (Above Target) Load

To estimate a total existing load for the purpose of estimating a required load reduction, the following equation will be used:

Equation 6-5: **Total Existing Load (Mcfu/day) = (X) (Y) (24.4)**

X = measured concentration in cfu/100 mL (median of calculated geometric means from sites with geometric mean target exceedances)
Y = streamflow in cubic feet per second (cfs)
24.4 = conversion factor

Only the median of the calculated geometric means of *E. coli* concentrations at sites that exceeded the target will be used to determine the total existing load, since concentrations greater than the target indicate that the TMDL is being exceeded and load reductions are necessary. Concentrations that are below the target are meeting the TMDL and do not require load reductions.

6.7.4 Load Reductions

Loads greater than the TMDL require load reductions to meet the TMDL; because the TMDL changes in direct proportion to flow multiplied by concentration, percent reductions in *E. coli* loads are the same as percent reductions in *E. coli* concentrations. **Equation 6-6** was used to calculate *E. coli* load reductions for Moore Creek:

Equation 6-6: Load Reduction = (1 - (TMDL/Total Existing Load))*100

TMDL = Total maximum daily load in (million cfu) Mcfu/day
*Total Existing Load = calculated total existing load in (million cfu) Mcfu/day (**Equation 6-5**)*

6.8 Moore Creek TMDL and Allocations

This section establishes the *E. coli* TMDL, natural background LAs, and composite LAs to identified sources. This section additionally provides *E. coli* loading estimates for natural and human-caused source categories, and estimates reductions necessary to meet water quality targets for Moore Creek.

The TMDL for *E. coli* is based on **Equation 6-1** and the TMDL allocations are based on **Equations 6-2, 6-3, and 6-4.** The value of the *E. coli* TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. **Figures 6-9** and **6-10** present the *E. coli* TMDLs for Moore Creek using the summer period *E. coli* targets and winter period *E. coli* targets respectively, with the loads expressed as a function of flow. The shaded areas underneath the TMDL line show the proportion of the different load allocations in relation to the TMDL at a given flow.

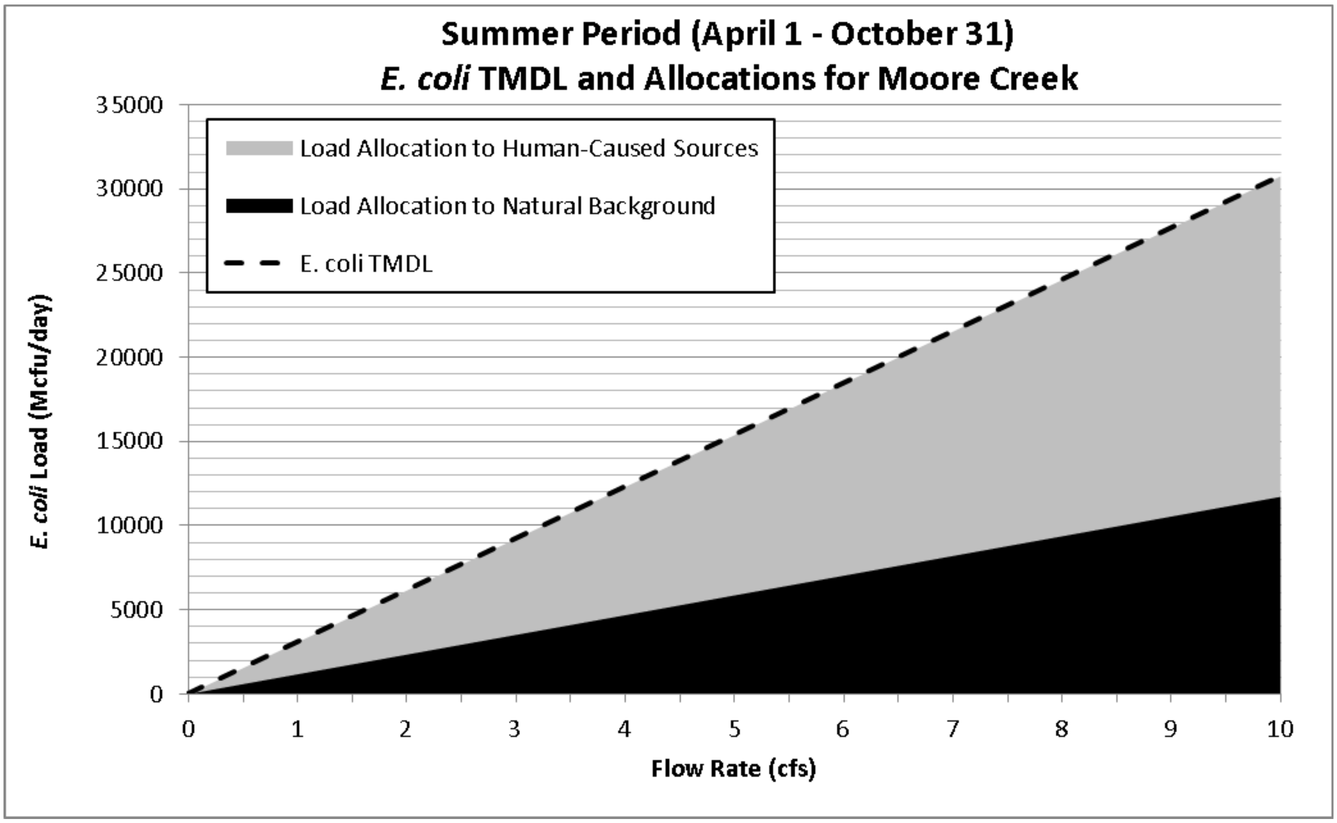

Figure 6-9. *E. coli* TMDL for the summer period and source allocations for Moore Creek

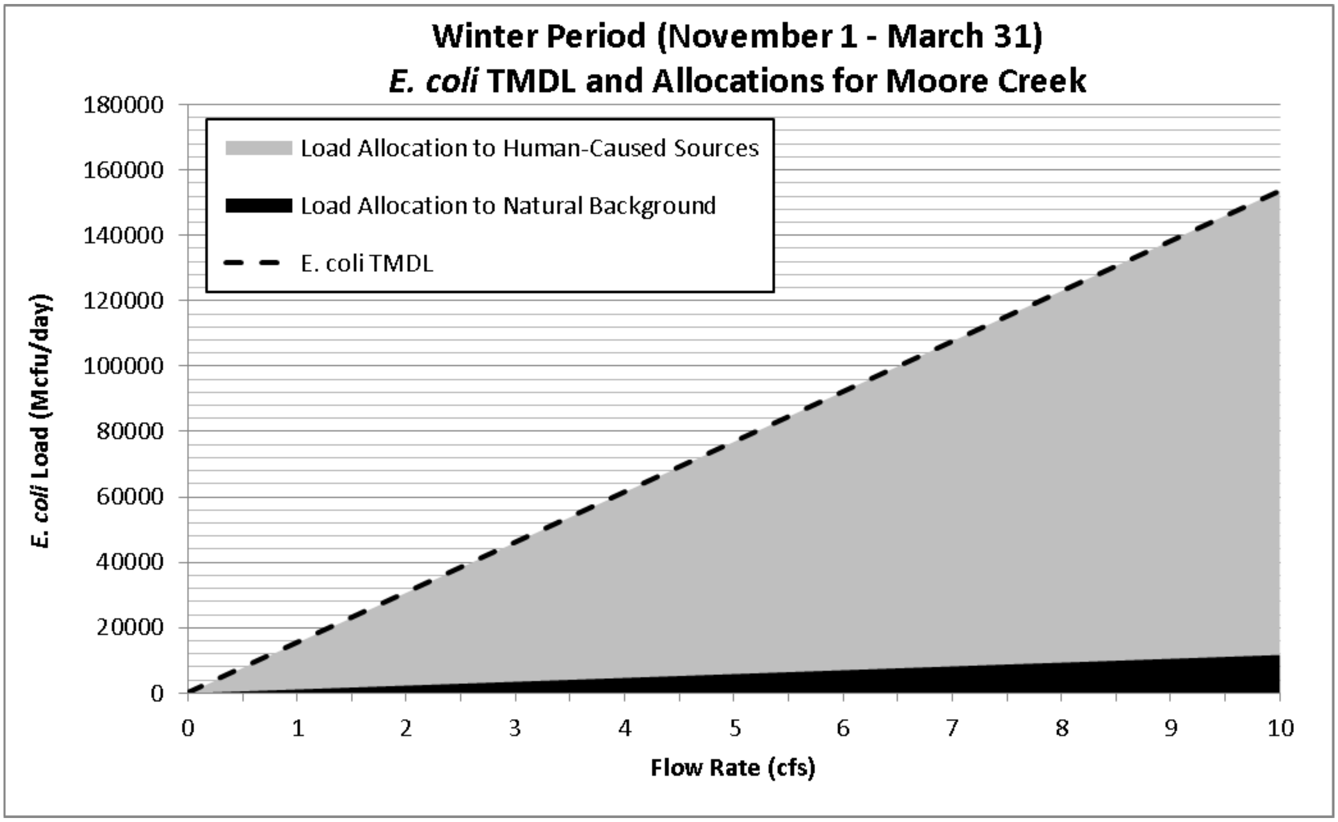

Figure 6-10. E. coli TMDL for the winter period and source allocations for Moore Creek

Estimates of Existing *E. coli* Loads

The total existing load, based on concentrations as discussed above in **Section 6.7.3**, is used to estimate load reductions by comparing it to the allowable (TMDL) load and computing a required percent reduction to meet the TMDL. No load reductions are given for natural background allocations, therefore all necessary load reductions apply to the nonpoint sources within the watershed.

The following are the Moore Creek *E. coli* TMDLs for the summer and winter periods expressed at a median flow rate of 2.0 cfs. This median flow rate was derived from measured flow values on all sites on Moore Creek during the 2012-2014 nutrient sampling effort, as flow was not collected during the *E. coli* sampling effort due to logistics and a short sample holding time requirement:

$$\mathbf{TMDL_{summer} = (126\ cfu/100\ mL)\ (2.0\ cfs)\ (24.4) = 6{,}148\ Mcfu/day}$$

$$\mathbf{TMDL_{winter} = (630\ cfu/100\ mL)\ (2.0\ cfs)\ (24.4) = 30{,}744\ Mcfu/day}$$

Equation 6-3 is the basis for the natural background load allocation for *E. coli*. Since the natural background load is not expected to vary seasonally, the load allocation to natural background sources is applicable for both the summer and winter periods. To continue with the calculation at a flow rate of 2.0 cfs, this allocation is as follows:

$$\mathbf{LA_{NB} = (48\ cfu/100\ mL)\ (2.0\ cfs)\ (24.4) = 2{,}342\ Mcfu/day}$$

Using **Equation 6-4**, the human-caused *E. coli* load allocation at a flow rate of 2.0 cfs can be calculated for the summer (**$LA_{H\text{-}Summer}$**) and winter (**$LA_{H\text{-}Winter}$**) periods as follows:

$LA_{H\text{-}Summer}$ = (6,148 Mcfu/day) – (2,342 Mcfu/day) = 3,806 Mcfu/day
$LA_{H\text{-}Winter}$ = (30,744 Mcfu/day) – (2,342 Mcfu/day) = 28,402 Mcfu/day

The total existing load at a flow rate of 2.0 cfs is based on **Equation 6-5**, and is calculated as follows using the median of *E. coli* geometric mean target exceedance values measured from Moore Creek from the summer 2012 sampling effort (643 cfu/100 mL):

Total Existing Load = (643 cfu/100 mL) (2.0 cfs) (24.4) = 31,378 Mcfu/day

A total existing load was not calculated for the winter period, as *E. coli* data were not collected during this period. Since *E. coli* sources are not likely to change seasonally, an assumption can be made that *E. coli* loads in the winter period are similar to or less than those in the summer period due to a slower bacterial colony growth rate and lower streamflow in the winter.

The portion of the total existing load for the summer period attributed to human-caused sources is 29,036 Mcfu/day, which is determined by subtracting out the 2,342 Mcfu/day background load. **Table 6-8** contains the results for the *E. coli* TMDL expressed at a median summer flow rate of 2.0 cfs, along with the LAs, and current loading for this same flow. In addition, it contains a percent reduction to the human-caused LA required to meet the water quality target for *E. coli*. At the median summer flow of 2.0 cfs, and the median of *E. coli* geometric mean target exceedance values, the current loading in Moore Creek is greater than the TMDL. Under these conditions, an 87% reduction of human-caused *E. coli* loads, which results in an overall 80% reduction of *E. coli* in Moore Creek, would result in the TMDL being met. The total existing load is dynamic and changes with variability in water quality conditions. Therefore, meeting instream *E. coli* concentration targets under all conditions will equate to meeting the TMDL.

Table 6-8. Moore Creek Summer Period *E. coli* TMDL at a Median Flow Rate, LAs, Current Loading, and Reductions

Source Category	**Allocation and TMDL (Mcfu/day)[1,2]**	**Existing Load (Mcfu/day)[1,2]**	**Percent Reduction Needed to Meet the TMDL**
Natural Background	2,342	2,342	0%
Human-caused (Nonpoint Source)	3,806	29,036	87%
	TMDL = 6,148	**Total = 31,378**	**Total = 80%**

[1] Based on a median summer flow rate of 2.0 cfs
[2] Loads are presented in million colony forming units (Mcfu) per day

The source assessment of the Moore Creek watershed indicates agriculture is the most likely source of *E. coli* in Moore Creek; load reductions should focus on limiting and controlling *E. coli* loading from this source. Meeting LAs for Moore Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 8.0**. It is assumed that load reductions through the implementation of Best Management Practices (BMPs) will reduce *E. coli* loads in both the summer and winter periods, and that meeting the summer period *E. coli* TMDL will equate to meeting the winter period *E. coli* TMDL because the summer period targets are more restrictive. It is important to note that although TMDL allocations will vary depending on the flow rate, present reductions needed for source allocations to meet the TMDL do not change with flow rate.

6.9 Seasonality and Margin of Safety

TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), Wasteload Allocations (WLAs) and Load Allocations (LAs). TMDL development must also incorporate a margin of safety (MOS) 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 are sufficiently protective of water quality and beneficial uses. This section describes seasonality and MOS in the Madison TMDL Planning Area *E. coli* TMDL development process.

6.9.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan, seasonality is an integral consideration. Water quality is recognized to have seasonal cycles. Specific examples of how seasonality has been addressed within this document include:

- Different water quality targets and subsequent allocations are applicable for two separate periods: the summer period (April 1 through October 31) where water temperatures are more conducive to bacterial colony growth, and the winter period (November 1 through March 31) where water temperatures suppress bacterial colony growth.
- *E. coli* data used to determine compliance with targets and to establish allowable loads were collected during the summer period to coincide with applicable *E. coli* targets and the time of highest recreational use. Data were collected for the summer period because *E. coli* targets are more restrictive during this period and therefore by meeting the summer period *E. coli* targets, it is assumed that the winter period *E. coli* targets will also be met.
- Flow values used in calculating the *E. coli* TMDLs and allocations contained in **Section 6.8** were collected within the summer period during nutrient sampling efforts and are considered representative of conditions during which the summer period *E. coli* targets apply.

6.9.2 Margin of Safety

A margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty about the pollutant loads and the quality of the receiving water and is intended to protect beneficial uses in the face of this uncertainty. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (U.S. Environmental Protection Agency 2001). This plan addresses MOS implicitly in a variety of ways:

- The geometric mean value for colony forming units was used to calculate TMDLs and load allocations. Using a geometric mean provides a margin of safety by ensuring that allowable daily load allocations do not result in the exceedance of water quality targets.
- The 90th percentile value of natural background concentrations was used to establish a natural background concentration for load allocation purposes. This is a conservative approach, and provides an additional MOS for anthropogenic *E. coli* loads during most conditions. This is because the application of a higher natural background load allocation equates to a higher percent load reduction from nonpoint sources needed to meet the TMDL.
- TMDLs and allocations were presented in this document using the geometric mean targets, which require a lower *E. coli* concentration to meet the target (126 cfu/100 mL) than the 10% exceedance target of 252 cfu/100 mL. It is assumed that meeting the geometric mean target under most circumstances equates to meeting the 10% exceedance target.

- Bacterial decay rates were not factored in while developing the TMDL, therefore adding an implicit margin of safety to the TMDL.
- Seasonality (discussed above) and variability in *E. coli* loading is considered in target development, monitoring design, and source assessment.
- An adaptive management approach (discussed below) is recommended to evaluate target attainment and allow for refinement of load allocations, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development over time.

6.10 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, source assessments, loading estimates, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. However, mitigation and reduction of uncertainties through adaptive management approaches is a key component of ongoing TMDL implementation and evaluation. The process of adaptive management is predicated on the premise that TMDL targets, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. Uncertainty is inherent in assessing *E. coli* sources and needed reductions. The main sources of uncertainty are summarized below.

6.10.1 Water Quality Conditions

It was assumed that sampling data for each waterbody segment are representative of conditions in each segment. Future monitoring as discussed in **Section 9.0** should help reduce the uncertainty regarding data representativeness, improve the understanding of the effectiveness of Best Management Practice (BMP) implementation, and increase the understanding of the load reductions needed to meet the TMDL.

It was also assumed that background concentrations are less than the target values, and based on sample data, this appears to be true. However, it is possible that target values are naturally exceeded during certain times or at certain locations in the watershed. Future monitoring should help reduce uncertainty regarding background *E. coli* concentrations.

6.10.2 Source Assessment

Source characterization and assessment to determine the major *E. coli* sources was conducted by using monitoring data collected from Moore Creek from 2012-2013, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Uncertainties in source assessment can occur by using data that does not reflect the current condition of the waterbody, the misinterpretation of aerial photos, using outdated GIS data, using field data that may not be representative of the overall condition of the waterbody, and referencing literature that was developed for areas outside of Moore Creek.

Water quality monitoring data used for source assessment includes the time period from 2012-2013. Sources of pollutants or the level of contribution from those sources may have changed since data collection, and therefore there is some uncertainty that the data used is reflective of the current conditions of Moore Creek. BMP implementation efforts have been underway on Moore Creek since the collection of this data, but in the absence of more recent data, an assumption was made that the data used are representative of current conditions. Data collected accurately characterizes that particular site, but there is some uncertainty as to whether or not that site is representative of the overall waterbody conditions. To address this, monitoring site locations were selected to generate the most representative samples.

When using aerial photography and GIS data, uncertainty may occur through the misinterpretation of aerial photos and using GIS data that may either be inaccurate or outdated. To reduce uncertainty, multiple years of aerial photos were analyzed and only GIS data containing complete metadata and generated from reliable sources were used for source assessment.

Literature referenced in this study helped to identify potential sources of *E. coli* and their level of contribution. Assumptions were made, based on literature values, to the potential *E. coli* contribution of these sources. There is inherent uncertainty in applying literature values derived outside of Moore Creek, but these values are assumed to be applicable to this area and helped to fill gaps where data do not exist.

6.10.3 Loading Estimates

Loading estimates are based on currently available data, and are only representative of the pollutant load at the time of data analysis. It is important to recognize that pollutant loads are not static and can therefore be different than the loads reported in this document. This brings some uncertainty into load reductions, as achieving the load reductions stated in this document may or may not result in meeting in-stream water quality targets based on current conditions. For the purpose of determining existing *E. coli* loads, the median of the geometric mean target exceedance values was used, which only reflects the existing load when the exceedances are occurring. Future additional water quality monitoring may be able to identify when the TMDL is being met and when the TMDL is being exceeded, which can help guide BMP implementation efforts by identifying the most significant *E. coli* sources. Adaptive management can address uncertainties related to loading estimates through the re-evaluation of water quality conditions as BMPs are installed, land uses change, or pollutant sources and their contribution levels change

7.0 Metals TMDL Components

This portion of the document focuses on metals as an identified cause of water quality impairment in the Madison TMDL Planning Area (TPA). It describes: (1) the effects metals have on beneficial use, (2) the specific stream segments (waterbodies) of concern in the TPA, (3) the presently available data pertaining to metals impairment in the watershed, (4) the water quality targets and a summary of TMDL development,(5) a description of the Total Maximum Daily Load (TMDL), (6) a detailed assessment of metals sources in the watershed, (7) metals TMDLs for the impaired waterbodies in the TPA and allocations of metals loads to specific sources, (8) a description of how seasonality and margins of safety are incorporated into the TMDL, and (9) an explanation of how uncertainty and adaptive management play a role in the TMDL process.

7.1 Effects of Excess Metals on Beneficial Uses

Waterbodies with elevated metals concentrations can impair beneficial uses such as aquatic life, coldwater fisheries and drinking water. Within aquatic ecosystems, elevated concentrations of metals can have a toxic, carcinogenic, or bio-concentrating effect on biota. Likewise, humans and wildlife can suffer acute and chronic effects from consuming water or fish with elevated metals concentrations. Because elevated metals concentrations can be toxic to plants and animals, high metals concentrations in irrigation or stock water may affect agricultural uses. Although arsenic and selenium are metalloids and nonmetals, they are treated as metals for TMDL development due to the similarity in sources, environmental effects and restoration strategies.

7.2 Stream Segments of Concern

A total of eleven waterbody segments are listed as impaired due to metals-related causes on the 2016 Montana 303(d) List (**Figure 7-1** and **Table 7-1**). All the 303(d)-listed stream segments are classified by DEQ as B-1. Waters classified as 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 (ARM 17.30.623(1)) (**Section 3.0**).

Metals-related 303(d) listings include arsenic, iron, selenium, lead and copper. Arsenic is naturally present in the Madison River, and a number of its tributaries. As a result of arsenic impairments being directly related to naturally occurring sources, arsenic impairments are not addressed within TMDLs contained in this document. DEQ's decision not to pursue arsenic TMDLs is discussed in further detail in **Section 7.4.3.**

Table 7-1. Waterbody Segments with Metals Listings on the 2016 303(d) List

Waterbody (Assessment Unit)	**Waterbody ID (Assessment Unit ID)**	**Impairment Cause**
Blaine Spring Creek, Headwaters to mouth (Madison River)	MT41F004_010	Arsenic
Buford Creek, Headwaters to confluence with West Fork Madison River	MT41F004_150	Arsenic
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Arsenic, Iron, Selenium
Ennis Lake	MT41F005_030	Arsenic
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Iron, Lead
Moore Creek, Springs to mouth (Fletcher Channel)	MT41F004_130	Arsenic
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Arsenic
Madison River, Ennis Dam to mouth (Missouri River)[1]	MT41F001_010	Arsenic
Madison River, Quake Lake to Ennis Lake	MT41F001_020	Arsenic
Madison River, Hebgen Dam to Quake Lake	MT41F001_030	Arsenic
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Copper

[1] The waterbody location description for MT41F001_010 provides an incorrect name for the dam; the correct name is the Madison Dam. The waterbody location description will be corrected in the 2018 Water Quality Integrated Report.

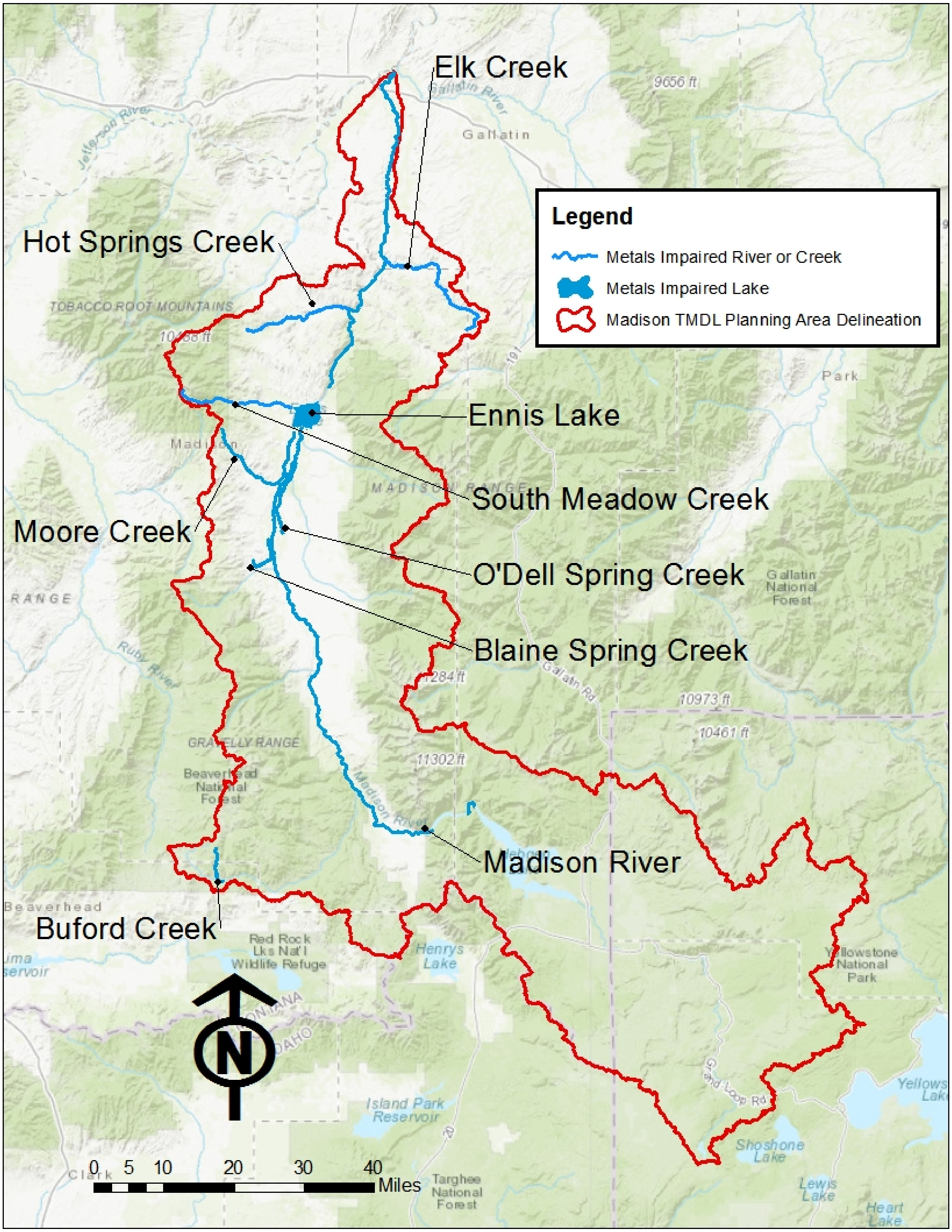

Figure 7-1. Waterbodies with a Metals Listing in the Madison Watershed on the 2016 303(d) List

7.3 Water Quality Data and Information Sources

To determine the location and magnitude of metals sources, available water quality data, GIS layers, and aerial photos were evaluated. Water quality data used in TMDL development includes DEQ's assessment data collected since 2011 as well as other data available in the national Water Quality Portal (**Appendix A**). **Table 7-2** provides a summary of data sources used in TMDL development. Summaries for relevant water quality parameters are provided in **Sections 7.4.3.1** through **7.4.3.3** for each of the impaired waterbody segments. Data used to assist in source characterization, target evaluation, loading analysis, and development of load allocations are derived from the aforementioned source assessment.

