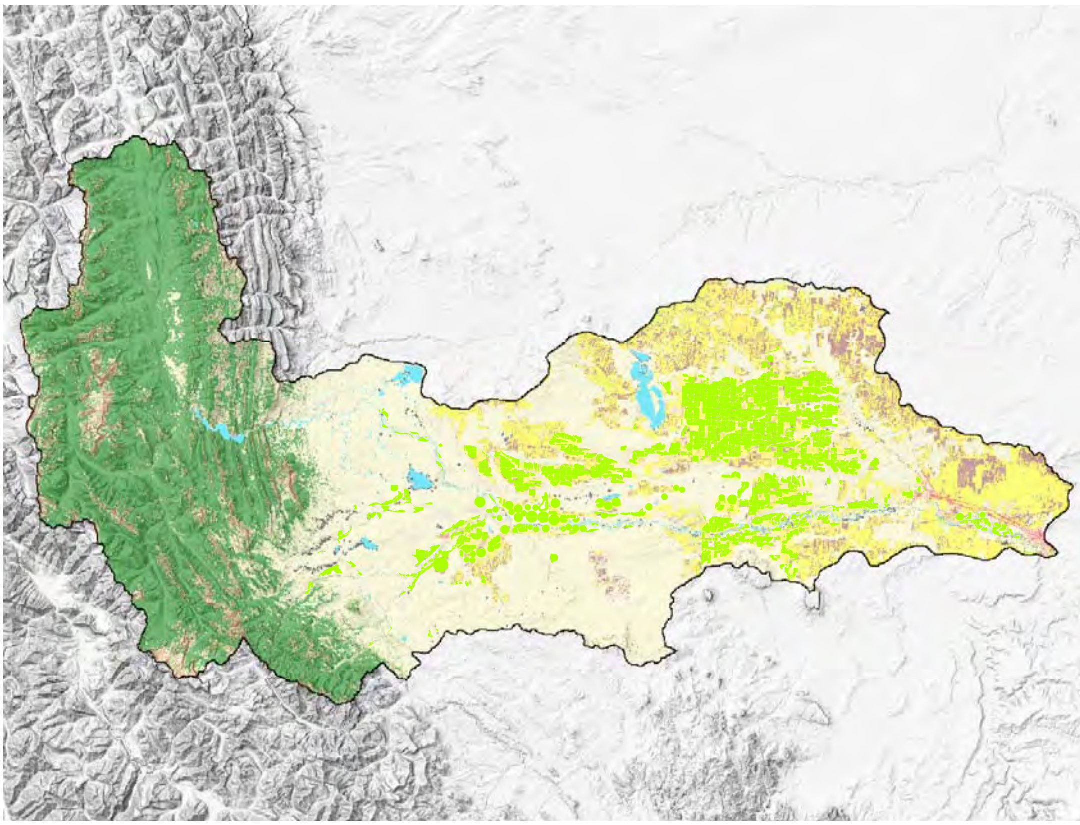
WATER QUALITY RESTORATION PLAN AND TOTAL MAXIMUM DAILY LOADS FOR THE SUN RIVER PLANNING AREA



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Montana Department of
ENVIRONMENTAL QUALITY

DOCUMENT SUMMARY

The Sun River watershed spans a number of land types: from the forested headwaters in the Rocky Mountain wilderness, to the mouth in the plains near the City of Great Falls, Montana. Agricultural land use predominates the majority of the watershed. The links between water quality, land use, and the natural variability of land types in the watershed are complex. This document attempts to use existing information to link water quality conditions to natural and human influences in the watershed.

The potentially impaired waters identified by the State of Montana 303(d) lists, found in the Sun River watershed are: Ford Creek, Gibson Reservoir, Willow Creek Reservoir, upper Sun River, lower Sun River, Freezeout Lake, and Muddy Creek. This document addresses all of the 1996 or 2002 303(d) listed waterbody-pollutant combinations by either providing a TMDL, providing justification that the waterbody is not impaired due to a pollutant, or providing a strategy to complete a TMDL if current information is not adequate for TMDL formation (Table E-1, Map 1-1). The general pollutant categories addressed in this document are sediment, temperature, selenium, nutrients, salts, and pH. Pollution listings are usually addressed by considering them as sources of a pollutant.

A cursorily review of each TMDL component is not feasible for inclusion in this portion of the document because it alone would fill too many pages. The document is structured in a format that will allow you to read about an individual waterbody quite easily. The document is structured in a way that Sections 1.0-4.0 provides background information about the Sun River watershed, Montana's water quality standards, and Montana's 303(d) listings. Sections 5.0-10.0 relate to a specific pollutant, and within each section each potentially impaired waterbody is addressed.

Table E-1. Current Water Quality Impairment Status of Waters in the Sun River.

Waterbody	Listed Probable Causes (pollutants)	303(d) List Status		Current Status	Action
		1996	2002		
Ford Creek	Silation Nutrients	Impaired	Impaired	Impaired	• Justification provided for no need of nutrient TMDL. • Addressed by a TMDL for Sediment.
Gibson Reservoir	Siltation Suspended Solids	Impaired	Not Listed due to Lacking Data	Not impaired due to Sediment or TSS.	• Conduct a 303(d) review
Willow Creek Reservoir	Only listed for pollution	Impaired	Not Listed due to Lacking Data	Potentially impaired	• Conduct a 303(d) review

Table E-1. Current Water Quality Impairment Status of Waters in the Sun River.

Waterbody	Listed Probable Causes (pollutants)	303(d) List Status		Current Status	Action
		1996	2002		
Upper Sun River	Siltation Suspended solids Nutrients Phosphorus Thermal modification	Impaired	Impaired	Impaired	• Justification provided for no need of nutrient or phosphorus TMDL. • All other pollutants are addressed by TMDLs.
Freezeout Lake	Nutrients Organic Enrichment/DO Sulfates Salinity/TDS/Chlorides Metals Selenium	Impaired	Impaired	Impaired	• Not enough information to determine if nutrient/Organic Enrichment/DO TMDL is needed. A plan is provided to gather information. • All other pollutants are addressed by TMDLs. • Investigate for potential reclassification.
Muddy Creek	Suspended Solids Nutrients Thermal modification Salinity/TDS/Sulfates pH	Impaired	Impaired	Impaired	• Justification provided for no need of pH TMDL. • All other pollutants are addressed by TMDLs. • Investigate for potential reclassification.
Lower Sun River	Siltation Suspended solids Nutrients Thermal modification Salinity/TDS/Sulfates	Impaired	Impaired	Impaired	• Justification provided for no need of temperature or salinity TMDLs. • All other pollutants are addressed by TMDLs. • Investigate for potential reclassification.

ACRONYMS AND ABBREVIATIONS

ARM	Administrative Rules of Montana
BMP	Best Management Practice
BUD	Beneficial Use Determination
BLM	Bureau of Land Management, United States
CFR	Clark Fork River
cfs	Cubic Feet Per Second
CRP	Conservation Reserve Program
CWA	Clean Water Act
DNRC	Department of Natural Resources and Conservation, Montana
EC	Electrical Conductance
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency, United States
EQIP	Environmental Quality Initiatives Program
F	Fahrenheit
FSID	Fort Shaw Irrigation District
GID	Greenfields Irrigation District
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrologic Unit (Code) from USGS
IWM	Irrigation Water Management
Lat.	Latitude
lbs/yr	pounds per year
Long.	Longitude
MBMG	Montana Bureau of Mines & Geology
MDEQ	Montana Department of Environmental Quality
MCA	Montana Code Annotated
MFWP	Montana Fish, Wildlife and Parks
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
mg/l	Milligrams per liter
MPDES	Montana Pollutant Discharge Elimination System
n	number of samples
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source pollution
MSU	Montana State University
NRCS	Natural Resource Conservation Service
PFC	Proper Functioning Condition (Riparian)
QA/QC	Quality Assurance and Quality Control
SAR	Sodium Adsorption Ratio
SCD	Sufficient Credible Data
SC	Specific Conductance
SRF	State Revolving Fund
SRWG	Sun River Watershed Group
SSC	Suspended Sediment Concentration
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus

TSS	Total Suspended Solids
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
USGS	United States Geological Survey
W/D Ratio	Width to Depth Ratio
WMA	Wildlife Management Area
WQB-7	Circular WQB-7, Montana Water Quality Standards
WQRP	Water Quality Restoration Plan

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SECTION 1.0
INTRODUCTION

1.1 National and State Clean Water Law Review

Section 303(d) of the Clean Water Act (CWA) requires states to identify public waters that do not meet applicable water quality standards or support designated beneficial uses. Specifically, the language of the CWA and related EPA regulations require states to identify waterbodies where water quality is impaired (does not fully meet Montana water quality standards) or is threatened (is likely to violate Montana water quality standards in the near future). Under the CWA, states are required to submit a biennial 303(d) list of these impaired or threatened waters to the EPA.

Montana's Clean Water Act provides guidance for surface water classification, water quality standards, and Total Maximum Daily Load (TMDL) development and implementation. With the exception of point source discharges, which are permitted under the federal or state pollution discharge elimination system, the non-point source and TMDL programs are based on the voluntary participation of stakeholders in implementing the identified actions that can reduce non-point source pollutants. Montana's Water Quality Act states: "*The department shall support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL developed and implemented pursuant to this section*" (Emphasis added) (75-5-703(8), MCA) and further provides protection to existing water rights: "*Nothing in this part may be construed to divest, impair, or diminish any water right recognized pursuant to Title 85*" (75-5-705, MCA). Therefore, local stakeholder and land manager involvement is crucial for carrying out the activities that will lead to achieving water quality standards.

Under Montana's Clean Water Act, natural sources are defined as conditions or material present over which man has no control, or from developed land where all reasonable land, soil, and water conservation practices have been applied. Natural sources are not discussed in great detail because each source assessment is tailored to identify human managed activities that can be addressed with reasonable land, soil, and water conservation practices. Land, soil, and water conservation practices and in-stream conditions relating to targets will be assessed during future TMDL reviews. Natural conditions are addressed by using water quality targets based on local or regional reference conditions and applying an adaptive management approach.

Montana's water quality standards allow for some level of anthropogenic (human-caused) impacts to water quality while still maintaining adequate support of beneficial uses assuming that "*all reasonable land, soil, and water conservation practices*" are followed. However, it should be noted that "*all reasonable land, soil, and water conservation practices*" is not synonymous with Best Management Practices (BMPs). The intent of "*all reasonable land, soil, and water conservation practices*" is to include any and all practices, beginning with currently established BMPs, which may be necessary to maintain or restore water quality to levels that support all beneficial uses. Measures or practices beyond "standard" BMPs may be needed where water quality has not been restored adequately. Montana's Water Quality Act acknowledges that landowners and stewards voluntarily apply conservation practices.

States are also required under Section 303(d) to develop TMDL plans identifying measures needed to bring the water quality of the listed waters into compliance with the applicable standards. Section §75-5-703 (4) of the Montana Codes Annotated (MCA), indicates that the Montana Department of Environmental Quality (MDEQ) shall provide guidance for TMDL development on any threatened or impaired waterbody, if the necessary funding and resources from sources outside the department are available to develop the TMDL and to monitor the effectiveness of implementation efforts. A collaborative approach was taken by the State and local interests to promote local involvement for implementing the restoration process in the Sun River Watershed.

The goal of Montana's TMDL program is to produce Water Quality Restoration Plans that meet the U.S. Environmental Protection Agency's (EPA) TMDL criteria. The State of Montana’s Nonpoint Source Management Plan indicates that Water Quality Restoration Plans with TMDL components should be used as guidance for nonpoint source restoration. Because TMDLs are integrated with water quality restoration planning, a state and local partnership is desirable where local watershed groups exist, such as in the Sun River Watershed. There are two active groups in the Sun River Watershed. The Muddy Creek Task Force is focused on curbing erosion on Muddy Creek. The Sun River Watershed Group focuses on a variety of water quality and quantity concerns across the watershed.

1.2 TMDL Development History in the Sun River Watershed

In this case, the Sun River Watershed Group initiated funding for nonpoint source restoration through grants acquired during the late 1990s. The purpose was to integrate Water Quality Restoration Planning and provide environmental information to support TMDL development. Since their formation in 1992, the Sun River Watershed Group and the Muddy Creek Task Force have supported many of the restoration activities identified in this document. The Sun River Watershed Group initiated a watershed wide water quality restoration process and MDEQ provided guidance for a number of years. During the past few years, the Sun River Watershed Group has worked closely with MDEQ staff to ensure that the Sun River Watershed Water Quality Restoration Plan was addressing all aspects of current TMDL regulations and was still receiving local input. This effort enabled MDEQ to produce a TMDL document containing all required elements, as established by EPA, while considering local input during the process.

While the Sun River Watershed Group has assisted in providing a much of the data for and also a venue for local concerns, the final TMDL document will be issued by MDEQ to EPA for acceptance and approval. All TMDL requirements identified in this plan are the result of a process outlined in Montana’s code and rule, which give the sole responsibility and liability for TMDL development to MDEQ and EPA. This process should not rule out the usefulness of this document for local water quality planning on a voluntary basis.

1.3 Document Intent and Background Information

This document addresses all necessary TMDLs for the waterbodies specified in Montana’s 1996 and 2002 303(d) list. It is also intended for use in local water quality planning. Muddy Creek, Ford Creek, two segments of the Sun River, Gibson Reservoir, Willow Creek Reservoir, and Freezeout Lake are specifically addressed in this document (Map 1-1). The Sun River is broken into two segments in each list. The Upper Sun River segment extends from Gibson Dam for 80.3 miles to the Muddy Creek confluence, and the lower segment is17.1 miles and extends from the Muddy Creek confluence to the confluence with the Missouri River. Although other tributaries to the Sun River are not on the Montana 303(d) lists, their conditions play an important role in supporting beneficial uses in the entire watershed. For that reason, tributaries not on any 303(d) list may be identified as sources.

The Sun River watershed is connected to the Teton River watershed via man-made canals and irrigation works. However, Total Maximum Daily Loads (TMDL) and Water Quality Management Plans for the Teton and Sun Rivers have been developed in separate documents. The development of each of these plans was coordinated since water quality in the Teton River basin is intricately linked to actions in the Sun River basin. The pivot point for these watersheds begins with irrigation water applied in the Freezeout Lake watershed. Water in Freezeout Lake flows to Priest Butte Lake and eventually the Teton River. Target setting, especially those set for Priest Butte Lake, were developed with an awareness of its potential implication for Freezeout Lake, the Greenfields Irrigation District (GID), and the Sun River. This document does not attempt to describe the complex functioning of the Priest Butte Lake area or the Teton River Watershed. That information and detail is contained in the Water Quality Management Plan and TMDLs for the Teton River Watershed. Water from the Sun River Watershed is also diverted to Benton Lake. A separate TMDL for Benton Lake will be developed at a later date.

Strategies identified in this document are intended to balance the varying uses of water while adhering to Montana’s water quality and water use laws. This plan addresses technical issues using existing knowledge, and will be adapted during future TMDL reviews when new data is available. This document should be considered dynamic, to meet an “adaptive management strategy” approach to restore water quality in the Sun River Watershed. This water quality plan is intended to identify the knowledge we have at present and to identify a future path for water quality restoration. As more knowledge is gained through the restoration process and future monitoring, this plan may change to accommodate new science and information. Montana’s water quality law provides for this process by providing for future TMDL reviews.