Data collected earlier than 10 years ago were used to aid in the initial coarse level source assessment and to help determine sampling locations for additional data collection, but are not used within this document in the existing data review due to potential data quality and reliability issues (e.g. reporting limits higher than water quality standards and uncertainty regarding collection, analysis and recording methods) and because conditions may have changed substantially since data collection.

Table 7-2. Water Quality Data Evaluated for TMDL Development

Data Source and Data Year	Data Description
Montana DEQ 2011-2013	Water quality and metals sediment sampling for impairment determination and TMDL Development
National Water Quality Portal 2011-2013	Miscellaneous metals sampling data

GIS data included the DEQ High Priority Abandoned Hardrock Mine sites, the DEQ Abandoned Hardrock Mines database, the DEQ Active Hardrock Mine sites, the Montana Bureau of Mines and Geology (MBMG) Abandoned and Inactive Mines database, and permitted point sources (i.e. Montana Pollutant Discharge Elimination System permits). Because geology and soil can influence water quality, geologic data from the USGS General Surficial Geology of Montana (**Figure 2-5**) and soils data from the State Soil Geographic (STATSGO) database were also examined (**Figure 2-6**).

7.4 Water Quality Data and Comparison to Targets

This section describes the available water quality data and how it was compiled and evaluated for attainment of water quality targets. In doing so it presents the evaluation framework, metals water quality targets used in the evaluation, and metals targets attainment evaluations for each impaired waterbody (**Table 7-8**).

7.4.1 Metals TMDL Evaluation Framework

Evaluating attainment of water quality standards for metals-related impairments, and subsequent determination of whether a TMDL is necessary for each waterbody segment involves three steps:

1. Evaluation of metals sources.

   Sources of metals in a watershed are both natural and anthropogenic. TMDLs are developed for waterbodies that are not meeting water standards, at least in part, due to human caused sources. Consequently, metals-impaired streams must demonstrate existence of significant anthropogenic metals sources to be appropriate candidates for TMDL development.

2. Development of numeric water quality targets that represent water quality conditions that are unimpaired for the pollutant of concern.

   A required component of TMDL plans is the establishment of numeric water quality criteria or *targets* that represent a condition that meets Montana's ambient water quality standards. Numeric targets are measurable water quality indicators that, either by themselves or in combination with others, reflect attainment of water quality criteria or represent a water quality condition that is unimpaired for the pollutant of concern. Metals water quality targets are presented in **Section 7.4.2**.

3. Comparison of existing data with water quality targets to evaluate water quality target attainment and, consequently, determine whether a TMDL is necessary.

   Attainment of water quality targets is evaluated by comparing existing water quality data and information to established metals water quality targets. Where exceedances of water quality targets are documented, and there are anthropogenic sources, a TMDL is developed. If recent data indicate no impairment, the data is incorporated into 303(d) list files and the cause is removed from the list. If there are no recent target exceedances, but there is insufficient data to fully evaluate all seasonal flow conditions, then TMDL development may not be pursued and further monitoring is recommended.

7.4.2 Metals Water Quality Targets

Water quality targets for metals-related impairments in the Madison TMDL Planning Area (TPA) consist of metals water quality targets (**Table 7-3**) and metals sediment quality targets (**Table 7-4**). Metals water quality targets are based on numeric acute and chronic metals water quality criteria for the protection of aquatic life as defined in DEQ Circular, DEQ-7 (Montana Department of Environmental Quality, 2017). The metals sediment quality targets are based on narrative criteria for toxins in sediment. Throughout this document, the terms "standard", "criteria" and "target" are used somewhat interchangeably.

7.4.2.1 Metals Water Quality Criteria

Metals numeric water quality criteria include values for protecting human health and for protecting aquatic life, and apply as water quality standards for the streams addressed within this Section due to their B-1 classification (**Section 3.0**). Aquatic life criteria include values for both acute and chronic effects. For any given pollutant, the most stringent of these criteria is adopted as the water quality target in order to protect all beneficial uses.

The aquatic life criteria for most metals are dependent upon water hardness values: usually increasing as the hardness increases. Water quality criteria (AAL and CAL, human health) for each parameter of concern at water hardness values of 25 milligrams per liter (mg/L) and 100 mg/L are shown in **Table 7-3**. These criteria translate into the applicable water quality targets and are expressed in micrograms per liter (µg/L) equivalent to parts per billion. Acute and chronic toxicity aquatic life criteria are intended to protect aquatic life uses, while the human health criteria is intended to protect drinking water uses. Note that arsenic and selenium do not have variable criteria. In these cases, the acute and chronic criteria are fixed and do not fluctuate with changes in hardness. The CAL and AAL criteria are identical for hardness values of 25 mg/L and 100 mg/L and all hardness values in-between. Also noteworthy is that iron has only one criteria (chronic aquatic life) at any hardness.

The evaluation process summarized below is derived from DEQ's Monitoring and Assessment program guidance for metals assessment methods (Drygas, 2012).

- A waterbody is considered impaired if a single sample exceeds the human health target.
- If more than 10% of the samples exceed the AAL or CAL target, then the waterbody is considered impaired for that pollutant.
- If both the AAL and CAL target exceedance rates are equal to or less than 10%, for a given metal, then it is not considered a cause of aquatic life impairment to the waterbody. A minimum 8 samples are required, and samples must represent both high and low flow conditions.
- There are two exceptions to the 10% aquatic life exceedance rate rule: a) if a single sample exceeds the AAL target by more than a factor of two, the waterbody is considered impaired regardless of the remaining data set; and b) if the exceedance rate is greater than 10% but no anthropogenic metals sources are identified, management is consulted for a case-by-case review.

Table 7-3. Metals Numeric Water Quality Targets Applicable to the Madison TMDL Planning Area

Metal of Concern	Aquatic Life Criteria (µg/L) at 25 mg/L Hardness		Aquatic Life Criteria (µg/L) at 100 mg/L Hardness		Human Health Criteria
	Acute	Chronic	Acute	Chronic	
Arsenic, TR*	340	150	340	150	10
Copper, TR	3.79	2.85	14.00	9.33	1,300
Iron, TR	---	1,000	---	1,000	---
Lead, TR	13.98	0.54	81.65	3.18	15
Selenium, TR	20	5	20	5	50

*TR = total recoverable

7.4.2.2 Metals Sediment Quality Criteria

Stream sediment data may also be indicative of impairment caused by elevated metals and are used as a supplementary indicator of impairment. In addition to directly impairing aquatic life that interacts with the elevated metals in the sediment, the elevated sediment values can also be an indicator of elevated concentrations of metals that become suspended during runoff conditions. This can be a particularly important supplemental indicator when high flow data is lacking. The state of Montana does not currently have numeric water quality criteria for metals in stream sediment, however general water quality prohibitions state that *"state surface waters must be free from substances…that will…create concentrations or combinations of materials that are toxic or harmful to aquatic life" (ARM 17.30.637(1)(d)).*

The National Oceanic and Atmospheric Administration (NOAA) developed Screening Quick Reference Tables for stream sediment quality that provides concentration guidelines for metals in freshwater sediment (see **Table 7-4**). Screening criteria concentrations come from a variety of studies and investigations, and are expressed in Probable Effects Levels (PEL). PELs represent the sediment concentration above which toxic effects to aquatic life frequently occur, and are calculated as the geometric mean of the 50th percentile concentration of the toxic effects data set and the 85th percentile of the no-effect data set (Buchman, 1999).

PELs act as a screening tool that may assist in identification of elevated metals in stream sediments, and can be used to assist in impairment determinations and metals source assessment where water chemistry data is limited. Where in-stream water quality data exceeds water quality targets, sediment quality data provide supporting information, but are not necessary to verify impairment. Where water quality data is limited or does not show exceedances of water quality targets, sediment quality data may demonstrate impairment due to high levels of metals toxicity in stream sediments. **Table 7-4** contains the PEL values (mg/Kg) for parameters of concern in the Madison TMDL Planning Area. Note that there are no published PEL values for iron and selenium.

Table 7-4. Screening Level Criteria for Sediment Metals Concentrations

Metal of Concern	Probable Effects Level (mg/kg)
Arsenic	17.0
Copper	197
Iron	--
Lead	91.3
Selenium	--

7.4.3 Existing Conditions and Comparison to Targets

For each waterbody segment listed on the 2016 303(d) List for metals (**Table 7-1**), recent water quality and sediment data is evaluated relative to the water quality targets to make a TMDL development determination. Data for existing metals listings is evaluated first, followed by evaluation of other metals that may have target exceedances.

The 2011-2013 water quality monitoring efforts conducted by DEQ for use with the Madison TPA water quality assessment and TMDL development have revealed that arsenic concentrations in the Madison River and a number of its tributaries are above the Human Health criterion of 10 µg/L.

Based on information and analysis by both USGS and DEQ, DEQ has concluded that arsenic is predominately linked to natural sources. DEQ has demonstrated that naturally occurring arsenic concentrations and loading in the Upper Missouri River Basin is a result of contributions from natural sources in an internal arsenic memo in 2015 (DEQ Arsenic Memo 2015). The United States Geological Survey (USGS) has determined that the largest source of arsenic loading to the Madison River and its tributaries is the local geologic formations and geothermal water of the Yellowstone Park Caldera in Yellowstone National Park (Nimick et.al, 2013), https://toxics.usgs.gov/highlights/yellowstone_mercury.html). Based on the decision framework provided in **Section 7.4.1**, TMDLs will not be developed for arsenic at this time. Those waterbodies with arsenic impairments include Blaine Spring Creek, Buford Creek, Ennis Lake, More Creek, O'Dell Spring Creek, Madison River (Madison Dam to the Missouri River, Madison River (Quake Lake to Ennis Lake) and the Madison River from Hebgen Dam to Quake Lake. Where there are no anthropogenic sources of elevated arsenic, DEQ believes that it would be better to address the situation via approaches that do not necessarily involve TMDL development.

7.4.3.1 Elk Creek (MT41F002_020)

Available Water Quality Data

Metals water quality data are used to evaluate attainment of water quality targets in Elk Creek. Water quality data used for this evaluation was comprised of recent 2012-2013 synoptic high and low flow sampling data collected by Montana DEQ for stream assessment and TMDL development (**Appendix A**). Water quality data collected along Elk Creek that was used to evaluate attainment of metals water quality targets are summarized in **Table 7-5**. No sediment data was used in this evaluation, as there are no PELs for iron or selenium.

Table 7-5. Elk Creek Metals Water Quality Data Summary

Measurement	**Iron**	**Selenium**
Number of Samples	13	13
Minimum Concentration*	30 (µg/L)	0.5 (µg/L)
Maximum Concentration*	2060 (µg/L)	8 (µg/L)
Median Concentration	930 (µg/L)	2 (µg/L)
Number of Acute Aquatic Life Exceedances	NA	0
Acute Aquatic Life Exceedance Rate	NA	0.0%
Number of Chronic Aquatic Life Exceedances	5	2
Chronic Aquatic Life Exceedance Rate	38.46%	15.38%
Number of Human Health Exceedances	NA	0

*In those cases where a value was reported as less than the detection limit, half of the detection limit was used for statistical purposes. This approach did not affect exceedance rates or impairment determinations since detection limits are below target values.

Comparison of Metals Concentrations to Water Quality Targets and TMDL Determination

Iron

Elk Creek is listed as impaired for iron on the 2016 303(d) List. The more recent (2012-2013) data and associated assessment verify the iron impairment determination. Of 13 samples collected since 2012 along Elk Creek, five (38.46%) exceeded the chronic aquatic life criteria. Iron was only compared to the Chronic Aquatic Life (CAL) standard, as there is no Acute Aquatic Life (AAL) or human health criteria for iron to be assessed against. There are also no PELs to compare iron sediment quality data to aid in impairment determination. Based on target exceedances of the CAL, an iron TMDL is developed for Elk Creek.

Selenium

Elk Creek is listed as impaired for selenium on the 2016 303(d) List. The more recent (2012-2013) data and associated assessment verify the selenium impairment determination. Of 13 samples collected from 2012-2013 along the length of the stream, two exceeded the CAL (a 15.38% exceedance rate). Selenium was compared to the Acute Aquatic Life (AAL) standard and the human health standard and was found to not be exceeding these standards. Selenium is not hardness dependent; as such it has fixed Acute and Chronic Aquatic Life standards (20 µg/L and 5 µg/L respectively). There are no PELs to compare selenium sediment quality data to aid in impairment determination. Based on target exceedances a selenium TMDL is provided for Elk Creek.

7.4.3.2 Hot Springs Creek (MT41F002_030)

Available Water Quality Data

Metals water quality and sediment data were used to evaluate attainment of water quality targets in Hot Springs Creek. Water quality data used for this evaluation was comprised of recent 2012-2013 synoptic high and low flow sampling data collected by Montana DEQ for TMDL development (**Appendix**

A). There is no sediment NOAA PEL for iron (**Table 7-4**), as such iron was not compared to the PELs. Sediment data for lead was compared to PEL, and there were no lead exceedances. Water quality data collected from Hot Springs Creek that was used to evaluate attainment of metals water quality targets are summarized in **Table 7-6**.

Table 7-6. Hot Springs Creek Metals Water Quality Data Summary

Measurement	Iron	Lead
Number of Samples	17	17
Minimum Concentration*	190 (µg/L)	0.15 (µg/L)
Maximum Concentration*	2000 (µg/L)	6.2 (µg/L)
Median Concentration	850 (µg/L)	1.1 (µg/L)
Number of Acute Exceedances	NA	0
Acute Exceedance Rate	NA	0.0%
Number of Chronic Exceedances	6	2
Chronic Exceedance Rate	35.29%	11.76%
Number of Human Health Exceedances	NA	0

*In those cases where a value was reported as less than the detection limit, half of the detection limit was used for statistical purposes. This approach did not affect exceedance rates or impairment determinations since detection limits are below target values.

Comparison of Metals Concentrations to Water Quality Targets and TMDL Determination

<u>Iron</u>
Hot Springs Creek is listed as impaired for iron on the 2016 303(d) List. The most recent (2012-2013) data and associated assessment verify the iron impairment determination. Of 17 samples collected since 2012 at several locations in Hot Springs Creek, six (35.29%) exceeded the CAL criteria. There are no AAL or human health criteria for iron to be assessed against. There is no iron PEL to compare sediment quality data to aid in impairment determination. Based on target exceedances of the CAL, an iron TMDL is developed for Hot Springs Creek.

<u>Lead</u>
Hot Springs Creek is listed as impaired for lead on the 2016 303(d) List. The most recent (2012-2013) data and associated assessment verify the lead impairment determination. Of 17 samples collected from 2012-2013 along the length of the stream, two exceeded the CAL standard (11.76% exceedance rate). There were no exceedances of the AAL or the human health standards during the 2012-2013 sampling efforts. Lead concentrations in stream sediment samples were compared to the PEL. Two samples were collected and neither exceeded the 91.3 µg/L PEL for lead. Based on the CAL target exceedance a lead TMDL is provided for Hot Springs Creek.

7.4.3.3 South Meadow Creek (MT41F004_070)

Available Water Quality Data
Metals water quality and sediment data were used to evaluate attainment of water quality targets in South Meadow Creek. Water quality data used for this evaluation was comprised of recent 2011-2012 synoptic high and low flow sampling data collected by Montana DEQ for waterbody assessment and TMDL development (**Appendix A**). Sediment data for copper was compared to the NOAA PEL, and there

were no copper exceedances. Water quality data collected along South Meadow Creek that was used to evaluate attainment of metals water quality targets are summarized in **Table 7-7**.

Table 7-7. South Meadow Creek Metals Water Quality Data Summary

Measurement	**Copper**
Number of Samples	24
Minimum Concentration*	0.5 (µg/L)
Maximum Concentration*	8 (µg/L)
Median Concentration	0.5 (µg/L)
Number of Acute Exceedances	1
Acute Exceedance Rate	4.17%
Number of Samples that are ≥ 2 X the Acute Standard	1
Number of Chronic Exceedances	1
Chronic Exceedance Rate	4.17%
Number of Human Health Exceedances	0.0

*In those cases where a value was reported as less than the detection limit, half of the detection limit was used for statistical purposes. This approach did not affect exceedance rates or impairment determinations since detection limits are below target values.

Comparison of Metals Concentrations to Water Quality Targets and TMDL Determination

<u>Copper</u>

South Meadow Creek is listed as impaired for copper on the 2016 303(d) List. Of 24 samples collected between 2011-2012 at several locations along South Meadow Creek, one copper exceedance violated the AAL standard by twice the allowable amount. On 8/24/2012, copper was reported to be 8.0 µg/L, while the hardness dependent acute aquatic life standard was 3.79 µg/L. Copper concentrations in South Meadow Creek did not exceed the human health criteria. Copper concentration in the one sediment sample collected in South Meadow did not exceed the PEL. Any time the acute aquatic life target for a hardness dependent metal is exceeded by twice its value the waterbody is considered impaired and there is a need for a TMDL. As such a copper TMDL is developed for South Meadow Creek.

7.4.4 Metals Target Attainment Evaluation and TMDL Development Summary

Eleven individual stream segments were listed as impaired for metals-related impairments in the Madison River TMDL Planning Area (**Table 7-1**); however, TMDLs for only five of the waterbody-pollutant combinations requiring metals TMDLs are contained in this document. **Table 7-8** presents a summary of existing metals impairment causes and metals for which target exceedances cause impairment and for which TMDLs are prepared. TMDLs and allocations for the impaired segments provided in the following section. Although elevated levels of arsenic are present in a number of the 2016 303(d)-listed waterbodies (**Table 7-1**), arsenic TMDLs will not be developed due to a lack of human sources of arsenic present in the watershed.

Table7-8. Waterbody Segments with Metal TMDLs Contained in this Document

Waterbody (Assessment Unit)	**Waterbody ID (Assessment Unit ID)**	**TMDL(s)**
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Iron, Selenium

Table7-8. Waterbody Segments with Metal TMDLs Contained in this Document

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	TMDL(s)
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Iron, Lead
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Copper

7.5 Total Maximum Daily Loads (TMDLs)

This section describes the general approach used for TMDL development and presents TMDLs for each of the waterbody-pollutant combinations under different flow conditions. **Section 7.7** describes in further detail the specific TMDLS for each waterbody-pollutant combination (**Table 7-8**) and outlines the allocations to each pollutant category. **Section 7.7** also discusses loading estimates and load allocations established for high and low flow scenarios, depending on when each pollutant was exceeded. Loading estimates and allocations are based on observed water quality data and flow conditions measured during these time periods.

Because streamflow varies seasonally, TMDLs are not expressed as a static value, but as an equation of the appropriate target multiplied by flow as shown in **Equation 7-1**:

Equation 7-1: TMDL (lbs/day) = (X) (Y) (0.0054)

*X = lowest applicable water quality target in µg/L (**Table 7-3**)*
Y = streamflow in cubic feet per second (cfs)
0.0054 = conversion factor

As flow increases, the allowable load (TMDL) increases as shown by the metals TMDLs in **Figures 7-2** through **Figure 7-5**. It is important to remember that the TMDLs in these figures are based on the applicable water quality standard (**Table 7-3**) and an example flow volume. As each metal has unique standards (Human Health, hardness dependent and hardness independent Chronic Aquatic Life) each TMDL represented below is unique. For all metals the lowest applicable standard could either be the chronic aquatic life standard or the human health standard, depending on stream hardness values at the time the sample was collected. Iron and selenium are not hardness dependent, as such only one standard (Chronic Aquatic Life standard) is presented in **Figures 7-2** and **7-3**.