SECTION 2.0
GENERAL WATERSHED CHARACTERISTICS

The Sun River is a tributary of the Missouri River in north-central Montana. The Sun River watershed encompasses approximately 2,200 square miles (mi^2) and flows through Cascade, Lewis & Clark, and Teton counties (Map 1-1). The river flows approximately 97.4 miles east, from an elevation of 9,000 feet (ft) along the Continental Divide to approximately 3,350 ft at its confluence with the Missouri River near Great Falls, Montana (McDonald, 2000).

2.1 Climate

The mean annual temperature ranges from 40.5° Fahrenheit (F) at Gibson Dam to 44° F at Simms. Average annual precipitation ranges from approximately 60 inches in the headwaters to 11 inches near Great Falls (PRISM Precipitation Model; Map 2-1). Eighty percent of the precipitation occurs from April through September.

2.2 Hydrography

The Sun River drainage is bordered by the Continental Divide to the west, the Teton River drainage to the north, and the Dearborn River drainage to the south. In the western portion of the watershed, the North and South Forks of the Sun River drain from the Continental Divide into Gibson Reservoir. The Sun River flows from Gibson Dam east toward Great Falls where it joins the Missouri River. Freezeout Lake basin is in the vicinity of the Town of Fairfield and receives water from irrigation activities that divert water from the Sun River. The Sun River drainage network exhibits an elongated shape and a dendritic pattern (Map 1-1). See Section 4.0 for more a more detailed review of hydrography, hydrology, and irrigation in the watershed.

2.3 Geology and Soils

Precambrian-age sedimentary rocks to Quaternary-age alluvial deposits outcrop in the Sun River watershed (Maughn, 1961; Lemke, 1977; Mudge et al., 1982; McDonald, 2000). Precambrian to Paleozoic-age rocks consisting of tightly folded and faulted fine-grained mudstones, sandstones, and impure carbonates are exposed along the Rocky Mountain Front. Relatively flat lying and undisturbed Mesozoic rocks of Jurassic and Cretaceous-age underlie the plains in the eastern portion of the watershed. The Mesozoic rocks consist mainly of marine mudstones, sandstones, and shale. Tertiary to Quaternary gravels overlie Cretaceous Colorado group shale in the eastern portion of the Sun River basin (Systems Technology, Inc., 1979). Quaternary glaciolacustrine deposits blanket large areas near the base of the mountains and overlie Quaternary terrace gravels across the plains. Lacustrine sediments deposited in glacial Lake Great Falls comprise most of the Quaternary strata on the eastern side of the basin. End-moraine, kame-delta, deltaic, and slope-wash deposits comprise the remainder of the glacially derived Quaternary sediments in the basin (Systems Technology, Inc., 1979). Alluvial deposits occupy stream valleys and veneer many of the elevated plateaus bordering the Sun River and Muddy Creek (McDonald, 2000; Map 2-2).

Predominant soil types in the Sun River watershed include loam, silt loam, and gravelly silt loams (Knapton et al., 1988). Soil parent materials include sandy to clayey glaciolacustrine deposits, shale and sandstone saprolite, and alluvium blanketing benches and valley floors. In the Muddy Creek drainage, excessive salt accumulations in the soil profile have created impervious layers, which impede drainage (Systems Technology, Inc., 1979). The most prevalent soil series outcropping in the Greenfields Irrigation District is Caleborolls-Calciorthids, a fine-grained, deep, well-drained and calcareous unit. Soils vary in texture from gravelly and sandy loams to light clays (Knapton et al., 1988). See Maps 2-3 and 2-4 for soil erosiveness and soil specific conductance.

2.4 Topography

The upper Sun River basin is situated in steep limestone and shale mountains within the Lewis and Clark National Forest (MFWP, 1989). Its upper tributaries converge at Gibson Reservoir located in the Sun River Gorge. Downstream from Gibson Dam, the river flows for only a few miles before encountering the Sun River Diversion Dam. Below this dam, the Sun River exits the mountains onto the prairie zone, first through a series of glacial outwash terraces, then till-covered foothills, and finally, through sedimentary benchlands.

From the Sun River Diversion Dam to the Elk Creek confluence, the river is entrenched in a narrow valley about 100 yards wide for the first 12 miles, broadening to about 400 yards wide near the lower end of the reach (MFWP, 1989). Benchlands of shale, limestone, and glacial till flank the river here and rise approximately 100 feet above the floodplain. From the Elk Creek confluence to Vaughn, the river occupies a fairly wide valley. Muddy Creek and Sun River below Vaughn are confined within additional benchland deposits. See Map 1-1 for shaded relief of the watershed.

2.5 Hydrologic Regime

In the upper section of the Sun River, the hydrograph is controlled by releases from Gibson Dam and numerous irrigation diversions located between Gibson Dam and Vaughn. The middle section of the Sun River, from the Sun River Diversion Dam to Ft. Shaw, is chronically dewatered (MFWP, 1997b). The Sun River is also impacted from Simms downstream to the mouth by irrigation return flows, which augment depleted in-stream flows. Flows typically peak in June at Simms during spring snowmelt. Flows near Vaughn below the Muddy Creek confluence typically peak in July and August due to return of ground water and surface water from irrigation activities (USGS, 2002).

A substantial portion of the Sun River's water is held in Gibson Reservoir and routed northeast to Pishkun Reservoir at the Sun River Diversion structure, then applied on the Fairfield and Asheulot Benches. Used or wasted water from the Greenfields Bench enters Muddy Creek, Freezeout Lake, Mill Coulee, Duck Creek and Big Coulee watersheds through surface or groundwater paths. Water is also diverted to Willow Creek Reservoir from the Sun River Diversion using a canal and Willow Creek as a conveyance system. Nilan Reservoir receives water from Smith and Ford Creeks and most of the captured water is used for irrigation in the Elk Creek watershed. There is a moderate amount of irrigated land in the low-lying areas in the

Elk Creek watershed and some of its tributaries. There is also a moderate amount of irrigation in the low-lying land by the Sun River upstream of the Muddy Creek confluence. About 106,655 acres or 167 square miles of irrigated land are currently being farmed in the Sun River watershed (Map 2-5). See Section 4.0 for more a more detailed review of hydrography, hydrology, and irrigation in the watershed.

2.6 Land Use and Land Ownership

The major land uses in the Sun River watershed include livestock grazing, crop production, forestlands, urban and rural residential, and wildlife habitat. The Sun River watershed contains approximately 100,000 acres of irrigated lands, 300,000 acres of dry cropland, 400,000 acres of rangeland, and 100,000 acres of pastures, all of which contribute to the impairment of water quality (Sun River Plan of Work, 1996).

Land use/land cover is 35 percent cropland, 28 percent rangeland, 35 percent forested, and two percent urban (Map 2-6, Table 2-1). The rangeland and forested areas are located principally in the western end of the watershed. Cropland consists of approximately 40 percent irrigated lands and 60 percent dry lands.

Approximately 57 percent of the land in the Sun River watershed is privately owned. The US Forest Service owns 33 percent of the land. The State, US Bureau of Reclamation, Bureau of Land Management and U.S. Fish & Wildlife Service own 7 percent, 1.5 percent, 0.5 percent and <0.1 percent respectively (Map 2-7, Table 2-2). Less than 1% is owned by a number of other entities.

Table 2-1. Land uses in the Sun River Watershed.

Primary Management	Estimated Arial Extent (acres)
Forested	480,000
Cropland	400,000
Rangeland	400,000
Pasture land	100,000
Wildlife habitat	20,000
Other	8,000
Total = 1,408,000 acres (2,200 square miles)	

Table 2-2. Land ownership in the Sun River Watershed.