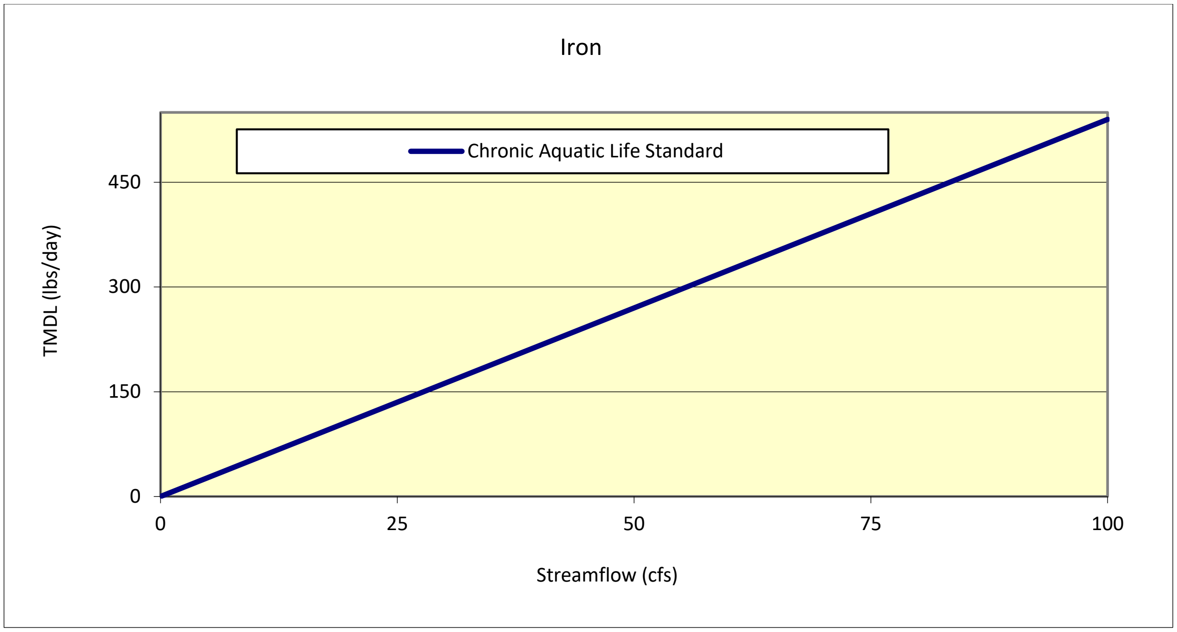

Figure 7-2. TMDL for Iron for streamflows ranging from 0 to 100 cfs

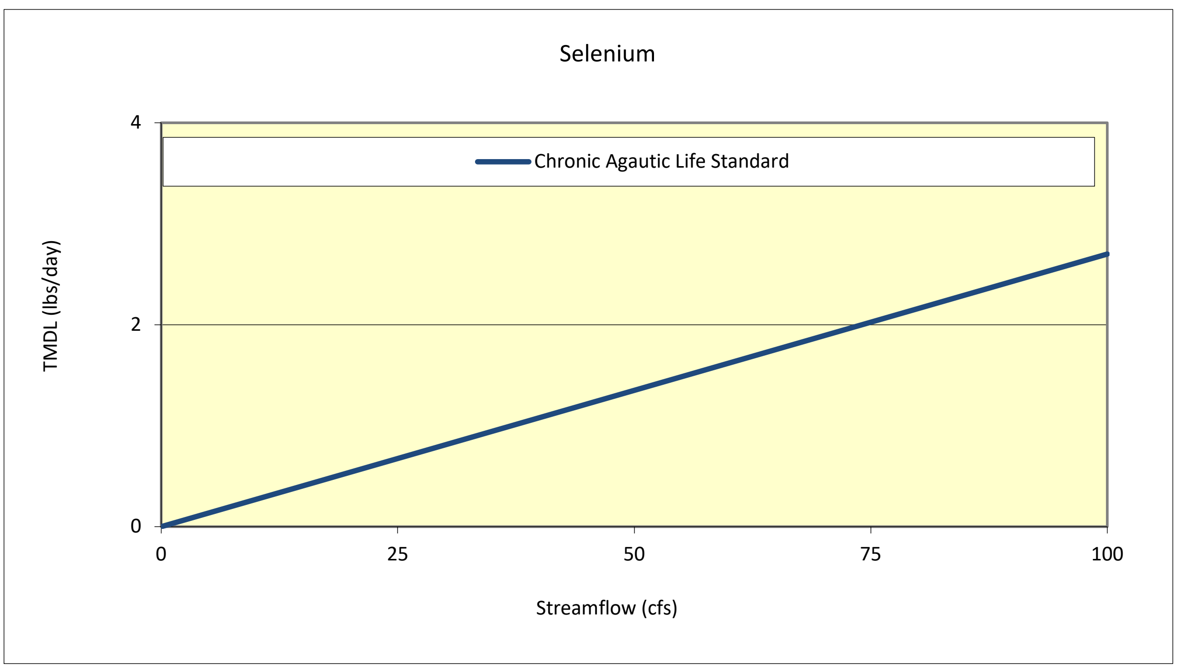

Figure 7-3. TMDL for Selenium for streamflows ranging from 0 to 100 cfs

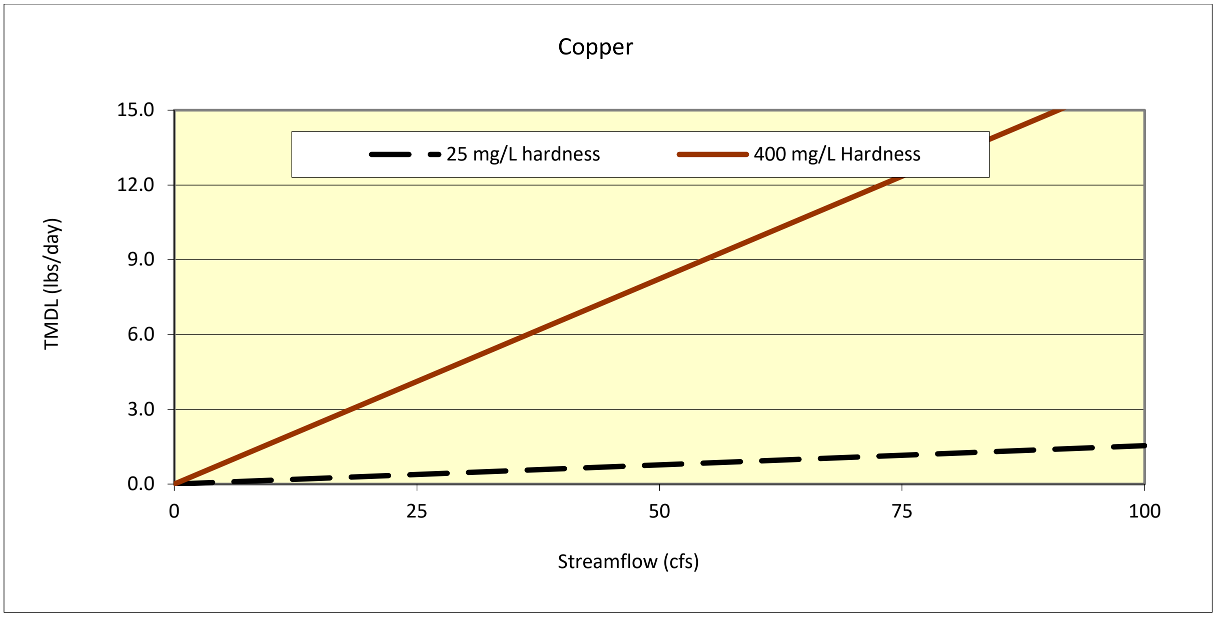

Figure 7-4. TMDL for Copper for streamflows ranging from 0 to 100 cfs

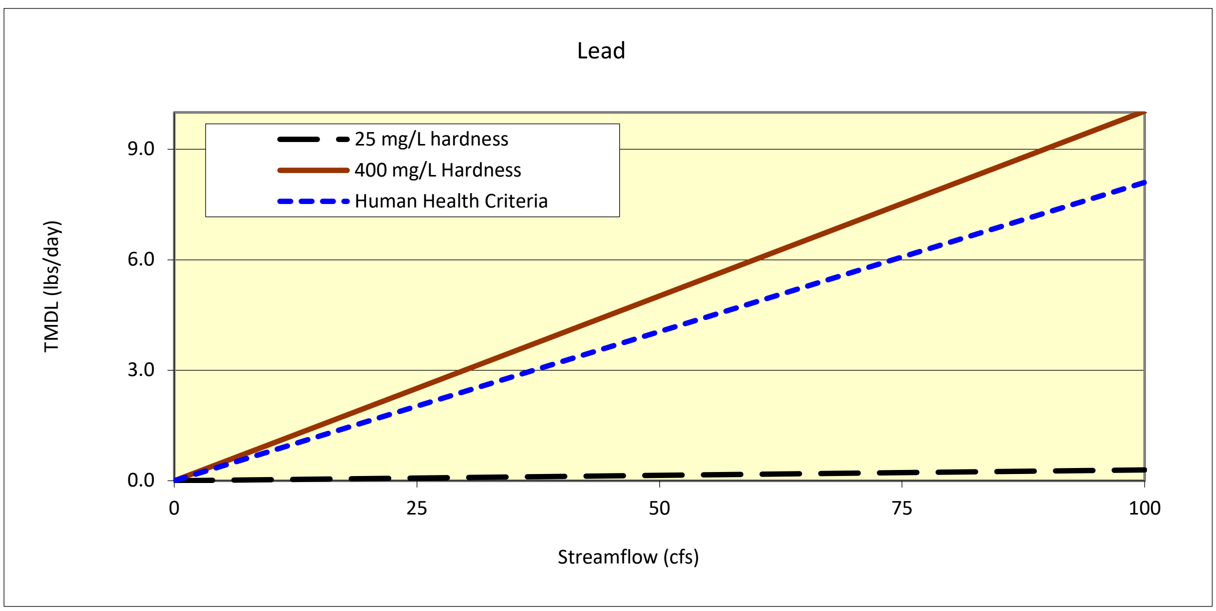

Figure 7-5. TMDL for lead for streamflows ranging from 0 to 100 cfs

7.6 Source Assessment

This section provides the approach and results of the source assessment, which characterizes the type and extent of sources contributing to metals loading to impaired streams. This section also establishes the basis for TMDL development and allocations to specific source categories in each of the watersheds identified in **Table 7-8**. Source characterization and assessment to determine the major sources in each of the metal impaired waterbodies was accomplished by using monitoring data collected from the Madison TMDL Planning Area (TPA) from 2011-2013, aerial photos, Geographic Information System (GIS) analysis, field reconnaissance and literature reviews.

Assessment of existing metals sources is needed to understand load allocations (LAs), and potential load reductions for different source categories. Source characterization links metals sources, loading, and supports the formulation of the allocation portion of the TMDL.

Examining water quality data under various hydrologic conditions is also necessary to characterize water chemistry metal conditions. The effect high flows can have on metals concentrations vary as high flow runoff increases stream bank erosion and erosion of soils and tailings containing metals. High flows may also dilute metals sources that enter the stream through groundwater. Areas that have been impacted by mining may contribute metals through groundwater discharge as well. While ground water discharges tend to occur year-round, they tend to be more apparent during low flow when surface water inputs are minimal.

Historical mining in the Madison TPA has been identified as the major contributing source of metals to the impaired waters. There are approximately 185 abandoned mines within the TPA according to the DEQ and MBMG abandoned mining databases. Approximately 60 abandoned mines occur in the metals impaired watersheds. The impaired watersheds also have 4 priority abandoned mines: the Boaz and Grubstake Mines in the Hot Springs Creek drainage and the Missouri and SE SE Section 25 Mine in the South Meadow Creek drainage. Priority abandoned mine types included in the databases are placer, hard rock/lode, mineral deposits and mill sites. Because of the different mine types in the databases, abandoned mine sites may range from small ground disturbances to areas with adits (which can be dry or discharging) and/or tailings and waste rock piles of different sizes. Waste rock dumps and tailings occur mainly in the upland areas; however, a few occur in the floodplain, streamside, or in stream channels. Depending on the parent geology, site stability, level of remediation and or re-vegetation, the capacity of these sites to leach metals and/or generate acid mine drainage the effects of mining wastes on stream water quality can vary greatly.

A query of applicable databases showed there is one mine with a DEQ operating permit in the Madison TPA. The mine in question is the Majesty Mine owned and operated by Nevada Colca Gold Inc. The Majesty Mine, located in the Hot Springs watershed, has a current operating permit issued through the Hard Rock Mining Bureau (DEQ operating permit #00165). This Majesty Mine is not currently mining ore, and is not expected to be in operation any time in the near future (personal communication with DEQ Hard Rock Mining Bureau staff, 2016). The Majesty mine does not have a Montana Pollutant Discharge Elimination System (MPDES) permit. MPDES permits are issued to point sources of pollution discharging to state waters. There are also a number of small miner exclusions (SMEs) in the Madison TPA, these occur primarily in the Hot Springs Creek watershed.

7.6.1 Elk Creek (MT41F002_020) Source Assessment

Elk Creek is a tributary to the Madison River, and is located within Hydrologic Unit Code 8 (HUC) (10020007). Elk Creek originates at mid-range elevations along the northern edge of the Madison Range and flows to the north. The approximately 22-mile reach of Elk Creek from the headwaters to the confluence with the Madison River is listed as impaired for metals (iron and selenium). This watershed is 90% private ownership, the remainder is comprised of approximately two and a half sections of State of Montana Trust Lands **(Figure 7-6)**. The upper 1/3 of the watershed is primarily herbaceous and sagebrush range land, relatively undisturbed, and receives some minor grazing. The middle 1/3 of the watershed begins a transition to more cultivated dryland crops and grazing. The lower 1/3 of the watershed sees heavier agricultural land use and cattle grazing. A livestock confinement area is located near the confluence of Elk Creek and the Madison River. The livestock confinement area is not considered a Concentrated Animal Feeding Operation (CAFO) and is not subject to MPDES permitting.

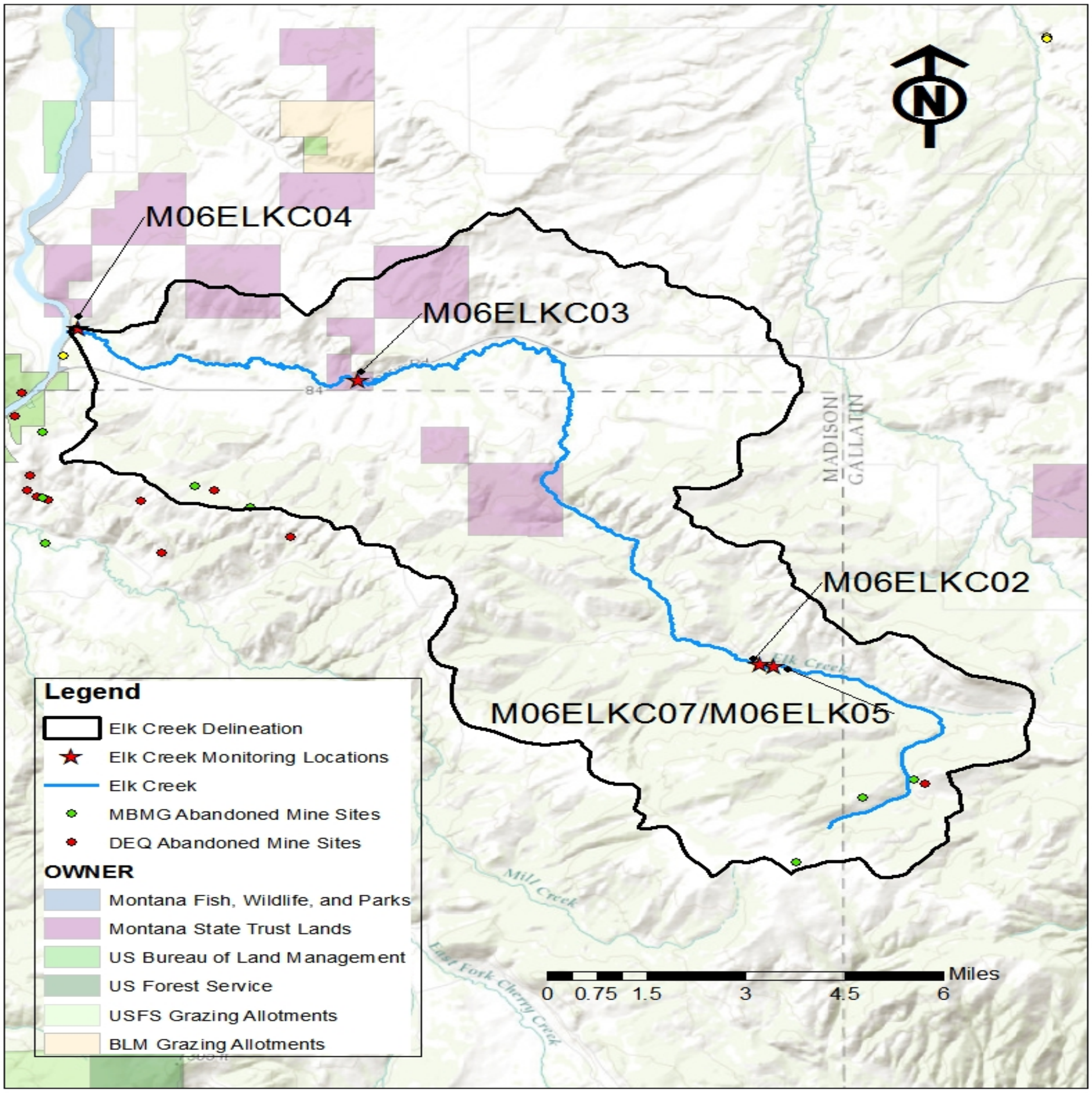

Figure 7-6. Elk Creek watershed showing metals sources

Metals Sources
The metals source assessment for Elk Creek included a review of relevant literature; compilation and review of GIS layers pertaining to land uses; land ownership, and locations of abandoned and inactive mines, as well as review of metals water quality data collected in Elk Creek in 2012 and 2013.
DEQ and MBMG records indicate that there are seven abandoned mines in the Elk Creek watershed (**Figure 7-6**). Three unnamed lode mines are located approximately four miles south west of the mouth of Elk Creek. There are several unnamed sillimanite mines in the headwaters, including the Galatian Corundum Deposit and the Elk Creek Corundum Mine.

The Elk Creek Corundum mine site is located adjacent to Elk Creek in the uppermost reach. The Montana Department of State Lands 1994 summary report on abandoned hardrock mine priority sites (Montana Department of State Lands, 1994) listed the Elk Creek Corundum Mine as a priority mine site. However, DEQ does not currently consider the Elk Creek Corundum mine a priority mine. The 1995 supplemental summary report of abandoned hardrock mine sites (Montana Department of Environmental Quality, 1996) removed the Elk Creek Corundum mine from the priority list (personal correspondence with Montana Department of Environmental Quality Abandoned Mines Section staff, 2016). The 1994 report indicated there was approximately 7,500 cubic yards of waste rock and two open mine shafts remaining onsite. The report also indicated that the East Fork of Elk Creek runs along the toe of a waste rock pile. Water quality sampling conducted in conjunction with this report indicated metals concentrations above background conditions. Review of recent aerial imagery indicates minimal surface disturbance.

The connection between land disturbances associated with agricultural operations and other human caused disturbances and their potential to contribute metals to Elk Creek is not clear. Cattle grazing and other human influenced sources are not direct sources of metals loading; however, disturbance of riparian and upland soils as a result of these activities can increase erosion. The resulting sediment has the potential to increase metals loading to Elk Creek if the sediment is from an area with elevated metals concentrations. As such, these sources of erosion cannot be totally discounted as potential metals sources. **Figure 2-13** shows the spatial extent of land in the Elk Creek watershed that is dedicated to agricultural land use (primarily private land) and subject to increased human disturbances.

Spatial and Seasonal Trends

During all 2012 and 2013 sampling events there was measurable flow in Elk Creek. Hardness values were relatively high, however they never exceeded 300 mg/L in any of the samples.

As a result of metals water quality sampling, it appears that iron concentrations are a factor of suspended sediment concentrations. During those periods with the highest total suspended solids (TSS) concentrations, Elk Creek also had the highest iron concentrations. While not directly linked to high flow, the high iron, high TSS correlation is evident for two of three high flow events that were sampled during the 2012-2013 sampling efforts (M06ELKC03 on 6/19/12 and M06ELKC03 on 6/12/13). The high iron and TSS trend may be indicative of iron loading associated with nonpoint sediment sources of erosion (historical mining, roads, agricultural practices, and erosion from human or natural causes).

Selenium exceedance did not correlate well with higher flow or higher TSS concentrations; as such there was no discernable high flow and high TSS trend in selenium concentrations. Selenium exceedances seem to occur during low flow events and only at M06ELKC03 (**Table 7-9**). It is important to note that selenium exceedances occurred when hardness values were high. There is a distinct possibility that selenium is being contributed to Elk Creek from groundwater, as high hardness concentrations in groundwater are typically a result of the soils and geologic materials through which it passes. These exceedances also occurred in August and September, when groundwater contributions would be more likely.

Table 7-9. Elk Creek Metals Water Quality Target Exceedances

Site ID	**Activity Date**	**Hardness (mg/L)**	**Flow** (cfs)	**Fe** (µg/L) **CAL=1,000 µg/L**	**Se** (µg/L) **TR AAL= 20 µg/L CAL= 5 µg/L**	**TSS** (µg/L)
M06ELKC07	8/17/13	131	0.01	190	0.45	1,500

Table 7-9. Elk Creek Metals Water Quality Target Exceedances

Site ID	**Activity Date**	**Hardness (mg/L)**	**Flow** (cfs)	**Fe** (µg/L) **CAL=1,000 µg/L**	**Se** (µg/L) **TR AAL= 20 µg/L CAL= 5 µg/L**	**TSS** (µg/L)
M06ELKC05	9/16/13	122	0.21	330	0.45	4,500
M06ELKC02	8/16/13	146	1.0	30	0.45	1,000
M06ELKC02	9/16/13	134	0.23	60	0.45	1,500
M06ELKC03	6/19/12	205	2.03	**2,060***	3	76,000
M06ELKC03	7/25/12	242	0.46	**1,140***	3	33,000
M06ELKC03	8/28/12	290	0.11	860	4	26,000
M06ELKC03	6/12/13	178	2.71	**1,550***	3	44,500
M06ELKC03	8/15/13	252	0.05	340	**8.1***	6,500
M06ELKC03	9/16/13	270	0.001	190	**8***	5,250
M06ELKC04	6/19/12	176	2.97	680	2	25,000
M06ELKC04	7/25/12	232	0.47	**1,170***	2	32,000
M06ELKC04	8/28/12	262	0.05	**1,000***	2	17,000

CAL = Chronic Aquatic Life standard. AAL = Acute Aquatic Life standard.
Fe= Iron, Pb = Lead, TSS = Total Suspended Solids
* Values demoted by an asterisk exceed water quality targets

The highest water quality target exceedance for iron and selenium occurred in the lower third of the watershed (**Figure 7-6**), closer to the mouth (M06ELKC03 and M06ELKC04). No iron or selenium water quality exceedances occurred in the headwaters (M06ELKC07, M06ELKC05 and M06ELKC02). Water quality exceedances were clustered lower in the watershed, despite potential sources of metals higher in the drainage, such as waste rock from the Elk Corundum Mine. This suggests that diffuse sources of metals (dispersed tailings piles, rock piles, reclaimed tailings, contributions from groundwater and soil disturbances associated with human activities such as agriculture) may be contributing minor loads that cumulatively cause exceedance of the targets in the lower portions of the watershed. Although there are number of potential iron and selenium sources, the data do not currently provide resolution specific enough to identify contributions from individual sources, and it is uncertain the extent to which natural sources may be contributing to elevated metals concentrations in Elk Creek.

7.6.2 Hot Springs Creek (MT41F002_030) Source Assessment

Hot Springs Creek is also tributary to the Madison River, and is located within HUC 8 (10020007). Hot Springs Creek originates along the foothills of the Tobacco Root Mountains west of Norris, at the confluence of the North Fork and Middle Fork of Hot Springs Creek. Hot Springs Creek is joined by the South Fork approximately 1.5 miles downstream of the aforementioned confluence. These tributaries along with Burnt Creek are the major contributing sources of flow to Hot Spring Creek. The approximately 17 miles of Hot Springs Creek from the headwaters to the Madison River is listed as impaired for metals (iron and lead).

The upper reaches of Hot Springs Creek are mostly contained within Bureau of Land Management (BLM) and U.S.D.A Forest Service (USFS) property (**Figure 7-7**). The majority of the BLM land is devoted to grazing, a smaller portion of the headwater land is dedicated to USFS grazing allotments. As such, the dominate land use in the upper reaches of the drainage is grazing for cattle. Grazing takes place in both forested and range land locations. Analysis of aerial imagery, geographic information system (GIS) and site observations reveals that grazing and irrigated hay production is common along the riparian zone.

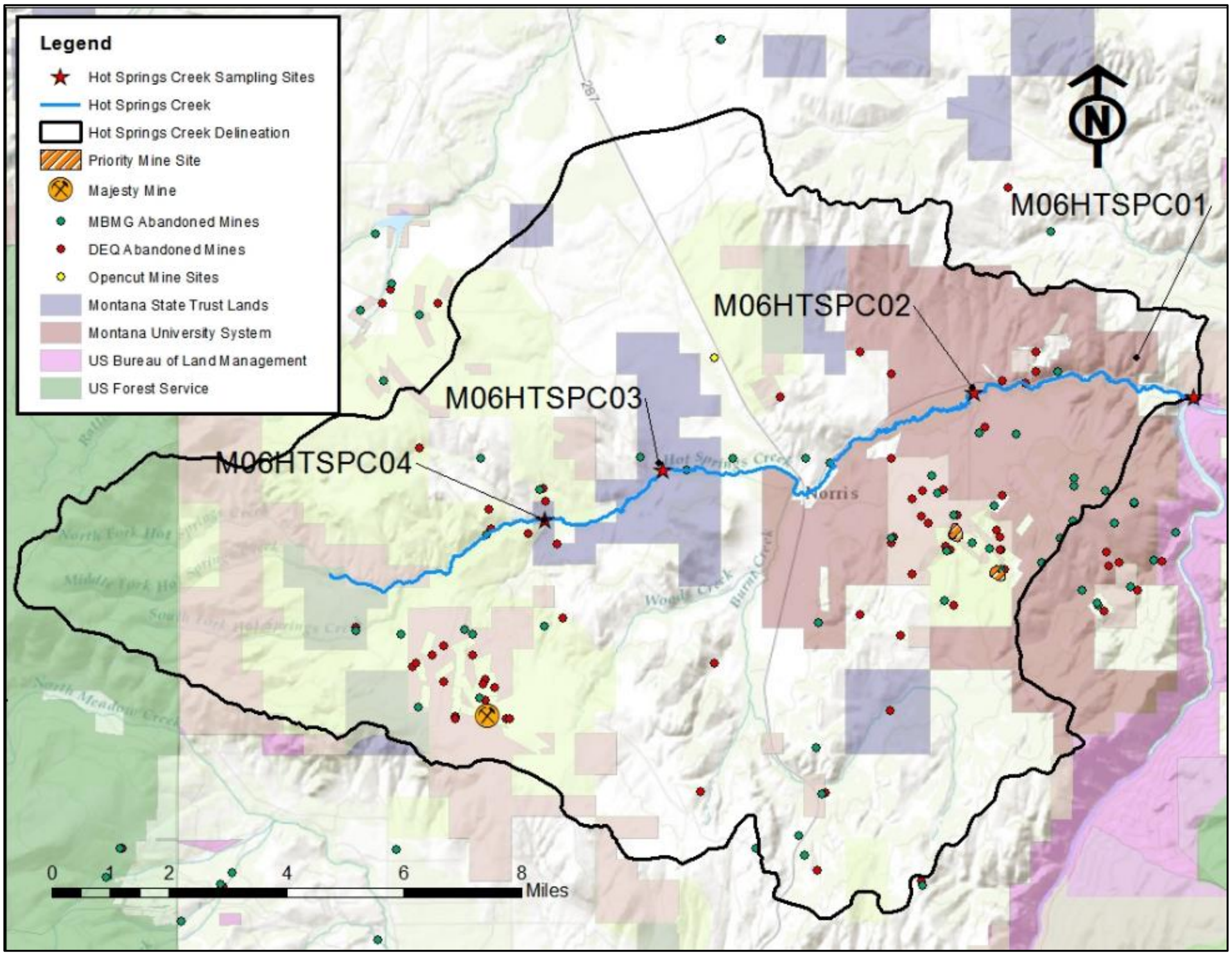

Figure 7-7 Hot Springs Creek watershed showing metals sources

Metals Sources

The metals source assessment for Hot Springs Creek included a review of relevant literature; compilation and review of GIS layers pertaining to: land ownership, locations of abandoned and inactive mines, and a review of metals water quality data collected in Hot Springs Creek.

As a result of historical mining many abandoned mines, mills and associated waste piles have been identified in the Hot Springs Creek watershed. According to DEQ and the Montana Bureau of Mines and Geology (MBMG) GIS coverages, approximately 60 abandoned mines exist in the Hot Springs drainage (**Figure 7-7**), many of which are within close proximity of the creek. Consequently, anthropogenic metals sources in the Hot Springs Creek watershed are comprised primarily of abandoned mining sites, with the majority being in the Norris/Red Bluff Mining Districts, positioned in the lower 1/3 of the watershed. According to the DEQ Abandoned Hardrock Mine Priority Sites 1995 Supplemental Summary Report (Montana Department of Environmental Quality, 1996), there are two priority abandoned mines in the Lower Hot Springs Mining Complex. These include the Boaz and Grubstake lode mines (silver, gold, copper, and lead mines).

The 1995 DEQ supplemental summary report of abandoned hardrock mine priority sites states the Boaz Mine site has approximately 56,500 cubic yards of tailings and 138,770 cubic yards of waste rock associated with it. Metals sampling (soil samples) conducted in the tailings and waste rock found lead and other metals to be three times background concentrations. The report also indicated that an unnamed tributary to Hot Springs Creek flowed directly through the onsite tailings. Water quality samples collected at the time of the site investigation upstream and downstream of the tailings indicated the presence of lead. Samples collected downstream of the tailings exceeded the CAL standard for lead. No discharging adits, water filled mine shafts, seeps, or springs were identified.

The DEQ summary report of abandoned hardrock mine priority sites reported the Grubstake mine has approximately 5,780 cubic yards of uncovered tailings onsite and 1,030 cubic yards of uncovered waste rock onsite. Lead concentrations were found to be three times above background concentrations in samples collected from both the tailings and the waste rock. The report also noted an ephemeral drainage on site. No discharging adits or open adits were identified.

There is one notable active mining operation in the Hot Springs Creek watershed. The Majesty Mine is located in the upper third of the watershed, upstream of the confluence of Burnt Creek and Hot Springs Creek (**Figure 7-7**). The Majesty Mine owned and operated by Nevada Colca Gold Inc. has a current operating permit issued through the DEQ's Hard Rock Mining Bureau (DEQ operating permit #00162), not to be confused with Montana Pollutant Discharge Elimination System (MPDES) discharge permits issued for surface water discharges. The Majesty mine is permitted for cyanide heap leach ore processing prior to the ban permitting for this type of ore processing. This mine is not currently processing ore and has not done so for the last 15 years. DEQ is not aware of any current plans by Nevada Colca Gold Inc. to begin mining or processing ore in the near future. Pursuant to Montana Code Annotated (MCA) 82-4-335, a person who is issued an Operating Permit, may not "impact surface water or groundwater." Therefore, it is the responsibility of the operating permit holder to ensure surface water and groundwater are not being impacted.

There are several Small Miner Exclusions (SMEs) that exist in the Hot Springs Creek watershed as well. These occur primarily in and around the area of the Red Bluff Mining District. SMEs allow for small mining operations or exploratory activities that are less than 5 acres of total surface disturbance. SMEs are not issued a permit (MPDES or Operating Permit) by DEQ. According to ARM 82-4-305 "the small miner will not pollute or contaminate any stream" as a result of their operations. It is the responsibility of the holder of the SME to adhere to ARM 82-4-305. There is also one small "opencut" mine in the watershed. Opencut mines are those that strip or excavate more than 10,000 cubic yards of soil, overburden or mine material from a site. This particular mine, is a gravel operation managed by the Madison County Road Department. Pursuant to 82-4-434 (3) (l), MCA, an Open Cut Mining permit holder must ensure that "surface water and ground water will be given appropriate protection, consistent with state law, from deterioration of water quality and quantity that may arise as a result of the opencut operation." As such it is the responsibility of the permit holder to adhere to the conditions of the permit and ensure that surface and groundwater are not being impacted.

The connection between land disturbances associated with agricultural operations, human caused erosional disturbances and their potential to contribute metals to Hot Springs Creek is not clear. Cattle grazing and other human influenced sources are not direct sources of metals loading; however, disturbance of riparian and upland soils as a result of these activities can increase erosion. The resulting sediment has the potential to increase metals loading to Hot Springs Creek if the sediment is from an area with elevated metals concentrations. As such cattle grazing, associated agricultural disturbances and other human caused sources of erosion cannot be totally discounted as potential metals sources. **(Figure 2-13)** shows the spatial extent of land in the Hot Springs Creek watershed that is dedicated to agricultural land use (USFS and BLM grazing allotments, etc.) and subject to increased human disturbances.

Spatial and Seasonal Trends
During all the 2012-2013 sampling efforts, there was measurable flow in in Hot Springs Creek. Hardness values were relatively high however they never exceeded 200 mg/L in any of the samples.
As with Elk Creek, iron metals concentrations in Hot Springs Creek appear to be a factor of suspended sediment. During those periods with the highest total suspended solids (TSS) concentrations, Hot Springs Creek also had the highest iron concentrations. That being said, there was no correlation between flow and high iron concentrations. High iron concentrations were observed during both higher and lower flow conditions. M06HTSPC01 was the only monitoring site that witnessed iron exceedances (**Table 7-10**). It is worth noting that TSS concentrations often increased from an upstream to downstream direction during sampling periods, with corresponding increases in iron concentration in the upstream to downstream direction.

The limited number of metals samples collected in Hot Springs Creek makes it difficult to discern much of a spatial or temporal pattern for lead. High lead concentrations in the creek do not correlate to high TSS or high or low flows. At M60HTSPC04 high lead concentration occur at average flows and lower TSS concentrations, while at M06HTSPC01 high lead concentrations occur at slightly higher flows and higher TSS concentrations (**Table 7-10**). M06HTSPC04 is located close to the headwaters, while M06HTSPC01 is closest to the mouth. Lead concentrations in sediment samples do not indicate high metals concentrations. It is worth noting that lead concentrations were found to be exceeding the standard at both high and low harness values. M06HTSPC04 was in exceedance of the standard at 48 mg/L hardness and M06HTSPC01 was in exceedance of the standard at 158 mg/L. The high hardness value coincided with a moderately high flow of 4.88 cfs. Relatively high hardness values that occur during higher flows are likely a result of the erosion of soils and geologic materials and may provide an explanation as to lead sources during higher flow and high hardness events.

Table 7-10. Hot Springs Creek Metals Water Quality Data Target Exceedances

Site ID	Activity Date	Hardness (mg/L)	Flow (cfs)	Fe (µg/L) TR CAL= 1000 µg/L	Pb (µg/L)	TSS (µg/L)
M06HTSPC04	6/13/12	48	2.69	540	**1.8***	16,000
M06HTSPC04	8/1/12	56	1.84	190	0.5	4,000
M06HTSPC04	7/9/13	47.4	2.4	290	0.7	5,750
M06HTSPC03	6/13/12	92	0.94	600	0.5	4,000
M06HTSPC03	7/25/12	103	0.27	900	0.6	4,000
M06HTSPC03	6/12/13	68.8	2.98	850	1	3,000
M06HTSPC03	7/9/13	71.7	2.46	660	0.7	5,250
M06HTSPC03	8/16/13	104	0.63	300	0.3	1,000
M06HTSPC02	6/13/12	183	3.19	720	1.1	14,000
M06HTSPC02	8/1/12	177	2.06	850	1.8	16,000
M06HTSPC02	8/27/12	164	3.59	480	1	12,000
M06HTSPC01	6/13/12	196	4.11	**1,480***	5.3	31,000
M06HTSPC01	8/1/12	176	2.56	**1,190***	4.9	24,000
M06HTSPC01	8/24/12	171	3.17	**1,380***	5.2	25,000
M06HTSPC01	6/12/13	141	9.28	**1,450***	4.3	29,000
M06HTSPC01	7/9/13	156	4.88	**2,000***	**6.2***	46,200

Table 7-10. Hot Springs Creek Metals Water Quality Data Target Exceedances

Site ID	Activity Date	Hardness (mg/L)	Flow (cfs)	Fe (µg/L) TR CAL= 1000 µg/L	Pb (µg/L)	TSS (µg/L)
M06HTSPC01	8/15/13	172	1.15	**1,010***	3.1	21,000

CAL = Chronic Aquatic Life standard, TR = Total Recoverable, Fe= Iron, Pb = Lead, TSS = Total Suspended Solids
* Values demoted by an asterisk exceed water quality targets

Average iron concentrations almost double from upstream monitoring site M06HTSPC02 to M06HTSPC01. M06HTSPC02 is located upstream of the Bradley Creek bridge. Bradley Creek drains a significant portion of the Lower Hot Springs Mining Complex (Norris/Red Bluff Mining Districts), which contains the priority abandoned mines Grubstake and Boaz. Given that iron water quality exceedances occur downstream of the confluence with Bradley Creek, closer to the mouth (M06HTSPC01), and the direct correlation between high iron concentrations and high TSS values, iron loading is likely associated with nonpoint sediment sources of erosion (existing and abandoned mine sites, general disturbances associated with mining activities, etc.) in the Bradley Creek sub-watershed. That being said, the increase in iron concentrations between M06HTSPC02 and M06HTSPC01 while flows at these monitoring sites remained relatively stable indicates that there is a significant contribution of iron from Bradley Creek. While there are fewer lead exceedances of the standard, lead generally follows the same loading pattern as iron. This is exemplified by the load contributions from the Bradley Creek watershed and the upper portion of the watershed.

7.6.3 South Meadow Creek (MT41F004_070) Source Assessment

South Meadow Creek originates in the Tobacco Root Mountains west of McAllister, Montana, and is a tributary to Ennis Lake, located within HUC 8 (10020007). From its headwaters, South Meadow Creek flows for approximately 1.5 miles to South Meadow Lake. From the outlet of the lake, it flows approximately 6.3 mile to the confluence with Daisy Creek, then 0.25 miles to Virginia Creek, 2.8 miles to Leonard Creek, and an additional 6.2 miles to the mouth at Ennis Lake. While these tributaries contribute enough flow volume to South Meadow Creek to be significant enough to alter impairment, water quality data indicate that they do not have a direct impact on metals concentrations, as is discussed below. The approximately 17.5 mile reach of South Meadow Creek from the headwaters to Ennis Lake is listed as impaired for copper (**Figure 7-8**).

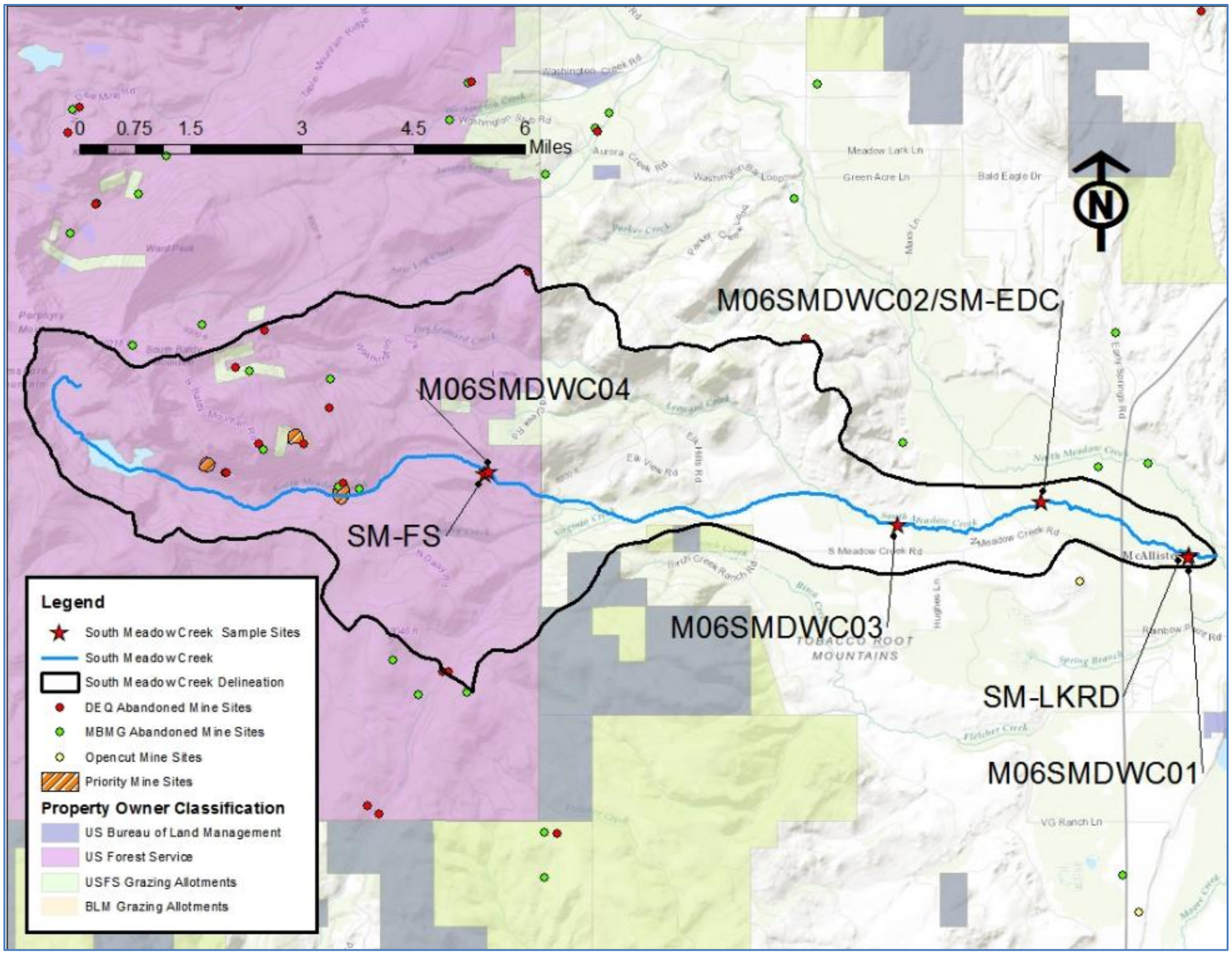

Figure 7-8. South Meadow Creek watershed showing metals sources

Metals Sources

The metals source assessment for South Meadow Creek included a review of relevant literature; compilation and review of GIS layers pertaining to land uses, land ownership, and locations of abandoned and inactive mines, and; a review of metals water quality data collected in South Meadow Creek.

A few abandoned placer and lode mines exist within the South Meadow Creek drainage. According to DEQ and MBMG GIS coverages, there are approximately twelve abandoned mines, all of which are located in the headwaters of the drainage (**Figure 7-8**). According to the Abandoned Hardrock Mine Priority Sites 1995 Supplemental Summary Report (Montana Department of Environmental Quality, 1996), there are two priority abandoned mines in the Washington Mining District, the Missouri and the SE SE Section 25. Both were hard rock mining operations, with the Missouri Mine producing gold, silver, lead and copper.

The supplemental summary report of abandoned hardrock mines priority sites indicates the Missouri site has approximately 12,111 cubic yards of tailings and 5,960 cubic yards of waste rock on site. Metals sampling conducted in the tailings and waste rock found elevated copper concentrations and other metals to be three times background concentrations. The report also indicated that South Meadow Creek flows immediately adjacent to the mine site. The mine report documented releases of sediment from the site to South Meadow Creek. There were no discharging adits, filled shafts, seeps or springs, however several open adits were identified.

The DEQ abandoned mines report also reported that the SE SE Section 25 mine has approximately 4,600 cubic yards of uncovered waste rock onsite. Copper concentrations were found to be three times above background concentrations in samples collected from the waste rock. One discharging adit was noted at the mine site. Water samples collected from the adit exceeded acute and chronic aquatic life standards for copper and other metals. Two open adits were also noted on site. The mine site is approximately 600 feet from the nearest surface water, a tributary to South Meadow Creek.

The upper half of the watershed is located in South Meadow USFS grazing allotments (U.S. Forest Service land in **Figure 7-8**). Small portions of the Miller and South Daisy allotments border the southern edge of the South Meadow Creek watershed. As such, the dominate land use in the upper reaches of the drainage is grazing for cattle. Grazing takes place on private land, in both forested and range land locations as well.

The connection between land disturbances associated with agricultural operations and other human caused erosional disturbances and their potential to contribute metals to South Meadow Creek is not clear. Cattle grazing and other human influenced sources are not direct sources of metals loading, however disturbance of riparian and upland soils as a result of these activities can increase erosion. The resulting sediment has the potential to increase metals loading if the sediment is from an area with elevated metals concentrations. As such cattle grazing, associated agricultural disturbances and other human caused sources of erosion cannot be totally discounted as potential metals sources. **Figure 2-13** shows the spatial extent of land that is dedicated to agricultural land use (grazing allotments etc.) in the South Meadow Creek watershed.

Spatial and Seasonal Trends

Flow was not measured on South Meadow Creek during all sampling efforts, so flow data is inconsistent. When collected, hardness values were relatively low, never exceeding 130 mg/L in any of the samples.

South Meadow Creek had only one exceedance of copper. On 8/24/2012 copper was reported to be 8.0 µg/L, which is twice the AAL standard. As this exceedance was a onetime occurrence spatial and temporal trends cannot be readily established (**Table 7-11**). This exceedance occurred in the headwaters at sampling location M06SMDWC04 (**Figure 7-8**). All the major tributaries to South Meadow Creek enter the main channel well below this point, as such metals loading coming from them cannot be considered as sources. Metals sediment data did not indicate the presence of copper. The one-time exceedance occurs at a moderate flow, and relatively low hardness, this adds additional uncertainty to determining the cause of this exceedance.

Table 7-11. South Meadow Creek Metals Water Quality Data Target Exceedances

Site ID	**Activity Date**	**Hardness** (mg/L)	**Flow** (cfs)	**Cu** (µg/L) **TR**	**TSS** (µg/L)
M06SMDWC04	6/18/12	25	36.37	0.5	5,000
M06SMDWC04	7/24/12	25	9.01	0.5	4,000
M06SMDWC04	08/24/12	25	8.42	**8***	4,000
SM-FS	10/25/11	41	N/A	0.5	10,000

Table 7-11. South Meadow Creek Metals Water Quality Data Target Exceedances

Site ID	**Activity Date**	**Hardness** (mg/L)	**Flow** (cfs)	**Cu** (µg/L) **TR**	**TSS** (µg/L)
SM-FS	07/02/12	25	N/A	0.5	ND
SM-FS	08/06/12	25	N/A	0.5	4,000
SM-FS	09/19/12	29	ND	0.5	4,000
M06SMDWC03	06/18/12	29	15.78	2	14,000
M06SMDWC03	07/24/12	49	4.7	0.5	6,000
M06SMDWC03	08/24/12	54	N/A	2	15,000
M06SMDWC02	06/18/12	35	7.52	2	27,000
M06SMDWC02	07/24/12	63	0.61	1	4,000
M06SMDWC02	08/24/12	57	0.01	0.5	4,000
SM-EDC	10/25/11	65	N/A	1	10,000
SM-EDC	07/02/12	47	N/A	1	ND
SM-EDC	08/06/12	49	N/A	0.5	4,000
SM-EDC	09/19/12	61	N/A	0.5	4,000
M06SMDWC01	06/18/12	115	6.73	0.5	6,000
M06SMDWC01	07/24/12	123	4.75	0.5	7,000
M06SMDWC01	08/24/12	130	4	0.5	8,000
SM-LKRD	10/25/11	88	N/A	0.5	4,000
SM-LKRD	07/02/12	112	N/A	0.5	ND
SM-LKRD	08/06/12	127	N/A	0.5	9,000
SM-LKRD	09/19/12	125	N/A	0.5	4,000

TR = total recoverable, Cu = Copper, TSS = Total Suspended Solids, N/A= Not Applicable (No Data Reported), ND = non-detect
* Values demoted by an asterisk exceed water quality targets

Although there are numerous potential copper sources, the data do not currently provide enough resolution to identify contributions from individual sources. That being said, the single copper concentration that exceeded the standard occurred in the headwaters and is at a location that is directly downstream of several priority abandoned mine sites. Also, worth noting is the weak downward trend of copper concentrations from the headwaters toward the mouth.

7.7 Metals TMDLs and Allocations

The following section describes the TMDLs and metals allocation for Elk Creek, Hot Springs Creek and South Meadow Creek. Metals TMDLs are presented herein and summarized in **Tables 7-13** through **7-15**. As described in **Section 7.5**, a TMDL is a calculation of the maximum pollutant load a waterbody can receive while maintaining water quality standards (**Equation 7-1**). The TMDLs presented below are based on the most stringent applicable water quality criteria identified in **Section 7.4.2** and an example streamflow.

7.7.1 Metals Allocations

Metals TMDLs are allocated to point (wasteload) and nonpoint (load) sources. The TMDL is comprised of the sum of the load allocations (LA) and wasteload allocations (WLA) to all significant point and nonpoint metals sources (natural and human), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. WLAs are allowable pollutant loads that are assigned to permitted and non-permitted point sources. LAs are allowable pollutant loads assigned to nonpoint sources and may include the pollutant load from naturally occurring sources, as well as human-caused nonpoint loading. The difference between point and nonpoint sources specific to the Madison TMDL Planning Area (TPA) are discussed in detail below.

In addition to metals load allocations, the TMDL must also take into account the seasonal variability of metals loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses. This is accomplished through the use of a margin of safety (MOS) in the TMDL calculation. These elements are combined in the following equation:

Equation 7-2: TMDL = ΣLA + ΣWLA + MOS

LA = Load allocation or the portion of the TMDL allocated to nonpoint sources and natural background
WLA = Wasteload allocation or the portion of the TMDL allocated to point sources
MOS = Margin of Safety

The MOS is an accounting of uncertainty about the relationship between metals loads and receiving water quality. An implicit MOS, as discussed in **Section 7-8**; is applied to all metals TMDLs. Therefore, the explicit MOS in the above equation is equal to zero and no longer included within the equation and discussion of allocations in this section.

Metals allocations are based on metal sources which include the following:

- Natural background (non-anthropomorphic sources such as influences from local geology)
- Active mines, including those permitted by DEQ and those that fall under the small miner exclusion and open cut permits
- Abandoned mines and other human sources
    - in-stream, and floodplain metals deposits from historical mining operations
    - drainage/runoff from abandoned mines and abandoned mine tailings
    - upland disturbances form human activities (agriculture, recreation)
    - nonpoint sources, which can accelerate erosion of mineralized soils

7.7.1.1 Natural Background Loading (LA_{NB})

Natural background loading of metals occurs as a result of regional and local geologic conditions. Therefore, the degree of loading can vary among subwatersheds, as geologic conditions are not consistent throughout the Madison TPA (**Figure 2-5**). Natural background loading will therefore be accounted for separately from other human-caused sources in final TMDL allocations.

Data collected by DEQ between 2011 and 2013 from Moore Creek (**Table 7-12**) were used to derive natural background metals concentrations for Elk Creek, Hot Springs Creek and South Meadow Creek. The 2011 to 2013 data set provided a substantial data set that covered a number of flow conditions allowing for a fairly accurate characterization of water quality in Moore Creek. Moore Creek is a tributary to the Madison River, and joins the Madison immediately prior to its confluence with Ennis

Lake. The abandoned mines databases do not show profuse mining activity in the Moore Creek watershed. While there are a few small abandoned mines that occur in the headwaters, they are disperse and not as concentrated as in the other watersheds. There is no mention of these or other mines in the Abandoned Hardrock Mine Priority Sites Project Report (MDSL 1994). Moore Creek watershed has similar geology to the other streams originating in the Tobacco Root Mountains. The Precambrian, metamorphic, Pre-Belt Gneiss and schists that dominate the other watersheds are equally present in Moore Creek.

Background concentrations for setting the load allocation to natural background were determined by taking the 75th percentile of available samples in Moore Creek (**Table 7-12**). By using the 75th percentile, DEQ has taken a conservative approach to estimating natural background. The 75th percentile allows for a higher than actual/average natural background concentration and a larger load. This will in turn require a small allocation to and reduction of human caused loads in order to meet the TMDL. For samples that were below the detection limit, half the detection limit was used to represent that sample. This methodology is used to account for all natural background sources of metals loading.

Thus, the natural background load is equal to the natural background allocation under all conditions in this document and can be calculated for each flow for each stream as follows:

Equation 7-3: LA_{NB} = Natural Background Load Allocation (lbs/day) = (X) (Y) (k)
X= Natural background concentration in µg/L (provided in **Table 7-12**)
Y= streamflow in cubic feet per second
k = conversion factor of 0.0054

If future monitoring allows for determination of a more representative natural background loading contribution, or indicates different background concentrations than indicated in **Table 7-12**, the allocations may be changed via the adaptive management process described in **Section 9.2**.

Table 7-12. Natural Background Concentrations used in TMDL Allocations

Parameter	Moore Creek Metals Water Quality Data Summary	
	Sample Count	75th Percentile Concentration
Copper (TR) (µg/L)	21	1
Iron (TR) (µg/L)	21	460
Lead (TR) (µg/L)	21	0.25
Selenium (TR) (µg/L)	21	0.5

7.7.1.2 Active Mines (LA_{Active})

Loading sources associated with active mining operations are similar to abandoned mines (dispersed tailings, waste rock piles), however for the metals impaired watersheds in the Madison TPA, they are not as widespread or abundant as abandoned mine sources. Unlike abandoned mines, point source loading from active mines would require the sources to have a Montana Pollutant Discharge Elimination System (MPDES) surface water discharge permit. Active mines include the Majesty Mine (DEQ Operating Permit #00162), and open cut surface mines and a number of mines covered under small miner exclusions (SME). The Majesty Mine is not operational and has no identified pollutant loading to surface or ground water that would be considered a point source and require a MPDES or Montana Ground Water Pollution Control System ground water discharge permit. To qualify for exclusion from the need for a MPDES or ground water permit, SMEs and open cut facilities are required to not pollute or contaminate any waterbody. There are no SMEs or open cut facilities with identified MPDES or ground water discharge permits (point sources) within the Madison watersheds with metal TMDLs.

Due to the lack of point sources discharges, no WLAs will be provided for these types of mines. Instead, active mines are provided with a composite LA that would include all active mining activities (those holding DEQ Operating Permits, SME's or Open Cut Permits). This composite LA is set equal to zero as there should be no loading to surface waters if conditions of their current DEQ Hard Rock Bureau Operating Permit, SMEs or Open Cut are being met. If, at a later date it is determined that a point source discharge permit (MPDES surface or groundwater discharge) is required for any of these mines, then the TMDL may be modified to incorporate a WLA for the mine in question. This would be a case-by-case determination depending on the nature of the permit limits and requirements.

7.7.1.3 Abandoned Mines and Other Human Caused Sources (Comp WLA_{AB+HS})

Pursuant to EPA guidance, metals sources associated with many historic mining activities (tailings, and waste rock piles, etc.) are addressed as point sources with wasteload allocations (WLAs). These sources are addressed as point sources because of the potential for an abandoned mine or similar site to be subject to future permit requirements if the site were to become an active mine with point source discharges once again. In the case of the metals impaired watersheds in the Madison TPA, there is not enough data from individual mining sources to allocate a percentage of the TMDL to an individual site relative to other abandoned mine sources.

As noted in **Section 7.6**, there are also a number of human activities that take place in these watersheds that may be mobilizing metals via increased erosion. These potential human-caused sources are diffuse low impact sources (roads, activities associated with agriculture, other sediment/metals producing sources). In most cases the connection between these land disturbances and their potential contributions of metals pollution is not clear. That being said these sources cannot be completely discounted as potential metals loading pathways or sources.

Although many or all the metals sources could fall under the definition of a nonpoint source and thus be addressed via one or more load allocations (LAs), a composite wasteload allocation (Comp WLA) will be applied. This approach was taken because the available data is not capable of identifying loading from individual sources. Therefore, the contribution from all historical mining activities (e.g. abandoned mines, waste rock, tailings, etc.) and all other human caused metals sources (agriculture, roads etc.) in a contributing area or entire watershed is grouped into a composite WLA for abandoned mines and human sources. This approach is based on the assumption that reductions in metals loading can be achieved through the remediation of the abandoned mines and the use of best management practices (BMPs) to control the other pollutant loads. The composite WLA_{AB+HS} is determined by calculating the difference between the TMDL and the natural background load allocation in the absence of active mine or other allocations.

7.7.2 Allocations by Waterbody Segment

In the sections that follow, a loading summary and source load allocations are provided for each waterbody-pollutant combination for which a TMDL is prepared. Loading summaries are based on the sample data used for metals target evaluations. For each waterbody-pollutant combination, water quality and flow volume data are used to calculate metals loading estimates and the required percent load reduction to achieve the TMDL. Load estimations and allocations are based on a limited data set and are assumed to approximate general metals loading during high and low flow conditions. Where possible, TMDLs were based on high and low example flow data from the same sampling site. For any sample data with a value less than the detection limit, one-half the detection limit was used to calculate the observed load.

7.7.2.1 Elk Creek MT41F002_020

TMDLs for Elk Creek address impairments that are a result of iron and selenium water quality standard exceedances. As noted in **Section 7.6**, there are no readily identifiable human caused metals sources or active mines. Therefore, metals allocations for Elk Creek consist of a composite WLA to abandoned mines and other human sources and an LA to natural background metals sources. A MOS is implicit in this allocation scheme, based on the conservative assumptions described in **Section 7.8,** and therefore equal to zero in the TMDL equation. Metals TMDLs for Elk Creek are described by the following equation:

$TMDL_{Elk\ Creek} = LA_{NB} + Comp\ WLA_{AB + HS}$

LA_{NB} = Load allocation to natural background sources
Comp $WLA_{AB +HS}$ = Wasteload allocation to abandoned mining point sources and all other human sources

The Elk Creek TMDL and allocations can be determined for all flow conditions as follows:

Step 1: Use **Equation 7-1** to determine the TMDL for any give flow.
Step 2: Calculate the natural background load allocation (LA_{NB}) using **Equation 7-3**.
Step 3: Subtract the LA_{NB} from the TMDL to provide the Comp $WLA_{AB +HS}$

Iron and selenium TMDLs and allocations for Elk Creek are presented for an example low flow (selenium), and example high and low flows for iron. These flow regimes represent the conditions during which water quality targets exceedances occurred (**Table 7-9**). Load reductions are needed for both iron and selenium during low flow and for iron during high flow conditions in order to meet water quality targets. The allocation scheme in **Table 7-13** assumes that natural loading rates do not cause water quality standards to be exceeded.