Land Ownership	Estimated Arial Extent (acres)
Private	800,000
U.S. Forest Service	484,000
Montana School Trust Lands	99,000
U.S. Bureau of Reclamation	18,000
Bureau of Land Management	5,000
U.S. Fish & Wildlife Service	160
Total = 1,408,000 acres (2,200 square miles)	

2.7 History

2.7.1 Culture, Land Use and Economics (from: Pictorial History of the Sun River Valley, 1989)

The story of people in the Sun River Valley dates back thousands of years. The oldest stories tell of early Native American people, primarily Crow, Salish, and Blackfeet, who hunted the abundant elk, deer, and migrating buffalo along the rich watershed of the Sun or the "Medicine" River. The Blackfeet called the Sun River Valley the "best game country west of the Mississippi" and "Corner of the World", as the Rocky Mountains to the south and to the west channeled wildlife into the Valley.

The recorded history of the Sun River of Montana began on June 14, 1805 when Captain Lewis ascended a hill and wrote, "Along this wide level country the Missouri pursued its winding course, filled with water to its even and grassy banks, while, about four miles above it was joined by a large (Medicine or Sun) river, flowing from the northwest through a valley three miles in width, and distinguished by the timber which adorned its shores". They also described the river as about 200 yards wide near its mouth and very deep. In July 1806, Meriwether Lewis traveled through the valley on the expedition's return. On his return trip from the Pacific Coast, Captain Lewis became the first to record a description of the middle portion of the Sun River from the Rocky Mountains eastward across the prairie. He indicated that there were many islands compared to other rivers he had encountered. On July 8, 1806 they were hunting in this area when they also documented the finding of "Shishequaw Creek" (now called South Fork by locals or officially, Elk Creek) - a stream about 20 yards wide with a considerable quantity of timber in its low grounds.

The Blackfeet dominated the valley until 1870 when treaties, the U.S. military presence at Ft. Shaw, increasing white settlement, disease, and starvation reduced the Blackfeet population and land base. Ranches were built in the valley areas in 1860s. With the military came more: cattlemen; gold, silver, and coal miners; the Great Northern railroad spur along the Sun River from Vaughn to Gilman by 1911; and homesteaders. The Homestead Act of 1912 brought even more people to the area, and the establishment of the Reclamation Project and subsequent irrigation from Gibson Dam, which was completed in 1929, concentrated farmsteads even further. Prospectors described the wildlife as abundant as they explored the mountainous area of the Sun River early on, however, gold was never discovered.

The foothill community became permanent in 1883 when Phil Manix founded the Town of Augusta. The foothills area showed signs of overgrazing by cattle and sheep by 1890. This led cattlemen to look for greener pastures, and in 1890, J. Ford became the first to move cattle into the mountainous area of the North Fork of the Sun River. Fish were also plentiful in the Sun River, and one catch of 163 fish weighing up to 3 pounds each was made in 1884. The Sun River valley became a transportation corridor for trees to supply lumber for the growing city of Great Falls. In 1889, the upper Sun River was explored for a possible irrigation dam site. By 1910, the demand for wood had declined due to the decreasing demand for railroad ties, and increasing use of coal from the Sand Coulee area.

Fire was a major historical ecological factor in the upper Sun River watershed. Newspapers estimated 10 percent of the Sun River forests were burned each year late in the 19th century. Although this was considered an overestimate (the burned area was probably closer to 2-3 percent annually), it did demonstrate the existence of an annual fire cycle that prevented the accumulation of large amounts of fuel in the upper watershed.

Floods have also been a frequent event on the Sun River. Large floods have occurred in 1908, 1916, 1927, 1964, and 1975. The 1964 flood over-topped Gibson Dam.

Much of the land in the Sun River watershed below Gibson Reservoir has been intensively cropped and grazed (Systems Technology, Inc., 1979). In the late nineteenth century, cattle from Texas were driven into the Sun River drainage. Considerable areas of the Sun River and Muddy Creek drainages are still used for grazing (Table 2-1).

2.7.2 Irrigation

The Sun River Valley Ditch Company began in 1868 when Robert Ford, Robert Vaughn, and others constructed a ditch to Mill Coulee for a flourmill. The ditch was later extended to 11.5 miles in length, irrigating over 3,000 acres from Sun River to Vaughn. Today, the Sun River Valley Ditch Canal empties into Muddy Creek just north of Vaughn. The Rocky Reef Ditch Company was formed in 1916 with the construction of a ditch 2.2 miles long, irrigating over 500 acres.

In 1903, the newly formed Reclamation Service identified the lands for the Sun River Project. The project was authorized in 1906 with construction starting for the Fort Shaw Division in 1907. It was completed in 1907 with the first water delivered in 1908. Construction began in 1913 for the Greenfields Division with the first water delivered in 1920.

To help provide additional water for the project, storage was designed at Gibson Reservoir, Willow Creek Reservoir, Pishkun Reservoir, Muddy Creek Reservoir, and Benton Lake Reservoir (The Fairfield Times, 1978). Areas east of the current Greenfields Irrigation District (GID), along Sun River, and north to the Teton River were initially proposed for inclusion within the project (Systems Technology, Inc., 1979). Opposition from a number of dry land farmers resulted in a reduction of the project area, so Muddy Creek and Benton Lake Reservoirs were never developed. Construction for the Greenfields District lateral distribution canal system was completed in 1936. Drainage systems, installed under the supervision of the U.S. Bureau of Reclamation, were completed in 1958.

Currently, Gibson, Pishkun, and Willow Creek Reservoirs have a collective storage capacity of 175,0447 acre-feet (Personal comm. Ed Everaert). The Sun River Slope Canal that delivers water to the Greenfield District extends east from Pishkun Reservoir and has a length of approximately 19 miles. The entire delivery and distribution system is made up of 99 miles of main supply canals, 385 miles of lateral distribution lines, and 239 miles of open drains. The Greenfield's Irrigation district services approximately 84,000 acres of irrigated lands and delivers an average of 250,000 acre-feet of irrigation water per year (Personal comm. Ed Everaert). Of the 84,000 acres, about 50,000 acres of irrigated land on the Greenfields Bench drain to Muddy Creek.

Average crop-water demand is about 159,000 acre-feet. The gravel aquifer underlying the bench is generally capable of high water yields with transmissivities from 192-22,600 ft^2/day (Osborne et al., 1983). Average on-farm irrigation efficiency was 33 percent (Osborne et al., 1983). Since Osborne's study, much of the area has been converted from flood to sprinkler irrigation, and on-farm irrigation efficiency has increased to 55-65% (Personal comm. Ed Everaert).

See Section 4.0 for further review of in-stream discharge and irrigation water use information.

2.8 Waterbody Characteristics

2.8.1 Gibson Reservoir

Gibson Reservoir has steep rock banks leading up to the forested surroundings. The reservoir length at full pool is 5.2 miles with an average width of 0.4 mile. The storage capacity of the reservoir is 99,100 acre-feet and is held behind a 195-foot high concrete dam. The drainage area above the dam is 559 square miles and is composed of high mountainous terrain along the eastern edge of the continental divide. The inflows are primarily from the North and South Forks of the Sun River (Ferrari, 1997).

Gibson Reservoir was built during 1926-29 to supply water to the Greenfields Irrigation District (GID). The structure is located just below the confluence of the South and North Forks of the Sun River. The average annual runoff into Gibson Reservoir has been 608,000 acre-feet with 275,000 and 992,000 acre-feet as the lowest and highest runoff respectively (Tim Felchle, per. comm.). This dam is owned by the US Bureau of Reclamation (USBR) and operated by GID. The reservoir was built solely for irrigation purposes and is now used primarily for irrigation purposes (Ferrari, 1997). Current uses also include recreation and a viable fishery. Campgrounds are located near the reservoir and public access sites are used for fishing, boating and swimming. The watershed area above this reservoir is mostly wilderness and is owned by the US Forest Service (USFS).