Table 7-13. Elk Creek Metals TMDLs and Allocations for Example Flow Conditions

Parameter	Flow*	Existing load (lb/day)	TMDL (lbs/day)	LA_{NB} (lbs/day)	Comp WLA_{AB+HS} (lbs/day)	Percent Reduction Needed
Iron	High	33.04	16.04	7.38	8.66	51%
	Low	0.11	0.054	0.025	0.029	51%
Selenium	Low	0.00043	0.00027	0.000027	0.00024	38%

* High flow value is equal to 2.97 cfs, low flow value is equal to 0.01 cfs for all calculations

Existing high flow load for iron is calculated using maximum measured flow (2.97 cfs) and maximum concentrations (2,060 µg/L). The existing load for low flow selenium and iron is calculated using the minimum measured low flow of 0.01 cfs and the maximum concentration (8.1 µg/L and 2,060 µg/L respectively). Following this method provides for a conservative estimate of a hypothetical high and low flow loads for Elk Creek.

The TMDLs for the high flow example for iron calculated by multiplying the maximum measured flow (2.97 cfs) by the water quality standard and a conversion factor (0.0054). The TMDL for the low flow example for iron and selenium follows the same foundation, yet it uses a minimum measured flow value (0.01 cfs). The water quality standards for iron and selenium are not hardness based, therefore the standards of 1,000 µg/L and 5.0 µg/L, respectively, were used in both high and low flow TMDL calculations.

The low flow natural background loads for both iron and selenium are calculated using the minimum flow (0.01 cfs) and the natural background values identified in **Table 7-12.** High flow natural background load for iron is calculated with the natural background values identified in **Table 7-12** and the maximum flow value (2.97 cfs). The composite WLA to abandoned mines and human sources is calculated as the difference between the TMDL and the LA to natural background. The percent reduction is then calculated from the TMDL and the existing load.

7.7.2.2 Hot Springs Creek MT41F002_030

TMDLs for Hot Springs Creek address impairments that are a result of iron and lead exceedances of the water quality standards. As discussed in **Section 7.6**, metals loading may be occurring from a combination of sources, particularly active mining activity in the Bradley Creek watershed and other human sources. Metals allocations for Hot Springs Creek consist of composite WLA to abandoned mines and human sources, a composite LA to active mines and a LA to natural background metals sources. A MOS is implicit in this allocation scheme, based on the conservative assumptions described in **Section 7.8**. Metals TMDLs for Hot Springs Creek are described by the following equation:

$\mathbf{TMDL_{Hot\ Springs} = LA_{NB} + Comp\ WLA_{AB+HS} + Comp\ LA_{ACTIVE}}$

LA_{NB} = Load allocation to natural background sources

Comp WLA_{AB+HS} = Wasteload allocation to abandoned mining point sources and all other human sources

Comp LA_{ACTIVE} = Composite Load allocation to active mining sources

The Hot Springs Creek TMDL and allocations can be determined for all flow conditions as follows:

Step 1: In the case of lead, calculate target value based on hardness and the appropriate equation in DEQ-7 (Montana Department of Environmental Quality, 2017). In the case of iron, use the CAL target value.

Step 2: Use **Equation 7-1** to determine the TMDL for a given flow

Step 3: Calculate the natural background load allocation (LA_{NB}) using **Equation 7-3**.

Step 4: Set the load from Comp LA_{ACTIVE} to zero (see below)

Step 5: Calculate the natural background load allocation (LA_{NB}) using **Equation 7-2**

Step 6: Subtract the LA_{NB} and the Comp LA_{ACTIVE} from the TMDL to provide the COMP WLA_{AB+HS}

Metals TMDLs and allocations for Hot Springs Creek are presented for example high and low flow conditions for iron and high flow for lead. These flow regimes represent the conditions during which water quality target exceedances occurred (**Table 7-10**). Load reductions are needed for both iron and lead during high flow conditions in order to meet water quality targets. A load reduction is needed for iron for low flow conditions. The allocation scheme in **Table 7-14** assumes that natural loading rates do not cause water quality standards to be exceeded.

Table 7-14. Hot Springs Creek Metals TMDLs and Allocations for Example Flow Conditions

Parameter	Flow*	Existing load (lb/day)	TMDL (lbs/day)	LA_{NB} (lbs/day)	Comp WLA_{AB+HS} (lbs/day)	Comp LA_{ACTIVE}	Percent Reduction Needed
Iron	High	100	50	23	27	0.0	50%
	Low	2.9	1.5	0.7	0.8	0.0	50%
Lead	High	0.31	0.24	0.013	0.23	0.0	20%

* High flow value is equal to 9.28 cfs, low flow value is equal to 0.27 cfs for all calculations

Existing loads for high flow iron and lead are calculated using maximum flow (9.28 cfs) and maximum concentrations for iron and lead (2,000 µg/L and 6.2 µg/L, respectively). The existing load for low flow iron is calculated using the minimum low flow of 0.27 cfs and the maximum concentration of of 2,000 µg/L. Following this method provides for a conservative estimate of a hypothetical high and low flow loads for Hot Springs Creek.

The high flow TMDL for iron is calculated by multiplying the maximum flow (9.28 cfs) by the applicable water quality standard and a conversion factor (0.0054). The TMDL for the low flow example for iron follows the same foundation, yet it uses a minimum measured flow value (0.27 cfs). The water quality standard for iron is not hardness based, therefore a value of 1,000 µg/L was used in both the high and low flow TMDL calculations. The lead water quality standard is based on the hardness values reported when high flow lead was collected, and are therefore variable. The water quality standard at high flow for lead (hardness 141 mg/L) is 4.9 µg/L. The high flow lead TMDL was calculated using the maximum flow of 9.28 cfs, the water quality standard of 4.9 µg/L and a conversion factor.

The high flow natural background loads for both iron and lead are calculated using the maximum flow (9.28 cfs) and the natural background values identified in **Table 7-12.** Low flow natural background load for iron is calculated with the natural background values identified in **Table 7-12** and the minimum flow value (0.27 cfs). The composite WLA to abandoned mines and human sources is calculated as the difference between the TMDL and the LA to natural background. The composite load allocation to active mining (Comp LA_{ACTIVE}) is set to zero. It is assumed that if the active mines follow the conditions of their permits (SME or Operating Permit) that no loading will occur from these facilities. The percent reduction is then calculated from the TMDL and the existing load.

7.7.2.3 South Meadow Creek MT41F004_070

The following TMDL for South Meadow Creek is a result of copper impairment. Metals allocations for South Meadow Creek consist of composite WLA to abandoned mines and human sources, and a LA to natural background metals sources. A MOS is implicit in this allocation scheme, based on the conservative assumptions described in **Section 7.8**. Metals TMDL for South Meadow Creek are described by the following equation:

$$\mathbf{TMDL_{South\ Meadow\ Creek} = LA_{NB} + Comp\ WLA_{AB+HS}}$$

LA_{NB} = Load allocation to natural background sources
Comp WLA_{AB+HS} = Wasteload allocation to abandoned mining point sources and all other human sources

The South Meadow TMDL and allocations can be determined for all flow conditions as follows:

Step 1: Use **Equation 7-1** to determine the TMDL for an example or measured flow.
Step 2: Calculate the natural background load allocation (LA_{NB}) using **Equation 7-3**.
Step 3: Subtract the LA_{NB} from the TMDL to provide the Comp WLA_{AB+HS}

Metals TMDLs and allocations for South Meadow Creek are presented for high and low flow for copper, as it is not clear which flow regime is most indicative of when exceedances occur (**Table 7-11**). Load reductions are needed for copper during high flow and low flow conditions to meet water quality targets. The allocation scheme in **Table 7-15** assumes that natural loading rates do not cause water quality standards to be exceeded.

Table 7-15. South Meadow Creek: Metals TMDLs and Allocations for Example Flow Conditions

Parameter	Flow	Existing Load (lb/day)	TMDL (lbs/day)	LA_{NB} (lbs/day)	Comp WLA_{AB+HS} (lbs/day)	Percent Reduction Needed
Copper	High	1.6	0.56	0.2	0.36	64%
	Low	0.00043	0.00031	0.00005	0.00026	28%

* High flow value is equal to 36.4 cfs, low flow value is equal to 0.01 cfs for all calculations

Existing loads for high flow copper are calculated using maximum measured flow (36.4 cfs) and the maximum concentration of 8.0 µg/L. The existing load for low flow copper is calculated using the minimum flow of 0.01 cfs and the maximum concentration of 8.0 µg/L. Following this method provides for a conservative estimate of hypothetical high and low flow loads for South Meadow Creek.

The TMDL for the high flow example for copper is calculated by multiplying the maximum measured flow (36.4 cfs) by the water quality standard and a conversion factor (0.0054). The TMDL for the low flow example for copper follows the same foundation, yet it uses a minimum measured flow value (0.01 cfs). The water quality standards are hardness based. The hardness values used to determine the standard used in TMDL calculations are those that were reported when high and low flow samples were collected in the field. High flow and low flow hardness values equate to water quality standards of 2.85 µg/L and 5.77 µg/L, respectively.

The high and low flow natural background loads for copper are calculated using the maximum flow (36.4 cfs) and the natural background values identified in **Table 7-12.** Low flow natural background load is calculated with the natural background values identified in **Table 7-12** and the minimum flow value (0.01 cfs). The composite WLA to abandoned mines and human sources is calculated as the difference between the TMDL and the LA to natural background. The percent reduction is then calculated from the TMDL and the existing load.

7.8 Seasonality and Margin of Safety

All TMDL documents must consider the seasonal variability (seasonality) on water quality impairment conditions, TMDLs and allocations. TMDL development must also incorporate a margin of safety (MOS) 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 the considerations of seasonality and an MOS in the Madison TPA metals TMDL development process.

7.8.1 Seasonality

Seasonality addresses the need to ensure year-round designated use support. Seasonality is considered for assessing loading conditions and for developing water quality targets, TMDLs, and allocation schemes. For metals TMDLs, seasonality is important because metals loading pathways and water hardness change from high to low flow conditions. During high flows, overland flow and erosion of metals-contaminated soils and mine wastes tend to be the major cause of elevated metals concentrations. During low flow, groundwater and/or adit discharges may be a more significant contributing source of elevated metals concentrations. Additional loading sources that are dependent on seasonality include contributions such as stormwater runoff and natural background. Seasonality is addressed in this document as follows:

- Metals concentrations and loading conditions are evaluated for both high flow and low flow conditions. DEQ's assessment method uses a combination of both high and low flow sampling for target evaluation since abandoned mines and other metals sources can lead to elevated metals loading during high and/or low flow conditions.
- Metals TMDLs incorporate streamflow as part of the TMDL equation.
- Metals concentration targets apply year round, with monitoring criteria for target attainment developed to address seasonal water quality extremes associated with loading and hardness variations.
- A sediment chemistry target is applied as a supplemental indicator to help capture impacts from episodic metals loading events that could be attributed to high flow seasonal runoff conditions.
- When applicable, targets, TMDLs and load reduction needs are developed for example high and low flow conditions. The TMDL equation incorporates all potential flow conditions that may occur during any season.

7.8.2 Margin of Safety

The MOS is to ensure that TMDLs and allocations are sufficient to sustain conditions that will support designated uses. All metals TMDLs incorporate an implicit MOS in several ways, using conservative assumptions throughout the TMDL development process, as summarized below:

- DEQ's assessment process includes a mix of high and low flow sampling since abandoned mines and other metals sources may contribute to elevated metals loading during high and/or low flow stream conditions. The seasonality considerations help identify the low range of hardness values and thus the lower range of applicable TMDL values shown within the TMDL graphs (**Figures 7-2 through 7-5**) and captured within the example TMDLs.
- Target attainment, refinement of allocations, and, in some cases, impairment validations and TMDL-development decisions are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.
- Although a 10% exceedance rate is allowed for chronic and acute based aquatic life targets, the TMDLs are set so the lowest applicable target is satisfied 100% of the time. This focuses remediation and restoration efforts toward 100% compliance with all targets, thereby providing an MOS for the majority of conditions where the most protective (lowest) target value typically linked to the numeric aquatic life or human health standard. As part of this, the existing water quality conditions and needed load reductions are based on the highest measured value for a given flow conditions in order to consistently achieve the TMDL.
- The monitoring results used to estimate existing water quality conditions are instantaneous measurements used to estimate a daily load, whereas CAL standards are based on average

conditions over a 96-hour period. This provides an MOS since a four-day loading limit could potentially allow higher daily loads in practice.

- The lowest or most stringent numeric water quality standard was used for TMDL target and impairment determination for all waterbody – pollutant combinations. This ensures protection of all designated beneficial uses.
- Sediment metals concentration criteria were used as a supplemental indicator target. This helps ensure that episodic loading events were not missed as part of the sampling and assessment activity.
- The TMDLs are based on numeric water quality standards developed at the national level via EPA and incorporate an MOS necessary for the protection of human health and aquatic life.

7.9 Uncertainty and Adaptive Management

The environmental analysis conducted as part of TMDL development include inherent uncertainties: accuracy of field and laboratory data, for example. Data concerns are managed by DEQ's data quality objectives process. The use of data quality objectives ensures that the data is of known (and acceptable) quality. The data quality objectives process develops criteria for data performance and acceptance that clarify study intent, define the appropriate type of data, and establish minimum standards for the quality and quantity of data.

The accuracy of source assessments and loading analyses is another source of uncertainty. An adaptive management approach that revisits, confirms, or updates loading assumptions is vital to maintaining stakeholder confidence and participation in water quality improvement. Adaptive management uses updated monitoring results to refine loading analysis, to further customize monitoring strategies and to develop a better understanding of impairment conditions and the processes that affect impairment. Adaptive management recognizes the dynamic nature of pollutant loading and water quality response to remediation.

Adaptive management also allows for continual feedback on the progress of restoration and the status of beneficial uses. Additional monitoring and resulting refinements to loading will also provide a measure of success. A remediation and monitoring framework is closely linked to the adaptive management process, and is addressed in **Section 9.0.**

The metals TMDLs developed for the Madison River TMDL Planning Area are based on future attainment of water quality standards. In order to achieve this, all significant sources of metals loading must be addressed via all reasonable land, soil, and water conservation practices. DEQ recognizes however, that in spite of all reasonable efforts, this may not be possible due to natural background conditions and/or the potential presence of unalterable human-caused sources that cannot be fully addressed via reasonable remediation approaches. For this reason, an adaptive management approach is adopted for all metals targets described within this document. Under this adaptive management approach, all metals impairments that required TMDLs will ultimately fall into one of the categories identified below:

- Restoration achieves the metal pollutant targets and all beneficial uses are supported.
- Targets are not attained because of insufficient controls; therefore, impairment remains, and additional source remedies are needed.
- Targets are not attained after all reasonable BMPs and applicable abandoned mine remediation activities are applied. Under these circumstances, site-specific standards may be necessary.
- Targets are unattainable due to naturally occurring metals sources. Under this scenario, site-specific water quality standards and/or the reclassification of the waterbody may be necessary.

This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target would reflect the background condition.

The Abandoned Mines Section of DEQ's Remediation Division will lead abandoned mine restoration projects funded by provisions of the Surface Mine Reclamation and Control Act of 1977.

Monitoring and restoration conducted by other parties (e.g., USFS, the Montana Department of Natural Resources & Conservation's (DNRC) Trust Lands Management Division, Montana Bureau of Mines and Geology) should be incorporated into the target attainment and review process as well. Cooperation among agency land managers in the adaptive management process for metals TMDLs will help identify further cleanup and load reduction needs, evaluate monitoring results, and identify water quality trends.

8.0 Water Quality Improvement Plan

8.1 Purpose of Improvement Strategy

This section describes an overall strategy and specific on-the-ground measures designed to restore water quality beneficial uses and attain water quality standards in Madison TPA streams. The strategy includes general measures for reducing loading from each identified significant pollutant source.

This section should assist stakeholders in developing a watershed restoration plan (WRP) that will provide more detailed information about restoration goals within the watershed. The WRP may also encompass broader goals than the water quality improvement strategy outlined in this document. The intent of the WRP is to serve as a locally organized “road map” for watershed activities, prioritizing types of projects, sequences of projects, and funding sources towards achieving local watershed goals. Within the WRP, local stakeholders 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.

8.2 Role of DEQ, Other Agencies, and Stakeholders

The Montana Department of Environmental Quality (DEQ) does not implement TMDL pollutant-reduction projects for nonpoint source activities, but may provide technical and financial assistance for stakeholders interested in improving their water quality. Successful implementation of TMDL pollutant-reduction projects requires collaboration among private landowners, land management agencies, and other stakeholders. 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 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 goals and to meet TMDL targets and load reductions. Specific stakeholders and agencies that will likely be vital to restoration efforts for streams discussed in this document include:

- Madison Conservation District
- Gallatin County Conservation District
- U.S. Forest Service (USFS)
- Natural Resources and Conservation Service (NRCS)
- U.S. Fish & Wildlife Service (USFWS)
- U.S. Environmental Protection Agency (EPA)
- Montana Department of Natural Resources and Conservation (DNRC)
- Montana Fish, Wildlife & Parks (FWP)
- Montana Department of Environmental Quality (DEQ)

Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include:

- Montana Trout Unlimited
- U.S. Army Corp of Engineers

- Montana Department of Transportation
- Montana Bureau of Mines and Geology
- Montana State University Extension Water Quality Program
- University of Montana Watershed Health Clinic
- Montana Aquatic Resources Services

8.3 Water Quality Restoration Objectives

The water quality restoration objectives for the Madison TPA are to reduce pollutant loads as identified throughout this document to meet the water quality standards and TMDL targets for full recovery of beneficial uses for all impaired streams. Meeting the TMDLs provided in this document will achieve this objective for all identified pollutant-impaired streams. Based on the assessment provided in this document, the TMDLs can be achieved through proper implementation of appropriate BMPs.

A watershed restoration plan (WRP) can provide a framework strategy for water quality restoration and monitoring in the Madison TMDL Planning Area, 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. WRPs 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 EPA requires nine minimum elements for a WRP, summarized here:

1. Identification of the causes and sources of pollutants
2. Estimated load reductions expected based on implemented management measures
3. Description of needed nonpoint source management measures
4. Estimate of the amounts of technical and financial assistance needed
5. An information/education component
6. Schedule for implementing the nonpoint source management measures
7. Description of interim, measurable milestones
8. Set of criteria that can be used to determine whether loading reductions are being achieved over time
9. A monitoring component to evaluate effectiveness of the implementation efforts over time

This document provides, or can serve as an outline, for many of the required elements. Water quality goals for nutrients, *E. coli*, and metals pollutants are detailed in **Sections 5.4, 6.4, and 7.4**, respectively. These goals include water quality targets as measures for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of waterbodies in the Madison TPA. It is presumed that meeting all water quality and habitat targets will achieve the water quality goals for each impaired waterbody. **Section 9.0** identifies a general monitoring strategy and recommendations to track post-implementation water quality conditions and measure restoration successes.

8.4 Overview of Management Recommendations

TMDLs were completed for five waterbody segments for nutrients, one waterbody segment for *E. coli*, and three waterbody segments for metals. Other streams in the planning area may be in need of restoration or pollutant reduction, but were not covered in this TMDL document or there is insufficient information about them that precludes TMDL development (see **Table 1-2** and **Sections 1.3** and **1.4**). The following sub-sections describe some generalized recommendations for implementing projects to achieve the TMDLs. Details specific to each stream, and therefore which of the following strategies may be most appropriate, are found within **Sections 5.0, 6.0 and 7.0**.

In general, restoration activities can be separated into two categories: active and passive. Passive restoration allows natural succession to occur within an ecosystem by removing a source of disturbance. Fencing off riparian areas from cattle grazing is a good example of passive restoration. Active restoration, on the other hand involves accelerating natural processes or changing the trajectory of succession. For example, historic placer mining often resulted in the straightening of stream channels and piling of processed rock on the streambank. These impacts would take so long to recover passively that active restoration methods involving removal of waste rock and rerouting of the stream channel would likely be necessary to improve stream and water quality conditions. In general, passive restoration is preferable because it is generally more cost effective, less labor intensive, and will not result in short term increase of pollutant loads as active restoration activities may. However, in some cases active restoration is the only feasible mechanism for achieving desired goals; these activities must be assessed on a case by case basis.

8.4.1 Nutrients Restoration Approach

The goal of the nutrient restoration strategy is to reduce nutrient input to streams 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 etc. Some restoration approaches that reduce nutrient loading from the most prevalent sources are discussed below.

Cropland filter strip extension, vegetative restoration, and long-term filter area maintenance are vital BMPs for agricultural areas. 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, frequency, and duration of near-stream grazing
- The spacing and exposure duration of on-stream watering locations
- Provision of off-stream 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
- Incorporation of streamside vegetation buffer to irrigated croplands and animal feeding areas

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 a comprehensive plan for farm and ranch operators. Sound planning combined with effective conservation BMPs should be sought whenever possible. 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.

8.4.2 E. coli Restoration Approach

Cattle grazing in riparian areas is identified as the most likely cause of elevated *E. coli* loading to Moore Creek. Manure management, septic systems and other residential sources are also identified as potential sources of *E. coli* loading. General recommendations for grazing management and septic systems and other sources of human caused *E. coli* loading to Moore Creek are outlined below. A WRP developed by local stakeholders would contain more detailed information on restoration priorities, milestones and specific BMP recommendations to address key pollutant sources. Monitoring is an important part of the restoration process and for evaluating BMP effectiveness. Specific monitoring recommendations are outlined in **Section 9.3**.

In watersheds that contain livestock, the goal of the *E. coli* restoration strategy is to reduce source input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, limiting the transport of *E. coli* (from manure on rangeland and cropland) to waterbodies. Specific BMPs include grazing management to improve riparian health by reducing livestock direct access to waterbodies and cropland filter strips. Grazing management that intends to increase vegetative post-grazing ground cover should be considered when the goal is to decrease *E. coli* loading from rangelands and cropland.

For areas where there are septic systems and other residential sources, efforts to monitor and maintain them are necessary to minimize the loading to surface waters. In addition, BMPs that include education and outreach to inform the public to the proper way to maintain their septic systems and routine maintenance by municipalities to repair broken or aging sewer lines could reduce the total loading of *E. coli* and other pathogens to the nearby waterbodies.

8.4.3 Metals Restoration Approach

Metal mining is the principal human-caused source of excess metals loading in the planning area. To date, federal and state government agencies have funded and completed reclamation projects associated with past mining. Statutory mechanisms and corresponding government agency programs will continue to have the leading role for future restoration. Restoration of metals sources is typically conducted under state and federal cleanup programs. Past efforts have produced abandoned mine site inventories with enough descriptive detail to prioritize the properties contributing the largest metals loads. Additional monitoring needed to further describe impairment conditions and loading sources is addressed in **Section 9.3**.

8.4.4 Non-Pollutant Restoration Approach

Although TMDL development is not required for non-pollutant listings, they are frequently linked to pollutants, and addressing non-pollutant causes, such as flow and habitat alterations, is an important component of TMDL implementation. Non-pollutant listings within the Madison TPA are described in **Section 1.3**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Therefore, if restoration goals within the Madison TPA are not also addressing non-pollutant impairments, additional non-pollutant related BMP implementation should be considered.

8.5 Restoration Approaches by Source

General management recommendations are outlined below for the major sources of human caused pollutant loads in the Madison TPA: agricultural sources, residential development, riparian and wetland vegetation removal, manure management, unmaintained septic systems and mining. Applying BMPs is the core of the nonpoint source pollutant reduction strategy, but BMPs are only part of a watershed restoration strategy. For each major source, BMPs will be most effective as part of a comprehensive management strategy. A WRP developed by local watershed groups should contain more detailed information on restoration goals and specific management recommendations that may be required to address key pollutant sources. Monitoring is an important part of the restoration process, and monitoring recommendations are outlined in **Section 9.3**.

8.5.1 Agriculture Sources

Reduction of pollutants from upland agricultural sources can be accomplished 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 Madison TPA 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. 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 Nonpoint Source Management Plan (Montana Department of Environmental Quality, Water Protection Bureau, 2017).

Conservation plans should include the following information (NRCS Conservation Practice Standard 590 and 590-1, Nutrient Management) (United States Department of Agriculture, Natural Resources Conservation Service, 2013):

- 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 environmentally sensitive areas, including streams, wetlands, springs, or other locations that deliver surface runoff to groundwater or surface water
- Guidelines for operation and maintenance

8.5.1.1 Grazing

Grazing has the potential to increase nutrient loads by direct and indirect (fertilization, runoff from pastures etc.) contributions of manure, altering riparian vegetation, but these effects can be mitigated with appropriate management. Development of riparian grazing management plans should be a goal for any landowner 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 necessarily eliminate all grazing in riparian corridors. In some areas however, a more limited management strategy may be necessary for a period of time in order to accelerate reestablishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The NRCS Prescribed Grazing Conservation Practice Standard (Code 528) recommends the plan include the following elements (Natural Resource Conservation Service, 2010):

- 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 in areas that prevent 'loafing' in riparian areas and help distribute animals
- 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 that takes season, frequency, and duration into consideration

The following resources provide guidance to help prevent pollution and maximize productivity from grazing operations:

- USDA, Natural Resources Conservation Service Offices (find your local USDA Agricultural Service Center listed in your phone directory or on the Internet at http://www.nrcs.usda.gov)
- Montana State University Extension Service (https://www.msuextension.org/)
- DEQ Watershed Protection Section: Nonpoint Source Management Plan (http://deq.mt.gov/Water)

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 Madison TPA 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 revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation.

8.5.1.2 Cropland

The primary strategy of the recommended cropland BMPs is to reduce nutrient inputs. The major factors involved in decreasing nutrient loads are reducing the rate of runoff, and intercepting runoff before it enters waterbodies. The main BMP recommendations for the Madison TPA are vegetated filter strips and riparian buffers. Both of these methods reduce the rate of runoff and promote infiltration of the soil (instead of delivering runoff directly to the stream). Effectiveness is typically about 70% for the filter strips and 50% for the buffers (Montana Department of Environmental Quality, Water Protection Bureau, 2017). 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 Nonpoint Source Management Plan (Montana Department of Environmental Quality, Water Protection Bureau, 2017).

8.5.1.3 Riparian Areas, Wetlands, and Floodplains

Healthy and functioning 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. Human activities affecting the quality of these transitional habitats or their connectivity can alter their performance and greatly affect the transport of water, and pollutants (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 Madison 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:

- Harvesting and transplanting locally available sod mats with an existing dense root mass provides immediate promotion of bank stability and filtering nutrients and sediments
- 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
- 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

In addition to the benefits described above, it should be noted that in some cases, wetlands act as areas of shallow subsurface groundwater recharge and/or storage areas. 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.

8.5.2 Septic

There are approximately 192 identified septic systems in the Moore Creek watershed. This number is likely to increase with future residential development in the Moore Creek watershed and other watersheds within the Madison TPA. While no information is available regarding failing septic systems in the Moore Creek watershed, the number of failing septic systems is likely very low and is not expected to be a significant contributor of *E. coli* to Moore Creek. Septic systems should already have minimum design/installation requirements, which should serve as a basic BMP. Older systems should be upgraded, and all new systems should meet these minimum requirements.

8.5.3 Mining

The Madison TPA and Montana more broadly, have a legacy of mining which continues today. Mining activities may have impacts that extend beyond increased metal concentrations in the water. Channel alteration, riparian degradation, and runoff and erosion associated with mining can lead to nutrient, habitat, sediment, and temperature impacts as well. The need for further characterization of impairment conditions and loading sources is addressed through the monitoring plan in **Section 9.3**.

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 Madison TMDL Planning Area include:

- The State of Montana Mine Waste Cleanup Bureau’s Abandoned Mine Lands 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).
- The federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

8.5.3.1 The Surface Mining Control and Reclamation Act (SMCRA)

DEQ’s Abandoned Mines Bureau is responsible for reclamation of abandoned mines in Montana. The Abandoned Mines Bureau reclamation program is funded through the Surface Mining Control and Reclamation Act of 1977 (SMCRA). SMCRA funding is collected as a per ton fee on coal production that is then distributed to states by the federal Office of Surface Mining Reclamation and Enforcement. Funding eligibility is based on land ownership and date of mining disturbance. Eligible abandoned coal mine sites have a priority for reclamation construction funding over eligible non-coal sites. Areas within federal Superfund sites and areas where there is a reclamation obligation under state or federal laws are not eligible for expenditures from the abandoned mine reclamation program. **Table 8-1** lists the priority abandoned mines in the Madison TMDL Planning Area.

Table 8-1. Priority Abandoned Mine Sites in the Madison TMDL Planning Area

Site Name	Receiving Stream	Original AIMSS Ranking Score*
Boaz Mine	Hot Springs Creek	76.47
Grubstake Mine	Hot Springs Creek	0.24
Missouri	South Meadow Creek	83
SE SE Section 25 Mine	South Meadow Creek	278

* AIMSS = Abandoned and Inactive Mines Scoring System

8.6 Potential Funding and Technical Assistance Sources

Prioritization and funding of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies and also a few non-governmental organizations fund or can provide assistance with watershed or water quality improvement projects or wetlands restoration projects. Below is a brief summary of potential funding sources and organizations to assist with TMDL implementation.

8.6.1 Section 319 Nonpoint Source Grant Program

DEQ issues a call for proposals every year to award federal Section 319 grant funds administered under the federal Clean Water Act. The primary goal of the 319 program is to restore water quality in waterbodies whose beneficial uses are impaired by nonpoint source pollution and whose water quality does not meet state standards. 319 funds are distributed competitively to support the most effective and highest priority projects. In order to receive funding, projects must directly implement a DEQ-accepted watershed restoration plan (WRP) and funds may either be used for the education and outreach component of the WRP or for implementing restoration projects. All funding has a 40% cost share requirement, and projects must be administered through a governmental entity such as a conservation district or county, or a nonprofit organization. For information about past grant awards and how to apply, please visit DEQ's Nonpoint Source Program website at: http://deq.mt.gov/Water.

8.6.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by Montana Fish, Wildlife & Parks (FWP) and offers funding for 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 Madison Planning Area include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats. For additional information about the program and how to apply, please visit http://fwp.mt.gov/fishAndWildlife/habitat/fish/futureFisheries/.

8.6.3 Watershed Planning and Assistance Grants

The 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. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/divisions/cardd/available-grants-and-loans.

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, Water Protection Bureau, 2017) and information regarding additional funding opportunities can be found at https://www.epa.gov/nps/watershed-funding.

8.6.4 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. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

8.6.5 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 DNRC that can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the DEQ Abandoned Mine Lands priority list, but of low enough priority where cleanup under DEQ Abandoned Mine Lands 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. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/divisions/cardd/resource-development/reclamation-and-development-grants-program.

8.6.6 Montana Partners for Fish and Wildlife

Montana Partners for Fish and Wildlife is a program under the U.S. Fish & Wildlife Service that assists private landowners to restore wetlands and riparian habitat by offering technical and financial assistance. For additional information about the program and to find your local contact for the Madison watershed, please visit: http://www.fws.gov/mountain-prairie/pfw/montana/.

8.6.7 Wetlands Reserve Program

The Wetlands Reserve Program is a voluntary conservation program administered by the NRCS that offers landowners the means to restore, enhance, and protect wetlands on their property through permanent easements, 30-year easements, or Land Treatment Contracts. The NRCS seeks sites on agricultural land where former wetlands have been drained, altered, or manipulated by man. The landowner must be interested in restoring the wetland and subsequently protecting the restored site. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/mt/programs/easements/wetlands/

8.6.8 Montana Wetland Council

The Montana Wetland Council is an active network of diverse interests that works cooperatively to conserve and restore Montana's wetland and riparian ecosystems. Please visit their website to find dates and locations of upcoming meetings, wetland program contacts, and additional information on potential grants and funding opportunities: wetlands.mt.gov.

8.6.9 Montana Natural Heritage Program

The Montana Natural Heritage Program is a valuable resource for restoration and implementation information including maps. Wetlands and riparian areas are one of the 14 themes in the Montana Spatial Data Infrastructure. The Montana Wetland and Riparian Mapping Center (found at: http://mtnhp.org/nwi/) is creating a statewide digital wetland and riparian layer as a resource for management, planning, and restoration efforts.

8.6.10 Montana Aquatic Resources Services, Inc.

Montana Aquatic Resources Services, Inc. (MARS) is a nonprofit organization focused on restoring and protecting Montana's rivers, streams and wetlands. MARS identifies and implements stream, lake, and wetland restoration projects, collaborating with private landowners, local watershed groups and conservation districts, state and federal agencies, and tribes. For additional information about the program, please visit http://montanaaquaticresources.org/.

9.0 Monitoring for Effectiveness

9.1 Monitoring Purpose

The monitoring strategies discussed in this section are an important component of watershed restoration, and a requirement of TMDL implementation under the Montana Water Quality Act (75-5-703(7), MCA), 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. The scale of the watershed analysis, coupled with constraints on time and resources, often result in necessary compromises that include estimations, extrapolation, and a level of uncertainty in TMDLs. The margin of safety (MOS) (**Section 4.0**) 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, the amount of reduction of instream pollutants (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 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 the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, DEQ will conduct a formal evaluation of the waterbody's impairment status and whether TMDL targets and water quality standards are being met.

9.2 Adaptive Management and Uncertainty

In accordance with the Montana Water Quality Act (75-5-703 (7) and (9), MCA), DEQ is required to assess the waters for which TMDLs have been completed and restoration measures, or best management practices (BMPs), have been applied to determine whether compliance with water quality standards has been attained. This aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process.

Adaptive management as discussed throughout this document is a systematic approach for improving resource management by learning from management outcomes, and allows for flexible decision making. There is an inherent amount of uncertainty involved in the TMDL process, including: establishing water quality targets, calculating existing pollutant loads and necessary load allocations, and determining effects of BMP implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments as well as achieve success in meeting the water quality standards and supporting all water quality beneficial uses. This approach further allows for adjustments to restoration goals, TMDLs, and/or allocations, as necessary.

For an in-depth look at the adaptive management approach, view the U.S. Department of the Interior's Technical Guide and description of the process at:

https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf. The U.S. Department of the Interior includes **Figure 9-1** below in their technical guide as a visual explanation of the cyclic process of adaptive management (Williams, B. K., et. al 2009).

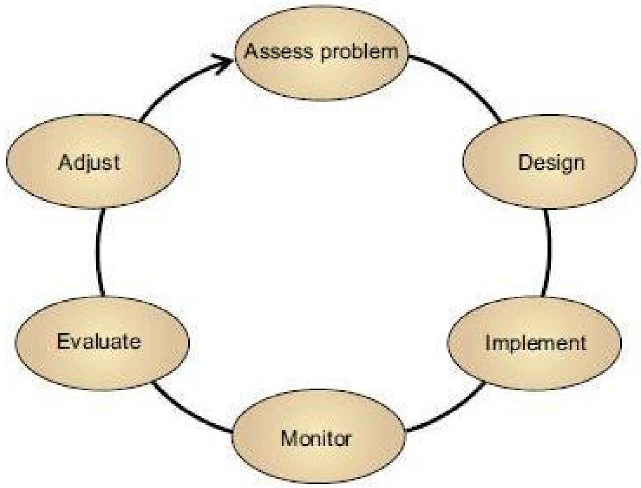

Figure 9-1. Diagram of the adaptive management process

9.3 Future Monitoring Guidance

The objectives for future monitoring in the Madison TPA include:

- Strengthen the spatial understanding of sources for future restoration work, which will also improve source assessment analysis for future TMDL review
- Gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development
- Gather consistent information among agencies and watershed groups that is comparable to the established water quality targets and allows for common threads in discussion and analysis
- Expand the understanding of streams throughout the Madison TPA beyond those where TMDL have been developed and address issues
- Track restoration projects as they are implemented and assess their effectiveness

9.3.1 Strengthening Source Assessment

In the Madison TPA, the identification of pollutant sources was conducted largely through tours of the watershed, assessments of aerial photographs, the incorporation of geographic information system information and reviewing and analyzing available data. Limited field-verification of the available data was able to be conducted. In many cases, assumptions were made based on known watershed conditions and extrapolated throughout the planning area. As a result, the level of detail often does not provide specific areas on which to focus restoration efforts, only broad source categories to reduce pollutant loads from each of the discussed streams and subwatersheds. Strategies for strengthening source assessments for each of the pollutant categories are outlined below.

Nutrients

- A better understanding of cattle grazing practices and the number of animals grazed in the Madison TPA

- A better understanding of natural background concentrations in the Madison TPA. This may include a more focused natural background assessment specific to Blaine Spring Creek and O'Dell Spring Creek.
- A more detailed understanding of nutrient contributions from historical and current mining within the watershed, particularly in those areas with abandoned mines
- A better understanding of septic system contributions to nutrient loads
- A review of land management practices specific to subwatersheds of concern to determine where the greatest potential for improvement can occur for the major land use categories
- Additional sampling in streams that have limited data

E. coli

- *E. coli* sampling should have adequate spatial distribution to capture potential loading from all sources.
- *E. coli* sampling during both high and low flow conditions.
- Thorough analysis of the number of septic systems in the watershed, their proximity to surface water and their state of repair.
- A better understanding of waste management relative to campgrounds and other recreational activities.
- A more detailed understanding of grazing and manure management practices within the watershed.

Metals

- Refinement of the sampling approach and locations to better partition pollutant loading from discrete sources within tributaries. This may require more seasonally stratified sampling or a more detailed field reconnaissance and follow-up sampling
- DEQ recommends additional monitoring of all metals parameters in all tributaries of the Madison River watershed. Additional monitoring of metals water quality data will yield a better understanding of metals source locations in the watershed.
- The inability to distinguish background metals loading from human-caused loading led to use of a broad composite allocation. Further sampling would allow better delineation of background and other human sources.
- A more detailed characterization of historical mining activities and human caused land disturbances directed at defining these sources as area of potential metals loading.

9.3.2 Increasing Available Data

While the Madison TPA has undergone remediation and restoration activities, data are 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.

Nutrients

Water quality sampling locations for nutrients were distributed spatially along each stream in order to best delineate nutrient sources and sampled over multiple sample seasons. That being said, there were limited opportunities to adjust sampling locations in attempts to gain a better understanding of loading sources to the impaired waterbodies. To better evaluate nutrient loading, source refinement will continue to be necessary on all streams with nutrient TMDLs and those that have not yet been assessed in the planning area. With changing land uses and/or new permitted discharges to surface waters, it will be important to continually assess nutrient sources in a watershed.

E.coli

Additional monitoring of *E. coli* should include all tributaries to the Madison River, spanning multiple field seasons and focus on those tributaries where there are significant impacts from grazing in riparian areas and/or significant impacts from septic systems. Additional monitoring will yield a better understanding of the localized *E. coli* sources located throughout the watershed and a better understanding of those known sources.

Metals

Additional monitoring may be helpful to better partition pollutant loading at sites with multiple sources, such as those having diffuse runoff from areas that experienced large scale mining and other various land disturbances. The needed refinements may require more seasonally stratified sampling or a more detailed field reconnaissance and follow-up sampling to better locate stream segments representing natural background conditions.

9.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Madison TPA for several years and by many different agencies and entities; however, the type and quality of information is often variable. Wherever 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.

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. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking. Future monitoring efforts should consult DEQ on updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect water quality 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 the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Montana Comprehensive Environmental Cleanup and Responsibility Act (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.

Nutrients, *E. coli*, and Metals

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 so that water quality data may be compared to TMDL targets. Contact DEQ prior to conducting water quality monitoring and lab analysis, to obtain the most recent monitoring parameter requirements. Metals monitoring should include analysis of a suite of total recoverable metals (e.g., Arsenic, Copper, Cadmium, Lead, Zinc), dissolved metals (Aluminum), metals sediment samples, hardness, pH, discharge, and total suspended solids (TSS). Additionally, stream discharge should be measured at time of sampling for nutrients, *E. coli*, and/or metals parameters.

9.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, monitoring is valuable to determine if restoration activities are improving water quality. Monitoring can help attribute water quality improvements to restoration activities and ensure that restoration activities are functioning effectively. Restoration projects will often require additional maintenance after initial implementation to ensure functionality. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process.

As restoration activities begin throughout the planning area, 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.

9.3.5 Watershed Wide Analyses

Recommendations for monitoring in the Madison TPA should not be confined to only those streams addressed within this document. The water quality targets presented in this document are applicable to all streams in the watershed, and the absence of a stream from the state's impaired waters list does not necessarily imply that the stream 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.

10.0 Public Participation and Public Comments

Stakeholder and public involvement is a component of total maximum daily load (TMDL) planning supported by U.S. Environmental Protection Agency (EPA) guidelines and required by Montana state law (Montana Code Annotated (MCA) 75-5-703 and 75-5-704) which directs the Department of Environmental Quality (DEQ) to consult with a watershed advisory group and local conservation districts during the TMDL development process. Technical advisors, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process for this project in the Madison TMDL Planning Area.

10.1 Participants and Roles

During completion of the nutrient, *E. coli*, and metals TMDLs in this document, DEQ worked to keep stakeholders apprised of project status and solicited input from a TMDL watershed advisory group. A description of the participants and their roles in the development of the TMDLs in this document is contained below.

Montana Department of Environmental Quality
Montana state law (75-5-703, MCA) directs DEQ to develop all necessary TMDLs. DEQ provided resources toward completion of these TMDLs in terms of staff, funding, internal planning, data collection, technical assessments, document development, and stakeholder communication and coordination. DEQ has worked with other state and federal agencies to gather data and conduct technical assessments.

United States Environmental Protection Agency
EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act (CWA). Section 303(d) of the CWA directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for reviewing and evaluating TMDLs to see that they meet all federal requirements.

Conservation Districts
DEQ consulted with the Madison and Gallatin County conservation districts during development of the TMDLs in this document, which included opportunities to provide comment during the various stages of TMDL development and an opportunity for participation in the watershed advisory group described below.

Madison TMDL Planning Area TMDL Watershed Advisory Group
The Madison TMDL Planning Area TMDL Watershed Advisory Group consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the Madison River watershed, and representatives of applicable interest groups. All members were solicited to participate and work with DEQ in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested participation from the interest groups defined in 75-5-704 MCA and included local city and county representatives; livestock-oriented and farming-oriented agriculture representatives; conservation groups; watershed groups; the hydroelectric industry; state and federal land management agencies; and representatives of fishing, recreation, and tourism interests. The advisory group also included additional

state and federal agency professionals with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary, and the level of involvement was at the discretion of the individual members. Members had the opportunity to attend meetings organized by DEQ for soliciting feedback on project planning. Communication with advisory group members was conducted through a series of group meetings and e-mails. Draft documents, project status updates, and meeting agendas and presentations were made available both via e-mail and through DEQ's website for water quality planning projects at: http://mtwaterqualityprojects.pbworks.com. Opportunities for review included a four-week review and comment period for a draft version of this TMDL document prior to the public comment period. Members' comments were incorporated into this version of the draft document. The draft TMDLs were also presented to and discussed with the group at a meeting in Ennis on August 22, 2018.

10.2 Response to Public Comments

Upon completion of a draft TMDL document, DEQ issues a press release and enters into a public comment period. During this timeframe, the draft TMDL document is made available for general public comment; DEQ then addresses and responds to all formal public comments. However, no public comments were received on this document.

The public comment period for this document was initiated on September 19, 2018 and closed on October 19, 2018. An electronic copy of the draft document was made available at the Madison Valley Public Library, and a public informational meeting was held at the library on September 26, 2018 at 5:30 p.m. At the meeting, DEQ provided an overview of the TMDL document, answered questions, and solicited input and comment on the document. The public comment period and public meeting were announced in a September 2018 press release from DEQ which was published on DEQ's website and was distributed to multiple media outlets across Montana. A public notice advertising the public comment period and public meeting was published in the Bozeman Daily Chronicle and the Madisonian newspapers. Additionally, the announcement was distributed to the project's TMDL watershed advisory group via e-mail.

11.0 References

Barbour, Michael T., Jeroen Gerritsen, Blaine D. Snyder, and James B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish: Second Edition. Washington, DC: United States Department of Environmental Protection, Office of Water. EPA 841-B-99-002.

Buchman MF. NOAA screening quick reference tables: NOAA HAZMAT Report 99–1. Seattle: Coastal Protection and Restoration Division; 1999

Drygas, Jonathan. 2012. The Montana Department of Environmental Quality Metals Assessment Method. Helena, MT: Montana Dept. of Environmental Quality.

Feller, M. C. and J. P. Kimmins. 1984. Effects of Clearcutting and Slash Burning on Streamwater Chemistry and Watershed Nutrient Budgets in Southwestern British Columbia. Water Resources Research. 20: 29-40.

Green, Douglas M. and J. B. Kauffman. 1989. "Nutrient Cycling at the Land-Water Interface: The Importance of the Riparian Zone," in Practical Approaches to Riparian Resource Management: An Education Workshop, Gresswell, Robert E., Barton, Bruce A., and Kershner, Jeffrey L., (Billings, MT: U.S. Bureau of Land Management): 61-68.

Hauer, F. R. and Craig N. Spencer. 1998. Phosphorous and Nitrogen Dynamics in Streams Associated with Wildfire: a Study of Intermediate and Longterm Effects. International Journal of Wildland Fire. 8(4): 183-198.

Jacobson, R. B. 2004. "Downstream Effects of Timber Harvest in the Ozarks of Missouri," in Toward Sustainability for Missouri Forests: 106-126.

Jepson, Wayne. 2015. Revenue Mine. Personal Communicaiton with Jordan Tollefson.

Kendy, Eloise and Tresch, R.E. 1996. Geographic, Geologic and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana. U.S. Geological Survey Water-Resources Investigations Reports 96-4025.

Likens, Gene E., F. H. Bormann, Robert S. Pierce, and W. A. Reiners. 1978. Recovery of a Deforested Ecosystem. Science. 199(4328): 492-496.

Martin, C. W. and R. D. Harr. 1989. Logging of Mature Douglas-Fir in Western Oregon Has Little Effect on Nutrient Output Budgets. Canadian Journal of Forest Research. 19(1): 35-43.

Montana Department of Environmental Quality. 2010. The West Fork Gallatin River Watershed Total Maximum Daily Loads (TMDLs) and Framework Watershed Water Quality Improvement Plan. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of Environmental Quality. 2014. Department Circular DEQ-12A, Montana Base Numeric Nutrient Standards. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of Environmental Quality. 2015. Memo to Environmental Protection Agency Region 8 Headquarters Regarding Arsenic.

Montana Department of Environmental Quality. 2016. Montana Final 2016 Water Quality Integrated Report. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of Environmental Quality, Abandoned Mine Reclamation Bureau. 1996. Abandoned Hardrock Mine Priority Sites 1995 Supplemental Summary Report. Butte, MT: Pioneer Technical Services, Inc.

Montana Department of Environmental Quality, Water Quality Planning Bureau. 2011. Water Quality Assessment Method. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of Environmental Quality, Water Quality Planning Bureau, Water Quality Standards and Modeling Section. 2017. DEQ-7 Montana Numeric Water Quality Standards. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of Environmental Quality, Watershed Protection Section. 2017. 2017 Montana Nonpoint Source Management Plan. Helena, MT: Montana Dept. of Environmental Quality.

Montana Department of State Lands, Abandoned Mine Reclamation Bureau. 1994. Abandoned Hardrock Mine Priority Sites Summary Report. Butte, MT: Pioneer Technical Services, Inc.

Nimick, D; Caldwell, Rodney; Skaar, D; Selch, Trevor. 2013. Fate of Geothermal Mercury from Yellowstone National Park in the Madison and Missouri Rivers, USA, Science of the Total Environment, Volume 443, Pages 40-54.

Priscu, John C. 1987. Environmental Factors Regulating the Dynamics of Blue-Green Algal Blooms in Canyon Ferry Reservoir, Montana. Bozeman, MT: Montana Water Resources Research Institute. Report # 159.

Schwarz, G.E. and Alexander, R.B. 1995. Soils Data for the Conterminous United States Derived from the NRCS State Soil Geographic (STATSGO) Data Base. U.S. Geological Survey Open File Report, 95-449.

Suplee, Michael W. and Christian Schmidt. 2013. Derivation of Site-Specific Numeric Criteria for Selected Streams in the Upper Clark Fork Basin: Addendum A to "Scientific and Technical Basis of the

Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers: Update 1". Helena, MT: Montana Department of Environmental Quality. WQPBWQSTD-008.

Suplee, Michael W., Mindy McCarthy, and Eric Urban. 2013. Technical Memorandum: Benchmark for Nitrate + Nitrite in Assessing Ambient Surface Water. Helena, MT: Montana Dept. of Environmental Quality.

Suplee, Michael W. and Rosie Sada de Suplee. 2011. Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus Levels. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau. WQPMASTR-01.

Suplee, Michael W., Arun Varghese, and Joshua Cleland. 2007. Developing Nutrient Criteria for Streams: An Evaluation of the Frequency Distribution Method. Journal of the American Water Resources Association. 43(2): 453-472.

Suplee, Michael W. and Vicki Watson. 2013. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers—Update 1. Helena, MT: Montana Department of Environmental Quality.

Suplee, Michael W., Vicki Watson, Mark E. Teply, and Heather McKee. 2009. How Green Is Too Green? Public Opinion of What Constitutes Undesirable Algae Levels in Streams. Journal of the American Water Resources Association. 45(1): 123-140.

Suplee, Michael W., Vicki Watson, Arun Varghese, and Joshua Cleland. 2008. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers. Helena, MT: Montana Department of Environmental Quality.

Suzuki, Kevin. 2015. Grazing Allotment Information. Personal Communication with Jordan Tollefson, Montana Dept. of Environmental Quality.

U.S. Department of Agriculture, Forest Service. 1997a. Allotment Management Plan for the North Meadow Creek C&H Allotment. U.S. Department of Agriculture, Forest Service, Madison Ranger District, Beaverhead National Forest.

U.S. Department of Agriculture, Forest Service. 1997b. Allotment Management Plan for the South Meadow Creek C&H Allotment. U.S. Department of Agriculture, Forest Service, Madison Ranger District, Beaverhead National Forest.

U.S. Department of Agriculture, Forest Service. 2008a. Allotment Management Plan for the Bear Creek On & Off C&H Allotment. U.S. Department of Agriculture, Forest Service, Madison Ranger District, Beaverhead National Forest.

U.S. Department of Agriculture, Forest Service. 2008b. Allotment Management Plan for the Cedar Creek On & Off C&H Allotment. U.S. Department of Agriculture, Forest Service, Madison Ranger District, Beaverhead National Forest.

U.S. Department of Agriculture, Forest Service. 2008c. Allotment Management Plan for the Jeffers On & Off C&H Allotment. U.S. Department of Agriculture, Forest Service, Madison Ranger District, Beaverhead National Forest.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2016. Cropscape - Cropland Data Layer. https://nassgeodata.gmu.edu/CropScape/. Accessed 1/14/2016.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2010. Natural Resources Conservation Service Practice Code 528.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2013. Natural Resources Conservation Service Nutrient Management Code 590.

U. S. Department of Interior, Bureau of Land Management. 2007a. South Tobacco Roots Watershed Assessment Executive Summary and Authorized Officer's Determination. U. S. Department of Interior, Bureau of Land Management, Dillon Field Office.

U. S. Department of Interior, Bureau of Land Management. 2007b. South Tobacco Roots Watershed Assessment Report. U. S. Department of Interior, Bureau of Land Management, Dillon Field Office.

U. S. Department of Interior, Bureau of Land Management. 2009a. Executive Summary and Authorized Officer's Determination for the Madison Watershed Assessment Report. U. S. Department of Interior, Bureau of Land Management, Dillon Field Office.

U. S. Department of Interior, Bureau of Land Management. 2009b. Madison Watershed Assessment Report. U. S. Department of Interior, Bureau of Land Management, Dillon Field Office.