Vegetation that surrounds Gibson Reservoir primarily consists of stands of sub-alpine fir and lodgepole pine. Vegetation in this area remains very similar to that recorded centuries ago. Natural fire events had been a factor in vegetation changes. Historic fire suppression caused a significant buildup in fuel. This buildup contributed to a major fire in 1988 on the North Fork of the Sun River changing vegetation conditions for many years to come.

Water levels in Gibson Reservoir fluctuate significantly to meet irrigation demands for the GID. The reservoir is typically filled during spring runoff and recedes during the irrigation season (Ferrari, 1997). The dam was built for irrigation purposes and USBR owns the water rights. The reservoir has a minimal pool depth of about 50 feet at a storage of 5,000 acre-feet that is usually set aside for fish populations. A minimum pool of 5,000 acre-feet is voluntarily stored by GID/USBR, but is not a reserved water right for the fishery (Verbal Comm. Ed Everaert). Gibson Reservoir's fishery consists of rainbow trout, west slope cutthroat trout, and arctic grayling (MFWP, 2002).

2.8.2 Ford Creek

Ford Creek is a tributary of Smith Creek. The Ford Creek watershed encompasses 80 mi^2 within the Sun River watershed. Ford Creek flows generally eastward, approximately 17 miles from an elevation of 6,860 ft to its confluence with Smith Creek at an elevation of 4,380 ft. Smith Creek flows into Elk Creek and Elk Creek flows into the Sun River.

Ford Creek originates in limestone and shale cliffs of the Lewis & Clark National Forest. It flows over steep terrain until it reaches foothill prairies where it flows through a broader valley bottom.

Willows, dogwood, forbs, and grasses dominate the lower two miles of Ford Creek. According to MDEQ field notes and pictures collected during 1998, willow densities decrease in a downstream direction from fairly continuous bands to scattered clusters.

Ford Creek flows have also been altered due to the diversion of water at several locations, including a diversion to Nilan Reservoir. These flow depletions have not measurably impacted biota sampled in 1998 (Bahls, 1999; Bollman, 1999). The U.S. Geological Survey (USGS) collected gauging data on Ford Creek from April 1906 to December 1912 (MFWP, 1989). The average annual recorded discharge was 32.3 cubic feet per second (cfs). The maximum discharge recorded was 1,230 cfs on June 19, 1909 during spring snowmelt.

The Ford Creek fishery is composed of approximately 90 percent brook trout, and 10 percent rainbow and cutthroat trout. MFWP surveys indicate brook, rainbow, brown and cutthroat trout are present (MFWP, 1989).

2.8.3 Sun River

From Gibson Dam to the Elk Creek confluence, the Sun River has inadequate stream flows and elevated water temperatures during the summer. The trout fishery is suppressed from inadequate stream flows in this reach even though good fishery habitat exists. Inadequate pool depths, food production, and fish cover result from altered stream flow. Sun River riparian vegetation is sparse from Gibson Dam to the Elk Creek confluence due to the narrow floodplain (MFWP, 1989). Scattered stands of cottonwoods and willows border the river along with undergrowth of rose, grasses, and forbs. As the floodplain widens for the 20 miles above the Elk Creek confluence, deciduous woodland dominated by cottonwoods comprises the riparian zone. When flows are high enough, the upper portion this reach is considered a challenging raft trip because of continuous class 3 rapids.

From the Elk Creek confluence to the mouth of Muddy Creek, the Sun River receives recharge water and a significant amount of sediment from surplus water as a result of irrigation on the benchlands north of the Sun River, via Big Coulee (Duck Creek) and Mill Coulee. This portion of the river has been severely dewatered, causing sediment transport problems and high water temperatures. Bank stability decreases in this reach of the river.

From the Muddy Creek confluence to the mouth, the Sun River receives major recharge from surplus water as a result of irrigation practices, principally via Muddy Creek. Here the channel is confined by sedimentary benchland deposits, as well as by dikes associated with residential development. The channel characteristics and flow are also influenced increasingly in a downstream direction by backwater effects from Black Eagle Dam, which is located on the Missouri River approximately 1.5 miles below the Sun River confluence. From the Elk Creek confluence to the mouth, the riparian zone is a cottonwood-dominated woodland with rose and willows being the common shrub species found in the understory. Grasses, sedges and forbs are also present in many riparian areas.

Attempts were made to estimate trout populations in Sun River in a 1973 - 1974 study by the Montana Department of Fish, Wildlife, and Parks (MFWP), but inadequate samples of fish were captured (Hill, 1976). In 1981, MFWP electrofished the Sun River near Vaughn and Muddy Creek (Hill and Wipperman, 1981). These surveys were conducted to update management files in anticipation of the Muddy Creek restoration project becoming a reality (Table 2-3). MFWP 1987 electrofishing efforts in the Upper Sun River yielded the results in Table 2-4 (Leathe et al., 1988). Three sections of Sun River were electrofished by MFWP in the spring of 2000 with the results in Table 2-5. Other species known to be in the river are fathead minnow and black bullhead.

Table 2-3. 1981 Montana Department of Fish, Wildlife and Parks Electrofishing Results near Vaughn.

Location	Species	No. of fish	Length Range (inches)	Weight Range (lbs)
Sun River above Muddy Creek	Rainbow trout	2	10.7-16.1	0.6-1.5
	Brown trout	6	9.6-11.7	0.3-0.6
	Brown trout	3	14.5-20.8	1.1-3.1
	Northern pike	1	33.1	10.0
	Also captured Carp, Mtn whitefish, Longnose sucker, White sucker			
Sun River below Muddy Creek	Rainbow trout	1	7.6	0.19
	Brown trout	1	9.8	0.38
	Brown trout	9	13.2-21.2	0.92-3.0
	Burbot (Ling)	1	28.5	3
	Also captured Carp, Mtn whitefish, Longnose sucker, White sucker			
Muddy Creek T22N, R2W, NW 1/4 5	Rainbow trout	2	11.9-13.7	0.74-1.00
	Also captured White sucker, Fathead chub, Lake chub, Longnose dace, Brassy minnow			
Muddy Creek T22N, R1W, SE 1/4 3	No trout; captured Lake chub, White sucker, Longnose sucker, Mtn sucker, Mottled sculpin			
Muddy Creek T22N, R1E, NW 1/4 32	Brown trout	2	10.8-19.7	0.44-3.02
	Mtn whitefish	1	13	0.9
	Also captured Longnose sucker, Mottled sculpin			

Table 2-4. 1987 Montana Department of Fish, Wildlife and Parks Electrofishing Results in the Upper Sun River.

Location	Section length	Species	No. of fish	Length Range (inches)	Weight Range (lbs)
Sun River Below Diversion Dam	500 yds.	Rainbow trout	15	4.6-8.4	0.03-0.21
		Rainbow trout	7	10.2-13.8	0.38-0.8
		Brown trout	1	12.6	0.69
		Brook trout	1	6.1	0.06
		Mtn whitefish	4	3.5-6.2	0.03-0.08
		Also captured Longnose sucker, Mtn sucker, Mottled sculpin			
Sun River 287 Bridge	1000 yds.	Brown trout	3	3.9-5.5	0.03-0.05
		Brown trout	11	7.3-16.5	0.16-1.47
		Rainbow trout	3	6.5-15.3	0.11-1.22
		Mtn whitefish	2	13.3-14.9	0.86-0.98
		Also captured Longnose sucker, Mtn sucker, Longnose dace, Mottled sculpin			
Sun River Simms Bridge	1 mile	Brown trout	29	3.3-5.8	0.03-0.06
		Brown trout	20	7.1-13	0.12-0.94
		Brown trout	15	16.2-22.5	1.44-3.54
		Rainbow trout	5	7.6-13.5	0.18-0.85
		Mtn whitefish	6	3.7-4.5	
		Mtn whitefish	6	8.1-13.9	0.16-0.79
		Mtn whitefish	1	18.4	2
		Also captured white sucker, Longnose sucker, Mtn sucker, Longnose dace, Lake chub, Mottled sculpin			

Table 2-5. 2000 Montana Department of Fish, Wildlife and Parks Electrofishing Results from the Upper Sun River – Provisional Data.

Section Location	Section Length (miles)	Year	No. of Trout Per Mile > 8 inches	80% Confidence Intervals
Just downstream from Highway 287 Bridge	2.6	1997	63	36-90
		2000	157	124-190
		2002	130	106-154
		2003	91	65-117
Between Lowery Bridge and Simms	5.0	1997	58	36-80
		2000	49	33-65
		2003	37	15-59
Just downstream from Town of Sun River	5.3	1997	-	-
		2000	81	41-121
		2003	48	15-81

There are a number of constraints on the trout fishery in the Sun River. Large fluctuations in stream flow, which often fall below minimum survival flows, are a significant limiting factor. Furthermore, the low flows coincide with elevated water temperatures during the summer months, thereby intensifying the stress on fish. Another limitation on fish populations is loss of fish to irrigation canals. This reduction in the fishery has been ongoing for at least the last 50 years (USFWS, 1952), and according to anglers and landowners, persists to this day. Finally, angling pressure presents a further limitation on the fishery of the Sun River. According to

MFWP (1989), the Sun River as a whole receives a fair amount of fishing pressure. In fact, in 1997, there was an estimated 11,486 angler days for the Sun River.

Rainbow trout and mountain whitefish are the most abundant game fish in the Sun River from the Diversion Dam to the Elk Creek confluence (MFWP, 1989). Recently, brown trout are more abundant on the lower end of this reach due to the decrease in channel gradient and warmer water temperatures.

From the Elk Creek confluence to the mouth, brown trout are the most abundant game fish (MFWP, 1989). Rainbow trout are uncommon throughout this reach, while mountain whitefish are fairly common in the upper half of the reach. A small population of burbot and pike reside in the lower 25 miles of this reach. The fishery here has been limited to short river segments where irrigation return flows and seepage provide marginal flow conditions for trout survival. The fishery in this segment has also been severely impacted by high sediment loads from Muddy Creek (Andrews, 1985b; Ingman et al., 1984).

2.8.4 Muddy Creek

Muddy Creek is a tributary of the Sun River. The Muddy Creek watershed encompasses an area of 314 mi^2 within the Sun River watershed (Andrews, 1985a). Muddy Creek flows approximately 40 miles from an elevation of 3,880 ft generally southeastward to the confluence with Sun River west of Great Falls at an elevation of 3,350 ft. The headwaters border the Teton River, Freezeout Lake, and Benton Lake watersheds.

Muddy Creek typically exhibits an F6, entrenched, channel type throughout its length. The degree of Muddy Creek channel incision increases in a downstream direction. From the headwaters to the Gordon Bridge, Muddy Creek's channel is influenced by underlying Colorado Shale bedrock and overlying Pleistocene gravel and silt deposits (Andrews, 1985a). Downcutting, or channel degradation, is restricted above the Gordon Bridge to some extent because of bedrock that underlies the stream channel. On the lower end, the channel meanders through Pleistocene gravels and glaciolacustrine deposits, which form benches a hundred feet or more above the creek. Bedrock is not controlling the stream channel in this area and in places the stream channel has downcut, or degraded, 30 feet or more. The overall average gradient of Muddy Creek is 0.002 ft/ft. Muddy Creek's stream bottom is composed mostly of silt.

Muddy Creek's hydrophobic riparian vegetation is sparse due to the incised nature of the channel. An overstory is generally lacking in the Muddy Creek riparian zone. Sparse willows, wild rose, and weedy forbs were the typical riparian vegetation found along Muddy Creek (Andrews, 1985a; Systems Technology, Inc., 1979). In areas of minimal disturbance, prairie cordgrass, basin wildrye, western and thickspike wheatgrass, smooth brome, buffalo berry, chokecherry, and snowberry were present (Systems Technology, Inc., 1979). Riparian vegetation types found in the vicinity of return flow confluences include: western and thickspike wheatgrass, basin wildrye, Sandberg bluegrass, blue gramma, green needlegrass, greasewood, Nuttall saltbush, inland saltgrass, foxtail, rubber rabbitbush, cheatgrass, and numerous forbs (Systems Technology, Inc., 1979). Andrews (1985a) describes fairly continuous bands of willows along Muddy Creek in a 1940 aerial photograph.

In the Muddy Creek watershed, return flows from numerous ditches and fields increase flows dramatically during the irrigation months of June through early October. Flows typically peak in July and August due to augmentation from irrigation discharges to wasteways and drains surrounding the Greenfields Bench (McDonald, 2000). Flow peaks during storm events are also appreciably increased during the irrigation season due to the drainage of storm runoff and unused irrigation water into the creek. Intense runoff events that occur during summer thunderstorms commonly accelerate erosion and streambank failures (Andrews, 1985a). Muddy Creek was once an intermittent stream; now baseflow is approximately 30-50 cfs (USGS, 2002).

The fishery is limited in Muddy Creek by habitat, siltation, and flow fluctuations (Hill and Wipperman, 1977). The limited fishery consists mostly of brown trout and whitefish. During recent years, irrigation discharges and energy dissipating restoration work have decreased on-stream erosion to a point that the fisheries likely have changed since the last time fisheries work was conducted.

2.8.5 Freezeout Lake

Freezeout Lake was originally a closed basin that drained an area between the Teton and Sun River watersheds. It is located just north of Fairfield along Highway 89. Previous to the Greenfields Bench Irrigation Project, Freezeout Lake water levels fluctuated naturally because of climate conditions in the area. Water levels were generally at or lower than present water levels but during very wet years water levels rose above current levels. Because Freezeout Lake was a closed basin without a surface water outlet, salinity, selenium and nutrient concentrations fluctuated with water levels. The lake now receives increased water yields through irrigation drainage and canal waste from the Greenfields Irrigation District (GID). Currently there are 27 drains entering Freezeout Lake originating from irrigation of surrounding farmland. As irrigation on Greenfields Bench began, surface and groundwater from the irrigation activities began to influence water levels in Freezeout Lake. Eventually the water level rose above the current SR89 roadbed. In 1953, an outlet ditch to Priest Butte Lake and onto the Teton River was installed. This area is owned and managed by MFWP (MFWP, 1997a). Water levels are regulated for bird production and to moderate salinity levels in the Teton River.

Freezeout Lake consists of shallow ponds that benefit large, diverse, fish, wildlife and bird populations associated with shallow salty wetlands of the arid west. A natural, closed basin has been altered throughout this century; the system now contains several small lake units separated by dike. Water is moved between basins for fish, wildlife and bird management in Freezeout Lake and for salinity control in the Teton River, which receives water from a constructed effluent. The primary inflows are from irrigation return flows from the Greenfields Bench (MFWP, 1997a).

Freezeout Lake is in a natural eutrophic condition and was in this same condition prior to surrounding irrigation (The Fairfield Times, 1954). The maximum lake size is 3,120 acres, but most of its area is actually a shallow, open water wetland. Maximum depth at full pool is 12 feet with an average depth of 4 feet. Less than 10 percent of the lake is greater than 5 feet deep. The MFWP lake database indicates that there is both summer and winterkill that impact fish populations in the lake. Winterkill is likely occurring because of the shallow nature of the Lake. Most people would think of this waterbody as large, shallow, open water wetland that would fall under a warm water classification. The highest use of this area comes during waterfowl hunting season.