U. S. Department of Interior, Bureau of Land Management. 2016. Fact Sheet on the BLM's Management of Livestock Grazing. Accessed 1/14/2016.

U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. Washington, D.C.: Office of Water, U.S. Environmental Protection Agency. EPA 841-B-99-007.

U.S. Environmental Protection Agency. 2001. Protocol for Developing Pathogen TMDLs. Washington, D.C.: Office of Water, U.S. Environmental Protection Agency. EPA 841-R-00-002.

U.S. Environmental Protection Agency. 2010. Using Stressor-Response Relationships to Derive Numeric Nutrient Criteria. Washington, DC: Office of Science and Technology, Office of Water, EPA. EPA-820-S-10-001.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses: guide to conservation planning. USDA, Agriculture Handbook 537. U.S. Government Printing Office, Washington, DC.

Woods, A.J., J.M. Omernik, W.H. Martin, G.J. Pond, W.M. Andrews, S.M. Call, J.A. Comstock, and D.D. Taylor. 2002. Ecoregions of Kentucky. (2 sided color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey, Reston, VA. Scale 1:1,000,000.

World Health Organization. 2003. Aluminum in Drinking Water Background Document for Development of WHO Guidelines for Drinking-Water Quality. Geneva, Switzerland: World Health Organization.

APPENDIX A – SURFACE WATER NUTRIENT, *E. COLI*, AND METAL DATA FOR THE MADISON TMDL PLANNING AREA

LIST OF TABLES

This appendix contains five tables of data used in development of the Madison nutrient, *E. coli*, and metal TMDLs. The tables are included to aid readers in finding data more easily. All data contained in the tables are available in the National Water Quality Portal at https://www.waterqualitydata.us/.

Table Descriptions

Table A-1 contains the data DEQ used to assess waterbodies in the Madison TMDL Planning Area for attainment of the nutrient water quality standards. This table includes surface water flow and water column nutrient concentration data for all the nutrient stream sampling locations discussed in the Madison Nutrient, *E. coli*, and Metal TMDLs and Water Quality Improvement Plan. **Tables A-2** through **A-3** contain algae and macroinvertebrate data that aided in the impairment determinations of those streams in Section 5.0, Nutrient TMDL Components, in the main body of the TMDL document.

Table A-4 contains the data DEQ used to assess waterbodies in the Madison TMDL Planning Area for attainment of the *E. coli* water quality standards. This table includes surface water flow and water column *E. coli* concentration data for all the stream sampling locations discussed in Section 6.0, Escherichia coli TMDL Components, in the main body of the document.

Table A-5 contains the data DEQ used to assess waterbodies in the Madison TMDL Planning Area for attainment of the metals water quality standards. This table includes surface water flow and water column metals concentration data for all metals stream sampling locations discussed in Section 7.0, Metals TMDL Components, in the main body of the document.

Table Symbols and Notations

Blank cell	Where no value is given, no data was collected
<	Non-detect samples where the detection limit is populated as the value
C	Calculated hardness value (Total Hardness as $CaCO_3$). The calculated hardness values presented in this table are computed from the results of separate determinations of calcium and magnesium. Hardness values that are not prefaced with a "C" are direct measurements of hardness using a different analytical procedure.
E	Estimated flow measurement
MDEQ_WQ_WQX	Organization ID: Montana Department of Environmental Quality
MTVOLWQM_WQX	Organization ID: Montana Volunteer Water Quality Monitoring

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Blaine Spring Creek inside spring box building	M06BLNSC07	7/23/2012	45.2222	-111.7942	13.23	**1.38**	0.007	**0.31**	
MDEQ_WQ_WQX	Blaine Spring Creek inside spring box building	M06BLNSC07	8/26/2012	45.2222	-111.7942	13.83	**0.35**	0.008	**0.33**	
MDEQ_WQ_WQX	Blaine Spring Creek inside spring box building	M06BLNSC07	7/11/2013	45.2222	-111.7942	10.68	**0.348**	0.013		**0.321**
MDEQ_WQ_WQX	Blaine Spring Creek inside spring box building	M06BLNSC07	9/18/2013	45.2222	-111.7942	13.91	0.265	0.006		**0.333**
MDEQ_WQ_WQX	Blaine Spring Creek at USGS gage below fish hatchery	M06BLNSC03	7/23/2012	45.21528	-111.7917	15.51	**0.38**	0.024	**0.3**	
MDEQ_WQ_WQX	Blaine Spring Creek at USGS gage below fish hatchery	M06BLNSC03	8/26/2012	45.21528	-111.7917	15.41	**0.4**	0.018	**0.31**	
MDEQ_WQ_WQX	Blaine Spring Creek at USGS gage below fish hatchery	M06BLNSC03	7/11/2013	45.21528	-111.7917	11.57	**0.353**	0.024		**0.31**

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Blaine Spring Creek at USGS gage below fish hatchery	M06BLNSC03	8/16/2013	45.21528	-111.7917	8.59	**0.344**	0.012		**0.336**
MDEQ_WQ_WQX	Blaine Spring Creek at USGS gage below fish hatchery	M06BLNSC03	9/18/2013	45.21528	-111.7917		**0.346**	0.015		**0.334**
MTVOLWQM_WQX	Blaine Spring Creek, hatchery weir	BS-HW	7/9/2014	45.21515	-111.7915	13.48	0.28	0.01	**0.28**	
MTVOLWQM_WQX	Blaine Spring Creek, hatchery weir	BS-HW	8/6/2014	45.21515	-111.7915	13.8024	**0.39**	0.024	**0.3**	
MTVOLWQM_WQX	Blaine Spring Creek, hatchery weir	BS-HW	9/5/2014	45.21515	-111.7915	19.03	**0.43**	0.014	**0.32**	
MDEQ_WQ_WQX	Blaine Spring Creek	M06BLNSC08	7/31/2012	45.2153	-111.7784	18.21	**0.42**	0.014	**0.29**	
MDEQ_WQ_WQX	Blaine Spring Creek	M06BLNSC08	8/26/2012	45.2153	-111.7784	17.44	**0.35**	0.015	**0.31**	
MDEQ_WQ_WQX	Blaine Spring Creek upstream intersection with Shewmaker Ditch	M06BLNSC11	9/5/2014	45.22057	-111.7644	28.48	**0.66**	0.017	**0.31**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Blaine Spring Creek downstream intersection with Shewmaker Ditch	M06BLNSC10	9/5/2014	45.22065	-111.7641	26.17	**0.35**	0.018	**0.25**	
MDEQ_WQ_WQX	Blaine Spring Creek	M06BLNSC06	7/23/2012	45.2454	-111.7615	18.9	0.26	0.006	**0.16**	
MTVOLWQM_WQX	Blaine Spring Creek, Alton Ranch	BS-AR	7/30/2013	45.24539	-111.7615	17.86	0.15	0.003	**0.11**	
MTVOLWQM_WQX	Blaine Spring Creek, Alton Ranch	BS-AR	8/27/2013	45.24539	-111.7615	20.61	**0.37**	**0.066**	**0.3**	
MTVOLWQM_WQX	Blaine Spring Creek, Alton Ranch	BS-AR	7/9/2014	45.24539	-111.7615	15.71	0.16	< 0.003	0.09	
MTVOLWQM_WQX	Blaine Spring Creek, Alton Ranch	BS-AR	8/6/2014	45.24539	-111.7615	20.501	0.29	0.008	**0.16**	
MTVOLWQM_WQX	Blaine Spring Creek, Alton Ranch	BS-AR	9/5/2014	45.24539	-111.7615	27.55	0.2	0.008	**0.2**	
MDEQ_WQ_WQX	Elk Creek near mouth (Madison River)	M06ELKC04	7/25/2012	45.65448	-111.5187	0.47	**0.59**	**0.114**	< 0.01	
MDEQ_WQ_WQX	Elk Creek near mouth (Madison River)	M06ELKC04	8/28/2012	45.65448	-111.5187	0.05	**0.66**	**0.052**	< 0.01	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	7/25/2012	45.64416	-111.4574	0.46	**0.95**	**0.147**	**0.38**	
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	8/28/2012	45.64416	-111.4574	0.11	**1.28**	**0.086**	**0.67**	
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	8/15/2013	45.64416	-111.4574	0.05	**0.759**	**0.111**		**0.23**
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	9/16/2013	45.64416	-111.4574	E 0.001	**0.984**	**0.06**		**0.484**
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	7/25/2007	45.6267	-111.4139		**0.52**	**0.1899**		0.0058
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	8/27/2009	45.6267	-111.4139		0.298	**0.107**	0.004	
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	9/26/2009	45.6267	-111.4139		0.198	**0.101**	0.004	
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	7/28/2010	45.6267	-111.4139		**0.36**	**0.11**		< 0.01
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	8/16/2013	45.6267	-111.4139		0.134	**0.056**		0.025
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	9/16/2013	45.6267	-111.4139	0.23	0.179	**0.07**		< 0.005
MDEQ_WQ_WQX	Elk Creek	M06ELKC07	8/17/2013	45.58689	-111.3666	0.01	0.214	**0.082**		< 0.005
MDEQ_WQ_WQX	Elk Creek near headwaters	M06ELKC05	9/16/2013	45.58734	-111.3695	0.21	0.224	**0.092**		< 0.005

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/1/2012	45.58614	-111.5944	2.56	0.42	0.154	0.05	
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/24/2012	45.58614	-111.5944	3.17	0.26	0.105	< 0.01	
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	7/9/2013	45.58614	-111.5944	4.88	0.58	0.219		0.06
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/15/2013	45.58614	-111.5944	1.15	0.377	0.195		0.01
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	9/19/2013	45.58614	-111.5944	4.95	0.637	0.426		0.098
MDEQ_WQ_WQX	Hot Springs Creek downstream Bradley Creek Rd crossing	M06HTSPC02	8/1/2012	45.58679	-111.6486	2.06	0.48	0.093	0.15	
MDEQ_WQ_WQX	Hot Springs Creek downstream Bradley Creek Rd crossing	M06HTSPC02	8/27/2012	45.58679	-111.6486	3.59	0.28	0.09	0.03	
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	7/25/2012	45.57358	-111.7251	0.27	0.63	0.178	0.25	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	7/9/2013	45.57358	-111.7251	2.46	0.499	0.112		0.297
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	8/16/2013	45.57358	-111.7251	0.63	0.598	0.112		0.494
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	9/19/2013	45.57358	-111.7251	1.1	0.394	0.069		0.298
MDEQ_WQ_WQX	Hot Springs Creek	M06HTSPC04	8/1/2012	45.56488	-111.754		0.58	0.033	0.42	
MDEQ_WQ_WQX	Hot Springs Creek	M06HTSPC04	7/9/2013	45.56488	-111.754		0.453	0.05		0.288
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	7/11/2012	45.40683	-111.71	E 5.34	0.3	0.023	0.05	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	8/14/2012	45.40683	-111.71	E 5.69	0.25	0.018	0.03	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	7/19/2013	45.40683	-111.71	7.32	0.28	0.024	< 0.01	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	8/28/2013	45.40683	-111.71	8.83	**0.36**	0.028	0.1	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	9/27/2013	45.40683	-111.71	10.98	**0.46**	0.025	**0.16**	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	7/17/2014	45.40683	-111.71	8.2915	0.25	0.024	0.08	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	8/13/2014	45.40683	-111.71	5.485	**0.6**	0.02	**0.25**	
MTVOLWQM_WQX	Moore Creek lower	MC-CNF	9/9/2014	45.40683	-111.71	7.293	**0.37**	0.016	**0.23**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	7/19/2013	45.3787	-111.7219	2.35	**0.58**	**0.033**	**0.31**	
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	8/28/2013	45.3787	-111.7219	2.02	**0.81**	**0.032**	**0.53**	
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	9/27/2013	45.3787	-111.7219	3.86	**0.58**	0.03	**0.33**	
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	7/17/2014	45.3787	-111.7219	1.8918	**0.7**	**0.09**	**0.46**	
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	8/13/2014	45.3787	-111.7219	2.497	**1.17**	**0.037**	**0.65**	
MTVOLWQM_WQX	Moore Creek middle	MC-GOG	9/9/2014	45.3787	-111.7219	3.504	**0.58**	0.022	**0.44**	
MDEQ_WQ_WQX	Moore Creek north of Ennis	M06MOREC01	7/20/2012	45.37192	-111.7229	2.06	**0.33**	**0.056**	0.08	
MDEQ_WQ_WQX	Moore Creek north of Ennis	M06MOREC01	8/22/2012	45.37192	-111.7229	0.38	0.29	0.029	< 0.01	
MDEQ_WQ_WQX	Moore Creek at Feeds-N-Needs	M06MOREC05	7/20/2012	45.3595	-111.7307	1.78	**0.88**	**0.069**	**0.19**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	7/19/2013	45.33858	-111.7377	1.51	**0.31**	**0.051**	**0.14**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	8/28/2013	45.33858	-111.7377	0.93	0.23	**0.035**	**0.12**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	9/27/2013	45.33858	-111.7377	1.49	**0.72**	**0.049**	**0.37**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	7/17/2014	45.33858	-111.7377	0.5481	**0.63**	**0.085**	**0.33**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	8/13/2014	45.33858	-111.7377	0.225	**0.5**	**0.078**	**0.25**	
MTVOLWQM_WQX	Moore Creek upper	MC-BRK	9/9/2014	45.33858	-111.7377	1.966	0.26	**0.04**	**0.18**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	Moore Creek at Hwy 287 crossing	M06MOREC02	7/19/2012	45.3369	-111.7412	0.9	**0.65**	**0.062**	**0.45**	
MDEQ_WQ_WQX	Moore Creek at Hwy 287 crossing	M06MOREC02	8/22/2012	45.3369	-111.7412	0.84	**0.55**	**0.048**	**0.38**	
MDEQ_WQ_WQX	Moore Creek about 30 ft downstream intersection with West Madison Canal	M06MOREC08	9/5/2014	45.33414	-111.7459	2.89	**-**	**0.068**	**0.22**	
MDEQ_WQ_WQX	Moore Creek above the intersection with West Madison Canal	M06MOREC07	9/5/2014	45.33419	-111.7462	2.5	**-**	**0.064**	**0.24**	
MDEQ_WQ_WQX	Moore Creek upper site	M06MOREC03	7/19/2012	45.33542	-111.768	0.85	**0.99**	**0.09**	**0.53**	
MDEQ_WQ_WQX	Moore Creek upper site	M06MOREC03	8/22/2012	45.33542	-111.768	0.77	**0.53**	0.029	**0.33**	
MDEQ_WQ_WQX	O'Dell Spring Creek near mouth	M06ODLSC01	7/25/2012	45.36399	-111.707	108.74	**0.37**	0.006	**0.17**	
MDEQ_WQ_WQX	O'Dell Spring Creek near mouth	M06ODLSC01	8/27/2012	45.36399	-111.707	117.83	**0.32**	0.006	**0.21**	
MDEQ_WQ_WQX	O'Dell Spring Creek near mouth	M06ODLSC01	9/17/2013	45.36399	-111.707		**0.333**	0.005		**0.262**
MTVOLWQM_WQX	O'Dell Creek lower	OD-VGR	9/23/2012	45.3639	-111.707	109	0.3	0.005	**0.23**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MTVOLWQM_ WQX	O'Dell Creek lower	OD-VGR	7/14/2013	45.3639	-111.707	111.73	0.29	0.006	**0.17**	
MTVOLWQM_ WQX	O'Dell Creek lower	OD-VGR	8/23/2013	45.3639	-111.707	107.96	0.28	0.007	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek lower	OD-VGR	7/25/2014	45.3639	-111.707	98.813	0.3	0.01	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek lower	OD-VGR	8/15/2014	45.3639	-111.707	114.57 4	**0.45**	0.008	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek lower	OD-VGR	9/19/2014	45.3639	-111.707	130.58	**0.35**	0.007	**0.26**	
MTVOLWQM_ WQX	O'Dell Creek near Rainbow Valley Lodge	OD-RVL	7/25/2014	45.34141	-111.7166	106.86	0.3	0.008	**0.21**	
MDEQ_WQ_WQ X	O'Dell Spring Creek just south of Ennis	M06ODLSC02	7/25/2012	45.33365	-111.7251	67.15	**0.35**	0.005	**0.25**	
MDEQ_WQ_WQ X	O'Dell Spring Creek just south of Ennis	M06ODLSC02	8/27/2012	45.33365	-111.7251	69.46	**0.35**	0.005	**0.25**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	8/26/2012	45.33178	-111.7269	65.96	**0.32**	0.004	**0.23**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/23/2012	45.33178	-111.7269		0.3	0.006	**0.26**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	7/14/2013	45.33178	-111.7269	71.93	0.29	0.006	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	8/23/2013	45.33178	-111.7269	62.88	0.3	0.005	**0.22**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/22/2013	45.33178	-111.7269	80.28	**0.38**	0.005	**0.26**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	8/15/2014	45.33178	-111.7269	55.885	**0.4**	0.008	**0.22**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/19/2014	45.33178	-111.7269	142.73	**0.4**	0.007	**0.27**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	7/28/2012	45.33178	-111.7269	64.11	**0.33**			
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/23/2012	45.33178	-111.7269	65.72	0.3	0.006	**0.26**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	7/14/2013	45.33178	-111.7269	71.93	0.29	0.006	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	8/23/2013	45.33178	-111.7269	62.88	0.3	0.005	**0.22**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/22/2013	45.33178	-111.7269	80.28	**0.38**	0.005	**0.26**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	8/15/2014	45.33178	-111.7269	55.885	**0.4**	0.008	**0.22**	
MTVOLWQM_ WQX	O'Dell Creek middle	OD-GNGR	9/19/2014	45.33178	-111.7269	142.73	**0.4**	0.007	**0.27**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	7/28/2012	45.26057	-111.7324	45.72	0.28	0.01	**0.18**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	8/26/2012	45.26057	-111.7324	44.02	0.24	0.008	**0.17**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	9/23/2012	45.26057	-111.7324	45.18	0.22	0.009	**0.19**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	7/14/2013	45.26057	-111.7324	39.39	0.25	0.011	**0.17**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	8/23/2013	45.26057	-111.7324	38.12	0.25	0.01	**0.16**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	9/22/2013	45.26057	-111.7324	40.04	0.29	0.011	**0.18**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	8/15/2014	45.26057	-111.7324	40.451 4	0.25	0.013	**0.14**	
MTVOLWQM_ WQX	O'Dell Creek upper	OD-RST	9/19/2014	45.26057	-111.7324	53.53	0.2	0.012	**0.16**	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	South Meadow Creek about 1/4 mile upstream from mouth	M06SMDWC01	7/24/2012	45.44377	-111.7184	4.75	**0.49**	0.024	**0.29**	
MDEQ_WQ_WQX	South Meadow Creek about 1/4 mile upstream from mouth	M06SMDWC01	8/24/2012	45.44377	-111.7184	4	**0.46**	0.021	**0.28**	
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	7/2/2012	45.44352	-111.7186	5.51	**0.41**	0.023	**0.21**	
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	9/19/2012	45.44352	-111.7186	4.2	**0.39**	0.017	**0.27**	
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	8/8/2013	45.44352	-111.7186	3.763	**0.49**	0.028	**0.3**	
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	9/18/2013	45.44352	-111.7186	4.69	**0.46**	**0.031**	**0.28**	
MTVOLWQM_WQX	South Meadow Creek upstream N Ennis Lake Road crossing	SM-CR	7/7/2014	45.44402	-111.719	24.43	0.29	**0.038**	0.08	
MTVOLWQM_WQX	South Meadow Creek upstream N Ennis Lake Road crossing	SM-CR	8/5/2014	45.44402	-111.719	5.68	**0.53**	**0.047**	**0.31**	
MTVOLWQM_WQX	South Meadow Creek upstream N Ennis Lake Road crossing	SM-CR	9/10/2014	45.44402	-111.719	6.46	**0.31**	0.029	**0.23**	
MDEQ_WQ_WQX	South Meadow Creek	M06SMDWC02	7/24/2012	45.45101	-111.7472	0.61	0.29	0.013 B	0.04	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	South Meadow Creek	M06SMDWC02	8/24/2012	45.45101	-111.7472	0.01	0.14	0.006	< 0.01	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	7/2/2012	45.45097	-111.7472	3.55	0.27	**0.037**	0.02	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	9/19/2012	45.45097	-111.7472	0.106	0.13	0.004	< 0.01	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	7/12/2013	45.45097	-111.7472	1.38	0.15	0.012	0.02	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	8/8/2013	45.45097	-111.7472	0.215	0.27	**0.032**	0.05	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	9/18/2013	45.45097	-111.7472		0.26	0.017	0.1	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	7/7/2014	45.45097	-111.7472	19.27	0.19	0.024	0.04	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	8/5/2014	45.45097	-111.7472	0.028	0.14	0.01	0.03	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	9/10/2014	45.45097	-111.7472	2.48	0.12	0.008	0.09	
MDEQ_WQ_WQX	South Meadow Creek downstream Leonard Creek	M06SMDWC03	7/24/2012	45.44785	-111.7752	4.7	**0.35**	0.01	0.07	
MDEQ_WQ_WQX	South Meadow Creek downstream Leonard Creek	M06SMDWC03	8/24/2012	45.44785	-111.7752	2.7	**0.51**	**0.032**	**0.12**	
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	7/24/2012	45.45484	-111.8555	9.01	0.07	< 0.003	0.01	
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	8/24/2012	45.45484	-111.8555	8.42	< 0.05	< 0.005	0.01	

Table A.1. Madison TMDL Planning Area Nutrient Data

Organization ID (Data Collection Entity)	**Station (Site) Name**	**Site ID**	**Activity Date**	**Latitude**	**Longitude**	**Flow (cfs)**	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**NO_2 + NO_3 as N** (mg/L)	**NO_2 + NO_3 as N (Dissolved)** (mg/L)
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	8/14/2013	45.45484	-111.8555		0.076	< 0.001		0.015
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	7/2/2012	45.45512	-111.855	27.06	0.08	< 0.003	0.03	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	9/19/2012	45.45512	-111.855	4.33	0.09	< 0.003	0.04	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	7/12/2013	45.45512	-111.855	10.59	0.08	< 0.003	0.02	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	9/18/2013	45.45512	-111.855	3.92	0.14	0.004	0.06	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	7/7/2014	45.45512	-111.855	41.03	0.07	< 0.003	0.03	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	8/5/2014	45.45512	-111.855	9.37	0.11	0.003	0.05	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	9/10/2014	45.45512	-111.855	5.85	< 0.04	0.003	0.07	

Table A-2. Madison TMDL Planning Area Algae Data

Station ID	Station Name	Latitude	Longitude	Sample Collection Date	Parameter	Value	Units
M06BLNSC08	Blaine Spring Creek	45.2153	-111.7784	7/31/2012	Chlorophyll a	7.8	mg/m2
M06BLNSC08	Blaine Spring Creek	45.2153	-111.7784	9/18/2013	Chlorophyll a	<0.01	mg/m3
M06BLNSC03	Blaine Spring Creek at USGS gage below fish hatchery	45.2152778	-111.791667	9/18/2013	Ash Fee Dry Mass	38.37	g/m2
M06BLNSC03	Blaine Spring Creek at USGS gage below fish hatchery	45.2152778	-111.791667	7/31/2012	Ash Fee Dry Mass	6.17	g/m2
M06ELKC04	Elk Creek near mouth (Madison River)	45.65448	-111.51871	7/25/2012	Chlorophyll a	13.8	mg/m2
M06ELKC03	Elk Creek downstream Norris Road crossing	45.64416	-111.45741	8/15/2013	Chlorophyll a	19.06	mg/m2
M06ELKC02	Elk Creek	45.6267	-111.4139	8/16/2013	Chlorophyll a	38.21	mg/m2
M06ELKC07	Elk Creek	45.58689	-111.36656	8/17/2013	Chlorophyll a	47.62	mg/m2
M06ELKC04	Elk Creek near mouth (Madison River)	45.65448	-111.51871	7/25/2012	Ash Fee Dry Mass	76	g/m2
M06ELKC03	Elk Creek downstream Norris Road crossing	45.64416	-111.45741	8/15/2013	Ash Fee Dry Mass	22	g/m2
M06ELKC02	Elk Creek	45.6267	-111.4139	8/16/2013	Ash Fee Dry Mass	3.78	g/m2
M06ELKC07	Elk Creek	45.58689	-111.36656	8/17/2013	Ash Fee Dry Mass	0.93	g/m2
M06HTSPC03	Hot Springs Creek upstream Sterling Rd crossing	45.57358	-111.72514	7/25/2012	Chlorophyll a	10.9	mg/m2
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	8/1/2012	Chlorophyll a	14.7	mg/m2
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	8/15/2013	Chlorophyll a	12.51	mg/m2
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	8/1/2012	Ash Fee Dry Mass	34.3	g/m2
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	8/15/2013	Ash Fee Dry Mass	5.02	g/m2
M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/20/2012	Chlorophyll a	9.2	mg/m2
M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/19/2012	Chlorophyll a	35.2	mg/m2
M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/20/2012	Ash Fee Dry Mass	19.35	g/m2
M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/19/2012	Ash Fee Dry Mass	6.12	g/m2
M06ODLSC02	O'Dell Spring Creek just south of Ennis	45.33365	-111.72508	7/25/2012	Chlorophyll a	18.4	mg/m2
M06ODLSC04	O'Dell Spring Creek on private ranch	45.26415	-111.73478	9/18/2014	Chlorophyll a	33.5	mg/m2
M06ODLSC04	O'Dell Spring Creek on private ranch	45.26415	-111.73478	9/18/2014	Ash Fee Dry Mass	34.73	g/m2
M06SMDWC02	South Meadow Creek	45.45101	-111.74717	7/24/2012	Chlorophyll a	16.2	mg/m2
M06SMDWC03	South Meadow Creek downstream Leonard Creek	45.44785	-111.7752	7/24/2012	Chlorophyll a	4.4	mg/m2
M06SMDWC04	South Meadow Creek upper site	45.45484	-111.85548	8/14/2013	Chlorophyll a	29.6	mg/m2
M06SMDWC02	South Meadow Creek	45.45101	-111.74717	7/24/2012	Ash Fee Dry Mass	12.1	g/m2
M06SMDWC03	South Meadow Creek downstream Leonard Creek	45.44785	-111.7752	7/24/2012	Ash Fee Dry Mass	2.14	g/m2
M06SMDWC04	South Meadow Creek upper site	45.45484	-111.85548	8/14/2013	Ash Fee Dry Mass	55.0	g/m2