The most abundant fish species in Freezeout Lake are carp (Cyprinus carpio) and stickleback (Culaea inconstans). Trout are not expected to sustain a viable population in this shallow lake or wetland setting. The most substantial historical and current use of Freezeout Lake is for waterfowl habitat, although fish, wildlife and other bird species are important components of the ecosystem. Water quality in the lake currently and prior to irrigation activities was most likely marginal at best for support of human drinking water, agriculture and industrial uses.

Lands adjacent to Freezeout Lake consist primarily of native and converted short grass range lands as well as continuous and crop-fallow lands. The basin drains benchlands and erosion formed hills. Dry land cropping and irrigated cropland have been developed in the Freezeout watershed (MFWP, 1997a). The Greenfields Bench lies to the south and west of Freezeout Lake.

MFWP estimates that 80-90 percent of water entering Freezout Wildlife Management Area (WMA) is derived from 3 drainage ditches originating in the Greenfield Irrigation District (MFWP, 1997a). Storm events and snowmelt contribute to most flows from watershed areas used for dry land farming and grazing, although, a couple of spring fed and intermittent drainages contribute somewhat consistent flows from nonirrigated areas. Flows from Freezeout Lake are managed depending on water levels in Priest Butte Lake and flow conditions of the Teton River. Most of the outflow to the Teton River occurs from May to July. Water releases out of Freezeout Lake are intended to maintain or improve water quality in the Teton River and adjust water levels relative to bird habitat in Freezout WMA (MFWP, 1997a). Prior to irrigation of the Greenfields Bench and subsequent drainage control, water levels fluctuated greatly from flooding of US89 to a dry alkali flat in the 1930s (The Fairfield Times, 1954).

Note: Freezeout Lake and Freezout Wildlife Management Area are spelled differently.

SECTION 3.0
WATER QUALITY STANDARDS AND 303(d) LISTING

This section outlines Montana's water quality standards and identifies streams that are listed as not meeting standards on Montana's impaired waters lists, also called 303(d) lists. Other waterbodies not identified on Montana's 303(d) lists that may need restoration are discussed in each of the pollutant sections as sources of the pollutant. This section also gives a brief overview of the point sources in the Sun River TMDL planning area.

3.1 Applicable Laws and Standards

3.2 Applicable Water Quality Standards

Water quality standards include; the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a waterbody. The ultimate goal of this water quality restoration plan, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described in each of the pollutant sections in this document (Sections 6.0-11.0). Pollutants addressed in this water quality restoration plan include: salts, selenium, nutrients, pH, sediment and temperature. This section provides a summary of the applicable water quality standards for each of these pollutants.

3.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. "Designated uses" or "beneficial uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of uses of state waters including: growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana Water Quality Act (WQA) directs the Board of Environmental Review (BER, i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (Administrative Rules of Montana (ARM) 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

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

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

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in Table 3-1. Within the Sun River TPA, the upper Sun River, Ford Creek, Freezeout Lake and Willow Creek Reservoir and Gibson Reservoir are classified as B-1, Muddy Creek is classified as I, and the lower Sun River is classified as B-3. The geographic distribution of stream classifications within the Sun River TPA is shown in Map 1-1. A number of these waterbodies are probably misclassified; see Section 3.2 for more information about the potential misclassifications.

Table 3-1. Montana Surface Water Classifications and Designated Beneficial Uses.

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

3.2.2 Standards

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria and incorporate a nondegradation policy that currently applies to the numeric criteria.

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the department Circular WQB-7 (MDEQ, 2002). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., life long) exposures as well as through direct contact such as swimming.

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

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

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

The standards applicable to the list of pollutants addressed in the Sun River TPA are summarized, one-by-one, below.

Sediment

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in Table 3-2. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a waterbody’s greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied (see definitions in Table 3-2).

Table 3-2. Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will…
17.30.637(1)(a)	…settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
	The maximum allowable increase above naturally occurring turbidity is: 0 NTU for A-closed; 5 NTU for A-1, B-1, and C-1; 10 NTU for B-2, C-2, and C-3).
17.30.602(17)	"Naturally occurring," means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.
17.30.602(21)	"Reasonable land, soil, and water conservation practices" means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.

Metals

Numeric criteria for metals in Montana include specific standards for the protection of both aquatic life and human health. As described above, both acute and chronic criteria have been established for the protection of aquatic life. The applicable numeric criteria for the metals of concern in the Sun River TPA are presented in Table 3-3.

It should be noted that recent studies have indicated some metals concentrations vary throughout the day because of diel pH and alkalinity changes. In some cases the daily variation can cross the standard threshold (both ways) for a metal. Montana water quality standards are not time of day dependent.

Table 3-3. Montana Numeric Surface Water Quality Standards for Metals.

Parameter	Aquatic Life (acute) (µL)[a]	Aquatic Life (chronic) (µL)[b]	Human Health (µL)[a]
Selenium	20	5	50

[a]Maximum allowable concentration.
[b]No 4-day (96-hour) or longer period average concentration may exceed these values.
Note: TR – total recoverable.

Dissolved Oxygen

The freshwater aquatic life standards for dissolved oxygen are presented in Table 3-4. A table of fish spawning times and schedule for the presence of early life stages of fish that are likely found in a given waterbody may be found at http://www.deq.state.mt.us/wqinfo/Standards/SpawningTimesFWP.pdf.

Table 3-4. Aquatic Life Standards for Dissolved Oxygen (mg/L).

Time Period	Use Class A-1, B-1, B-2, C-1, and C-2		Use Classes B-3, C-3, and I	
	Early Life Stages[a]	Other Life Stages	Early Life Stages	Other Life Stages
30-day average	NA	6.5	NA	5.5
7-day average	9.5 (6.5)	NA	6.0	NA
7-day average minimum	NA	5.0	NA	4.0
1-day minimum	8.0 (5.0)	4.0	5.0	3.0

[a]These are water column concentrations recommended to achieve the required intergravel DO concentrations shown in parentheses. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

Temperature

Montana’s temperature standards were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the temperature standards address a maximum allowable increase above “naturally occurring” temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana’s temperature standards address the maximum allowable rate at which temperature changes (i.e., above or below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as B-1, the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67º Fahrenheit) is 1°F and the rate of change cannot exceed 2° F per hour. If the natural occurring temperature is greater than 67º F, the maximum allowable increase is 0.5º F (ARM 17.30.623(e)). For waters classified B-3, the maximum allowable increase over naturally occurring temperature is 3° F and the rate of change cannot exceed 2° F per hour (ARM 17.30.625(e)). For waters classified I, no increase in naturally occurring temperature is allowed which will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife (ARM 17.30.628(e)).

Nutrients

Most waters of Montana are protected from excessive nutrient concentrations by narrative standards. The exception is the Clark Fork River above the confluence with the Flathead River, where numeric water quality standards for total nitrogen (300 ug/l) and total phosphorus (20 ug/l upstream of the confluence with the Blackfoot River and 39 ug/l downstream of the confluence) as well as algal biomass measured as chlorophyll *a* (summer mean and maximum of 100 and 150 mg/m^2, respectively) have been established.

The narrative standards applicable to nutrients elsewhere in Montana are contained in the general prohibitions of the surface water quality standards (ARM 17.30.637 et. seq.). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients.

pH (Hydrogen Ion Concentration)

For I classified waters, hydrogen ion concentration must be maintained within the range of 6.5-9.5 units (ARM 17.30.628(c)). For all other waters, induced variation of hydrogen ion concentration (pH) within the range of 6.5-9.5 units must be less than 0.5 pH units. Natural pH outside this range must be maintained without change and pH naturally above 7.0 must be maintained above 7.0 units.