Table A-3. Madison TMDL Planning Area Macroinvertebrate Data

Station ID	Waterbody Name	Latitude	Longitude	HUC	Collection Date	HBI
M06BLNSC08	Blaine Spring Creek	45.2153	-111.7784	10020007	7/31/2012	5.44
M06BLNSC03	Blaine Spring Creek	45.215278	-111.79167	10020007	9/18/2013	4.93
M06ELKC02	Elk Creek	45.6267	-111.413	10020007	8/19/2013	6.15
M06ELKC03	Elk Creek downstream Norris Road crossing	45.6442	-111.4574	10020007	8/15/2013	6.60
M06ELKC05	Elk Creek near headwaters	45.5873	-111.3695	10020007	8/22/2013	5.15
M06ELKC04	Elk Creek near mouth (Madison River)	45.65448	-111.51871	10020007	7/25/2012	3.88
M06ELKC07	Elk Creek	45.58689	-111.36656	10020007	8/17/2013	5.45
M06HTSPC05	Hot Springs Creek Middle Fork upstream confluence	45.5553	-111.8085	10020007	8/21/2013	4.96
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	10020007	8/1/2012	5.61
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	10020007	8/15/2013	5.11
M06HTSPC01	Hot Springs Creek near mouth	45.58614	-111.59436	10020007	7/9/2013	4.97
M06HTSPC03	Hot Springs Creek upstream Sterling Rd crossing	45.57358	-111.72514	10020007	7/25/2012	6.04
M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	10020007	7/20/2012	6.05
M06MOREC03	Moore Creek upper site	45.33542	-111.76801	10020007	7/19/2012	6.63
M06ODLSC02	O'Dell Spring Creek just south of Ennis	45.33365	-111.72508	10020007	7/25/2012	5.69
M06SMDWC02	South Meadow Creek	45.45101	-111.74717	10020007	7/24/2012	4.21
M06SMDWC03	South Meadow Creek downstream Leonard Creek	45.44785	-111.7752	10020007	7/24/2012	4.41
M06SMDWC04	South Meadow Creek upper site	45.45484	-111.85548	10020007	8/14/2013	4.09

Table A-4. Madison TMDL Planning Area Escherichia Coli Data

Organization ID (Data Collection Entity)	Station ID	Station Name	Latitude	Longitude	Collection Date	Parameter	Value	Units
MDEQ_WQ_WQX	M06MOREC05	Moore Creek at Feeds-N-Needs	45.3595	-111.7307	7/18/2012	Escherichia coli	547.5	cfu/100mL
MDEQ_WQ_WQX	M06MOREC05	Moore Creek at Feeds-N-Needs	45.3595	-111.7307	7/19/2012	Escherichia coli	517.2	cfu/100mL
MDEQ_WQ_WQX	M06MOREC05	Moore Creek at Feeds-N-Needs	45.3595	-111.7307	7/20/2012	Escherichia coli	1553.1	cfu/100mL
MDEQ_WQ_WQX	M06MOREC05	Moore Creek at Feeds-N-Needs	45.3595	-111.7307	7/21/2012	Escherichia coli	2419.6	cfu/100mL

Table A-4. Madison TMDL Planning Area Escherichia Coli Data

Organization ID (Data Collection Entity)	Station ID	Station Name	Latitude	Longitude	Collection Date	Parameter	Value	Units
MDEQ_WQ_WQX	M06MOREC05	Moore Creek at Feeds-N-Needs	45.3595	-111.7307	7/22/2012	Escherichia coli	920.8	cfu/100mL
MDEQ_WQ_WQX	M06MOREC02	Moore Creek at Hwy 287 crossing	45.3369	-111.74122	7/18/2012	Escherichia coli	228.2	cfu/100mL
MDEQ_WQ_WQX	M06MOREC02	Moore Creek at Hwy 287 crossing	45.3369	-111.74122	7/19/2012	Escherichia coli	167	cfu/100mL
MDEQ_WQ_WQX	M06MOREC02	Moore Creek at Hwy 287 crossing	45.3369	-111.74122	7/20/2012	Escherichia coli	325.5	cfu/100mL
MDEQ_WQ_WQX	M06MOREC02	Moore Creek at Hwy 287 crossing	45.3369	-111.74122	7/21/2012	Escherichia coli	378.4	cfu/100mL
MDEQ_WQ_WQX	M06MOREC02	Moore Creek at Hwy 287 crossing	45.3369	-111.74122	7/22/2012	Escherichia coli	410.6	cfu/100mL
MDEQ_WQ_WQX	M06MOREC04	Moore Creek just north of Ennis	45.35381	-111.72965	7/18/2012	Escherichia coli	435.2	cfu/100mL
MDEQ_WQ_WQX	M06MOREC04	Moore Creek just north of Ennis	45.35381	-111.72965	7/19/2012	Escherichia coli	193.5	cfu/100mL
MDEQ_WQ_WQX	M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/18/2012	Escherichia coli	866.4	cfu/100mL
MDEQ_WQ_WQX	M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/19/2012	Escherichia coli	980.4	cfu/100mL
MDEQ_WQ_WQX	M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/20/2012	Escherichia coli	1553.1	cfu/100mL
MDEQ_WQ_WQX	M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/21/2012	Escherichia coli	1299.7	cfu/100mL
MDEQ_WQ_WQX	M06MOREC01	Moore Creek north of Ennis	45.37192	-111.72287	7/22/2012	Escherichia coli	1299.7	cfu/100mL
MDEQ_WQ_WQX	M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/18/2012	Escherichia coli	21.5	cfu/100mL
MDEQ_WQ_WQX	M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/19/2012	Escherichia coli	12	cfu/100mL
MDEQ_WQ_WQX	M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/20/2012	Escherichia coli	18.3	cfu/100mL

Table A-4. Madison TMDL Planning Area Escherichia Coli Data

Organization ID (Data Collection Entity)	Station ID	Station Name	Latitude	Longitude	Collection Date	Parameter	Value	Units
MDEQ_WQ_WQX	M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/21/2012	Escherichia coli	52.9	cfu/100mL
MDEQ_WQ_WQX	M06MOREC03	Moore Creek upper site	45.33542	-111.76801	7/22/2012	Escherichia coli	35.9	cfu/100mL

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	Elk Creek	M06ELKC07	8/17/2013	45.58689	-111.36656	C 131	0.01	< 1	< 0.3	190	< 0.9
MDEQ_WQ_WQX	Elk Creek near headwaters	M06ELKC05	9/16/2013	45.58734	-111.36948	C 122	0.21	< 1	< 0.3	330	< 0.9
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	8/16/2013	45.6267	-111.4139	C 146	E 1	1	< 0.3	30	< 0.9
MDEQ_WQ_WQX	Elk Creek	M06ELKC02	9/16/2013	45.6267	-111.4139	C 134	0.23	< 1	< 0.3	60	< 0.9
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	6/19/2012	45.64416	-111.45741	C 205	2.03	4	1.5	2060	3
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	7/25/2012	45.64416	-111.45741	C 242	0.46	3	0.7	1140	3
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	8/28/2012	45.64416	-111.45741	C 290	0.11	2	0.5	860	4

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	6/12/2013	45.64416	-111.45741	C 178	2.71	5	1	1550	3
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	8/15/2013	45.64416	-111.45741	C 252	0.05	2	< 0.3	340	8.1
MDEQ_WQ_WQX	Elk Creek downstream Norris Road crossing	M06ELKC03	9/16/2013	45.64416	-111.45741	C 270	0.001	2	< 0.3	190	8
MDEQ_WQ_WQX	Elk Creek near mouth (Madison River)	M06ELKC04	6/19/2012	45.65448	-111.51871	C 176	2.97	2	< 0.5	680	2
MDEQ_WQ_WQX	Elk Creek near mouth (Madison River)	M06ELKC04	7/25/2012	45.65448	-111.51871	C 232	0.47	3	0.7	1170	2
MDEQ_WQ_WQX	Elk Creek near mouth (Madison River)	M06ELKC04	8/28/2012	45.65448	-111.51871	C 262	0.05	3	0.6	1000	2
MDEQ_WQ_WQX	Hot Springs Creek	M06HTSPC04	6/13/2012	45.56488	-111.75402	48	2.69	2	1.8	540	< 1
MDEQ_WQ_WQX	Hot Springs Creek	M06HTSPC04	8/1/2012	45.56488	-111.75402	56	1.84	< 1	< 0.5	190	< 1
MDEQ_WQ_WQX	Hot Springs Creek	M06HTSPC04	7/9/2013	45.56488	-111.75402	47.4	2.4	< 1	0.7	290	< 1

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	6/13/2012	45.57358	-111.72514	92	0.94	1	< 0.5	600	< 1
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	7/25/2012	45.57358	-111.72514	103	0.27	1	0.6	900	< 1
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	6/12/2013	45.57358	-111.72514	68.8	2.98	2	1	850	< 1
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	7/9/2013	45.57358	-111.72514	71.7	2.46	< 1	0.7	660	< 1
MDEQ_WQ_WQX	Hot Springs Creek upstream Sterling Rd crossing	M06HTSPC03	8/16/2013	45.57358	-111.72514	104	0.63	< 1	< 0.3	300	< 0.9
MDEQ_WQ_WQX	Hot Springs Creek downstream Bradley Creek Rd crossing	M06HTSPC02	6/13/2012	45.58679	-111.64858	183	3.19	1	1.1	720	< 1

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	Hot Springs Creek downstream Bradley Creek Rd crossing	M06HTSPC02	8/1/2012	45.58679	-111.64858	177	2.06	2	1.8	850	< 1
MDEQ_WQ_WQX	Hot Springs Creek downstream Bradley Creek Rd crossing	M06HTSPC02	8/27/2012	45.58679	-111.64858	164	3.59	1	1	480	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	6/13/2012	45.58614	-111.59436	196	4.11	3	5.3	1480	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/1/2012	45.58614	-111.59436	176	2.56	3	4.9	1190	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/24/2012	45.58614	-111.59436	171	3.17	3	5.2	1380	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	6/12/2013	45.58614	-111.59436	141	9.28	3	4.3	1450	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	7/9/2013	45.58614	-111.59436	156	4.88	4	6.2	2000	< 1
MDEQ_WQ_WQX	Hot Springs Creek near mouth	M06HTSPC01	8/15/2013	45.58614	-111.59436	172	1.15	3	3.1	1010	1.5

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	6/18/2012	45.45484	-111.85548	C 25	36.37	< 1	< 0.5	60	< 1
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	7/24/2012	45.45484	-111.85548	C 25	9.01	< 1	< 0.5	< 50	< 1
MDEQ_WQ_WQX	South Meadow Creek upper site	M06SMDWC04	8/24/2012	45.45484	-111.85548	C 25	8.42	8	< 0.5	< 50	< 1
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	10/25/2011	45.45511	-111.855	C 41		< 1	< 0.5	< 30	
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	7/2/2012	45.45511	-111.855	C 25		< 1	< 0.5	30	< 1
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	8/6/2012	45.45511	-111.855	C 25		< 1	<0 .5	< 30	< 1
MTVOLWQM_WQX	South Meadow Creek upper	SM-FS	9/19/2012	45.45511	-111.855	C 29		< 1	< 0.5	< 30	< 1
MDEQ_WQ_WQX	South Meadow Creek downstream Leonard Creek	M06SMDWC03	6/18/2012	45.44785	-111.7752	C 29	15.78	2	1.8	550	< 1

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	South Meadow Creek downstream Leonard Creek	M06SMDWC03	7/24/2012	45.44785	-111.7752	C 49	4.7	< 1	0.5	330	< 1
MDEQ_WQ_WQX	South Meadow Creek downstream Leonard Creek	M06SMDWC03	8/24/2012	45.44785	-111.7752	C 54		2	0.8	560	< 1
MDEQ_WQ_WQX	South Meadow Creek	M06SMDWC02	6/18/2012	45.45101	-111.74717	C 35	7.52	2	2.8	1120	< 1
MDEQ_WQ_WQX	South Meadow Creek	M06SMDWC02	7/24/2012	45.45101	-111.74717	C 63	0.61	1	< 0.5	160	< 1
MDEQ_WQ_WQX	South Meadow Creek	M06SMDWC02	8/24/2012	45.45101	-111.74717	C 57	0.01	< 1	< 0.5	60	< 1
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	10/25/2011	45.45096	-111.747217	C 65		1	0.5	430	
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	7/2/2012	45.45096	-111.747217	C 47		1	0.8	410	< 1
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	8/6/2012	45.45096	-111.747217	C 49		< 1	< 0.5	50	< 1
MTVOLWQM_WQX	South Meadow Creek middle	SM-EDC	9/19/2012	45.45096	-111.747217	C 61		< 1	< 0.5	50	< 1

Table A-5. Madison River TMDL Project Area Metals Data

Organization ID (Data Collection Entity)	Station Name	Site ID	Activity Date	Latitude	Longitude	Hardness (mg/L)	Flow (cfs)	Copper (µg/L)	Lead (µg/L)	Iron (µg/L)	Selenium (µg/L)
MDEQ_WQ_WQX	South Meadow Creek about 1/4 mile upstream from mouth	M06SMDWC01	6/18/2012	45.44377	-111.7184	C 115	6.73	< 1	< 0.5	250	< 1
MDEQ_WQ_WQX	South Meadow Creek about 1/4 mile upstream from mouth	M06SMDWC01	7/24/2012	45.44377	-111.7184	C 123	4.75	< 1	< 0.5	440	< 1
MDEQ_WQ_WQX	South Meadow Creek about 1/4 mile upstream from mouth	M06SMDWC01	8/24/2012	45.44377	-111.7184	C 130	4	< 1	< 0.5	350	< 1
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	10/25/2011	45.44351	-111.718617	C 88		< 1	< 0.5	190	
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	7/2/2012	45.44351	-111.718617	C 112		< 1	< 0.5	270	< 1
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	8/6/2012	45.44351	-111.718617	C 127		< 1	< 0.5	340	< 1
MTVOLWQM_WQX	South Meadow Creek lower	SM-LKRD	9/19/2012	45.44351	-111.718617	C 125		< 1	< 0.5	290	< 1

Appendix B – Method for Estimating Attenuation of Nutrients from Septic Systems Model Results (MEANSS) for the Madison TMDL Planning Area

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List of Tables

This appendix contains the results of the Method for Estimating Attenuation of Nutrients from Septic Systems (MEANSS) model for the Madison TMDL Planning Area, and is intended to aid readers in understanding how this information was used for nutrient loading in Section 5.0, Nutrient TMDL Components, in the main body of the TMDL document.

B1.0 MEANSS MODEL DESCRIPTION

The following is a brief description of the MEANSS model and how the model is used to estimate nutrient loadings to surface water from septic systems. The location of each septic system in the six sub-watersheds shown in the tables was estimated by plotting points at the center of each structure classified as "dwelling," "mobile home," or "farm/ranch" in the Montana Structures Framework (http://geoinfo.msl.mt.gov/Home/msdi/structures_and_-addresses). Other structures such as commercial establishments, government buildings, hospitals, schools, etc. are not included in the analysis because effluent from the population covered under the dwellings, mobile homes, and farm/ranch categories likely accounts for wastewater usage from those public facilities. Also, many of the public facilities in the six sub-watersheds are located in Ennis, which has a public wastewater system that is accounted for separately from the septic system loading in the TMDL document. The structure location database is used as an estimate of the drainfield location because there is no electronic database of drainfield locations.

Once the septic locations were determined, a spreadsheet approach, Method for Estimating Attenuation of Nutrients from Septic Systems (MEANSS), was used for estimating the reduction of nitrogen and phosphorus between disposal at the drainfield and subsequent discharge to surface water. The parameters used to estimate nitrogen and phosphorus reduction are described below.

MEANSS is only designed for use on a larger basin-wide scale that effectively allows averaging of the wide variation of processes that occur in the subsurface between wastewater discharge in the vadose zone and subsequent migration into the surface water.

B2.0 NITROGEN

MEANSS uses a matrix and is based on the three primary factors impacting the amount of nitrogen attenuation via denitrification: soil type beneath the drainfield, soil type in the riparian area, and distance to surface water (**Table B-1**). Soil type is based the Natural Resources and Conservation Service (NRCS) hydrologic soil group (HSG) classification system (**Table B-1**). In the matrix, each drainfield is assigned a percent denitrification factor for each of the three criteria. The percentages assigned for each column are then added to provide the total percent nitrogen removal for that septic system. The nitrogen loading rate (for example, 30.5 lbs/year for a conventional septic system) to the surface water is then reduced accordingly. Any system with a percent reduction of 100% or more is assumed to contribute no nitrogen to the surface water. This method assumes steady-state conditions exist in that it does not account for the time needed for the nitrogen load to migrate towards the receiving surface water. That lag time is dependent on the distance to the receiving water and the travel rate through both the vadose and saturated zones. MEANSS also does not account for in-stream nutrient cycling.

Table B-1. MEANSS Septic System Nitrogen Loading Matrix

Percent Nitrogen Load Reduction[1]	Soil Type @ Drainfield[1]	Soil Type within 100' of surface water[2]	Distance to surface water (ft)
0	A	A	≤ 100
10	B		> 100 - 500
20	C	B	> 500 - 5000
30	D	C	> 5000 - 20,000
50		D	> 20,000

[1] The total nitrogen reduction is the sum of the individual reductions for each column of the table. For example, the nitrogen load reduction associated with a drainfield in a type C soil that drains to a surface water with type B soil, and is 200 feet from the nearest surface water would be 50 percent (e.g., 20% + 20% + 10% = 50%, or 30.5 lbs/year * 0.5 = 15.25 lbs/year).

[2] Soil drainage class:

A = excessively drained or somewhat excessively drained
B = well drained or moderately well drained
C = somewhat poorly drained
D = poorly drained or very poorly drained

Defining the hydrologic soil group (HSG) at the drainfield, the HSG within 100 feet of surface water, and the distance to surface water in the matrix are completed using GIS analysis of the NRCS database called the Soil Survey Geographic Database (SSURGO) and the National Hydrography Dataset (NHD). SSURGO is used to determine the hydrologic soil group. The NHD is used to determine locations of perennial streams for the distance factor.

The HSG for each drainfield was based on the GIS intersection of the Montana Structures data and the SSURGO map for the dominant HSG at each drainfield. To determine the HSG adjacent to surface water for each septic system, the HSG at the closest perennial stream was determined by map analysis of each drainfield. Where no data was available at a drainfield site or river site in SSURGO, the HSG from the nearest classified soil was used. Distance to surface water was based on buffers created in GIS at the 100, 500, 5,000 and 20,000-foot distances.

B3.0 PHOSPHORUS

DEQ's method for estimating phosphorus loading to surface waters from septic systems uses a matrix similar to nitrogen (**Table B-2**). The matrix combines three factors that have been shown to impact the amount of phosphorus attenuation: soil type beneath the drainfield, calcium carbonate percent in the soil beneath the drainfield, and distance to surface water. In the matrix (**Table B-2**), each drainfield is assigned a percent phosphorus reduction for only one of the first three columns (the soil and calcium carbonate type), and then an additional percent phosphorus reduction for the fourth column (distance to surface water). The percentages assigned for each column are then added to provide the total percent phosphorus removal for that septic system. The phosphorus loading rate (6.44 lbs/year for a conventional or level 2 system) to the surface water is then reduced accordingly. Any system with a percent reduction of 100% or more is assumed to contribute no phosphorus to the surface water. This method assumes steady-state conditions exist in that it does not account for the time needed for the phosphorus load to migrate towards the receiving surface water. That lag time is dependent on the distance to the receiving water and the travel rate through both the vadose and saturated zones.

Table B-2. MEANSS Septic System Phosphorus Loading Matrix

Percent Phosphorus Load Reduction[1]	Soil Type @ Drainfield[2] ($CaCO_3$ ≤ 1%)	Soil Type @ Drainfield[2] ($CaCO_3$ > 1% and < 15%)	Soil Type @ Drainfield[2] ($CaCO_3$ ≥ 15%)	Distance to surface water (ft)
10	A	A	A	≤ 100
20			B	
40		B	C	
50				> 100 - 500
60	B	C	D	
80	C	D		> 500 - 5,000
100	D			> 5,000

[1] The total phosphorus reduction is the sum of the two reductions for soil type/$CaCO_3$ and distance. For example, the phosphorus load reduction associated with a drainfield that is in a type C soil with greater than 15 percent $CaCO_3$ (40 percent) and is 300 feet from the surface water (50 percent) would be 90 percent (40% + 50% = 90%, or 6.44 lbs/year * 0.9 = 5.8 lbs/year removed prior to discharge to surface water).

[2] Soil drainage class:
A = excessively drained or somewhat excessively drained
B = well drained or moderately well drained
C = somewhat poorly drained
D = poorly drained or very poorly drained

In the phosphorus analysis, the HSG at the drainfield and the distance to surface water are the same as used in the nitrogen analysis. The $CaCO_3$ for each drainfield was based on the GIS intersection of the Montana Structures data and the SSURGO $CaCO_3$ percent value. Soils between 24 inches to 60 inches below ground surface were used to determine the dominant $CaCO_3$; most drainfields are buried 24 inches deep, therefore the analysis did not use the upper 24 inches of soil. Where no data was available at a drainfield site in SSURGO, the $CaCO_3$ from the nearest dominant classified soil was used, or if there was no clear dominant type, then the $CaCO_3$ was estimated as the middle of the three categories used in MEANSS (1 to 15 percent).

B4.0 Potential Uncertainty Associated with MEANSS

MEANSS is designed to be a simple method to provide an estimate of nutrient loadings from septic systems. As such, it has several simplifications of actual processes that control nutrient attenuation that can create uncertainty in the final results. These simplifications, and other potential sources of uncertainty, include:

- MEANSS is a steady-state method, which does not account for seasonal variation of wastewater discharge that could be caused by high groundwater recharge rates during spring runoff and other times of heavy recharge. The seasonality of discharge rates is likely more pronounced for septic systems located closer to surface waters as compared to those located further away with a longer travel time to the surface water.
- Since the model is steady-state, there is an implicit assumption that nutrient breakthrough is occurring regardless of age or date of the septic installation.
- The effluent loading values used in MEANSS are based on average values (i.e., per capital flow and concentration), and does not account for septic systems that may have higher levels of

treatment (e.g., level 2 septic systems) or for systems with higher or lower usage due to occupancy rates.

- Failed septic systems are not accounted for in MEANSS because subsurface failures of drainfields typically do not effect nutrient treatment, while failures that allow untreated nutrients to enter surface water via overland flow typically are repaired quickly and do not have a significant effect on long-term nutrient loading of surface waters.
- Once the reductions for distance and soil type are accounted for, the entire remaining nutrient load is assumed to enter the surface water. This assumes that all septic loads in shallow groundwater are in connection with, and enter surface water. However, in many cases only a portion of the shallow groundwater will actually enter surface water. Some of the groundwater may flow underneath and by-pass the stream or it may parallel the surface water but remain as groundwater beneath the surface water. This conceptual discrepancy would tend to over-predict the amount of nutrients entering the surface water, and would be more likely to introduce error as the distance between the septic system and surface water increases.
- The soil information used from SSURGO is not designed to be used on field-level scale as is being done in MEANSS. The accuracy of the soil information could affect the accuracy of MEANSS.
- Although MEANSS has been validated against other models and against measured field data, the reduction percentages used for distances and soil types are only estimates. The uncertainty ranges associated with those percentages have not been determined.

As more site-specific information regarding septic systems becomes available, or as more accurate models are developed for calculation septic loadings, the results of MEANSS can be updated or replaced to improve the TMDL source assessment.

B5.0 MEANSS Model Results for the Madison TMDL Planning Area

Tables B-3 and **B-4** on the next page contains the MEANSS Model results used for specific waterbodies in the Madison TMDL Planning Area to assess potential nitrogen and phosphorus loading from septic systems.

Table B-3. Madison TMDL Planning Area MEANSS Nitrogen Analysis

Sub-Basin Name	**Number of Septic Systems**	**% Nitrogen removed due to drainfield soil**	**% Nitrogen removed due to soil type at river**	**% Nitrogen removed due to distance**	**Total Percent Nitrogen Removed Prior to Stream Discharge**	**Total Nitrogen Load from Septic Systems (lbs/day)[1]**	**Total Nitrogen Load Entering Streams (lbs/day)**
O'Dell Spring Creek (HUC 10)	178	8.88	14.83	14.16	37.87	14.87	**9.24**
Elk Creek (HUC 12)	17	15.29	29.41	21.18	65.88	1.42	**0.48**
Hot Springs Creek (HUC 10)	51	8.04	19.61	16.27	43.92	4.26	**2.39**
Moore Creek (HUC 12)	192	6.46	25.05	19.17	50.68	16.04	**7.91**
South Meadow Creek (HUC 12)	74	6.35	20.00	16.35	42.70	6.18	**3.54**
Blaine Spring Creek (partial HUC 12)	131	11.30	18.02	18.17	47.48	10.95	**5.75**
Average		**8.46**	**18.96**	**17.08**	**44.49**		
Sum	**643**					**53.73**	**29.32**

[1] Nitrogen loading from each septic system is estimated as 30.5 lbs/yr

Table B-4. Madison TMDL Planning Area MEANSS Phosphorus Analysis

HUC-6 Sub-basin	**Number of Septic Systems**	**% Phosphorus removed due to soil type**	**% Phosphorus removed due to distance**	**Total Percent Phosphorus Removed Prior to Stream Discharge**	**Total Phosphorus Load from Septic Systems (lbs/day)[1]**	**Total Phosphorus Load Entering Streams (lbs/day)**
O'Dell Spring Creek (HUC 10)	178	30.28	61.69	87.47	3.14	**0.39**
Elk Creek (HUC 12)	17	40.59	78.82	96.47	0.30	**0.01**
Hot Springs Creek (HUC 10)	51	22.55	67.06	85.49	0.90	**0.13**
Moore Creek (HUC 12)	192	18.85	76.82	93.70	3.39	**0.21**
South Meadow Creek (HUC 12)	74	35.27	68.78	91.76	1.31	**0.11**
Blaine Spring Creek (partial HUC 12)	131	25.73	73.59	92.44	2.31	**0.17**
Average		**26.67**	**70.33**	**91.12**		
Sum	**643**				**11.34**	**1.03**

[1] Phosphorus loading from each septic system is estimated as 6.44 lbs/yr