Salts

There are two narrative standards that relate to salts in state waters. Narrative standards indicate that waters classified as B-1 should be suitable for agricultural use. Other narrative standards applicable to salts in Montana are contained in the general prohibitions of the surface water quality standards (ARM 17.30.637 et. seq.). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to salinity affects upon aquatic life.

3.3 Freezeout Lake, Muddy Creek and Lower Sun River Classifications

In terms of beneficial uses of state waters, Montana first classified its waters in the mid- 1950's followed by a further refinement in the early 1970's. Montana's beneficial water use classifications are based on large-scale basin characteristics, and *all* waters in the state are classified. This approach is in sharp contrast to various other states (e.g., Iowa), where individual waterbodies are named and classified but many waterbodies are left without any classification –or associated water quality standards– short of narrative "free froms". Nevertheless, Montana's water use classification system and the associated water quality standards were developed primarily with the state's flowing waters in mind. This broad-brush approach has assured that all state waters have designated uses and are protected by numeric and narrative water quality standards, but the approach leads to cases where certain waterbodies are not particularly well described by their associated classification. The Department realizes that this all-encompassing classification approach periodically leads to difficulty in the interpretation of some water quality standards and the designated uses vs. existing uses they are to protect. This is particularly obvious in the case of lakes where, for example, the state's dissolved oxygen standards are not always met, even in lakes that have no human-caused impairments.

The Department has not been idle in dealing with this issue; quite the contrary, it has been actively pursuing the development of a lake and reservoir classification system. In late 2002 the Department invested significant time and applied for a nearly $1,000,000.00 federal STAR (Science to Achieve Results) grant specifically geared towards the creation of a lake/reservoir classification system for Montana. Although the Department did not receive the grant, that effort did lead to the development of an *a priori* classification for lakes and reservoirs that can serve as a starting point for a refined classification system. Nutrients and algal density (i.e., trophic state) have long been recognized as key characteristics of non-flowing waterbodies. Since 2003 the Department has been actively sampling both high quality (reference) and a variety of impacted lakes & reservoirs throughout the state for chlorophyll *a*, nutrients, basic water quality measures and shoreline condition. These efforts are continuing.

In summary, the Department is actively researching and progressing towards a lake and reservoir classification system that can be proposed to the Board of Environmental Review through the rulemaking process for consideration, and eventual adoption, into rule. This system will include shallow, saline lakes such as Priest Butte and Freezeout, and the Department believes that this effort is the best means by which the state's lakes and reservoirs can be classified and receive accurate, appropriate water quality standards.

Currently, Freezeout Lake is classified as a B-1 water and thus is 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*." MDEQ recognizes that this may be an inappropriate use classification given the saline and eutrophic condition of the lake. But as discussed above, The Department is actively researching and progressing towards a lake and reservoir classification system that, ultimately, will deal with this issue. This document provides selenium and salinity TMDLs for Freezeout Lake by providing targets that relate to what are thought to be appropriate uses for a shallow saline lake. If the lake and reservoir classification system and subsequent rule making determine a different use classification than those provided for in this document, the Freezeout Lake TMDLs will be revised to reflect appropriate uses at that time. A nutrient TMDL could not be completed for Freezeout Lake because the potential for nutrient conditions in Freezeout Lake is less certain than selenium and salinity and because of lacking data. The nutrient TMDL is phased to be completed after reclassification is considered.

Muddy Creek is classified as an I, or "impaired", water. The I classification acknowledges that all uses are not attainable at this time, but it is the goal of the State of Montana to attain full support of the "*following uses: drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply*". An analysis should be performed for Muddy Creek during a triennial standards review after further fisheries and associated aquatic life and other use data is collected. Subsequent to this analysis, Muddy Creek may be reclassified into an existing use classification that is more appropriate. A new beneficial use support determination would need to be completed after any reclassification. Because the State of Montana has the goal full attainment of uses in Muddy Creek, this document provides selenium, nutrients, salinity, sediment, and temperature TMDLs for Muddy Creek that relate to marginal cold-water fishery. If analysis and subsequent rule making determine a different use classification, the Muddy Creek TMDLs in this document will be revised to reflect appropriate uses at that time.

Currently, the lower Sun River is classified as a B-3 water and thus is "*maintained suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply*." MDEQ recognizes that this may be an inappropriate use classification given that there is a brown trout population in at least a portion of this segment (Table 2-3). Waterbody classifications above and below this segment of the Sun River indicate that the upstream and downstream segments support at least a marginal cold-water fishery. Documents support the fact that Muddy Creek has a negative impact to cold-water fish and associated aquatic life in the lower Sun River (Chrest et al., 1987; Ingman et al., 1984). It is likely that the lower Sun River was classified as a warm water fishery because Muddy Creek influenced cold-water fish habitat conditions in the lower Sun River when the classification originally occurred. Now that Muddy Creek, which is the most influential source of impairment for the lower Sun River, has been addressed with significant restoration practices, a marginal cold-water fishery may be a more appropriate use classification in the lower Sun River. The lower Sun River's use classification will be investigated after further fisheries and associated aquatic life data is collected. Subsequent to this analysis the lower Sun River may be reclassified. TMDL targets and restoration strategies in this document currently address the lower Sun River's B-3 existing classification.

3.4 303(d) List Status

Section 303 of the Clean Water Act requires states to submit a list (i.e., the 303(d) list) of impaired and threatened waterbodies to the EPA every two years. Impaired or threatened waterbodies are those that do not at present fully support all beneficial uses according to the waterbody's classification or meet water quality standards, or are likely to be impaired in the near future. The 303(d) list identifies which beneficial uses are impaired and indicates the probable causes (i.e., the pollutant) and probable sources of impairment.

Six waterbodies in the Sun River Basin occur on the Montana's 1996 303(d) list. The causes and sources of impairment for each 1996 listing is indicated in Table 3-5 and the locations of the waters are shown in Map 1-1. The impairment causes and sources included on the 1996 303(d) list for this watershed were usually based on data that showed impairments, but some of the old listings were based upon professional judgment. While the 2002 303(d) list is now Montana's most current approved list, and is based on greater scientific analysis than the 1996 list, a ruling by the U.S. District Court (CV97-35-M-DWM) on September 21, 2000 stipulated that the state of Montana must complete all necessary TMDLs for waters listed as impaired or threatened on the 1996 303(d) list. Causes and sources of impairment for the 2002 303(d) list are indicated in

Table 3-6. The level of support for beneficial uses indicated in these two lists is identified in Table 3-7. In general terms for the 2002 listings, full support of aquatic life and fisheries uses indicates no standard exceedances and biological communities >75% of potential. Partial support of aquatic life indicates minor standard exceedances and biological communities <75% but >50% of potential. Non-support of aquatic life indicates standard exceedances and biological communities <50% of potential. For detailed listing guidance for aquatic life, fisheries, drinking water, agricultural, industrial and recreational uses see appendix A of Montana's 2002 303d list. Impaired uses, causes, and sources on the 1996 303(d) list may differ from the 2002 listings below as a result of the data review and associated list revisions stipulated by 75-5-702, MCA. This document addresses all pollutant listings on the 1996 and 2002 303(d) lists by either providing a TMDL/Restoration Plan or giving scientific justification that the 303(d) pollutant listing was not justified when further investigation for TMDL formation occurred. Willow Creek Reservoir was only listed for flow alteration on the 1996 303(d) list and is in need of 303(d) monitoring. Willow Creek Reservoir is addressed in this document except by a restoration strategy in Section 11. In this document, the most sensitive beneficial uses are addressed and it is assumed the less sensitive uses will also be met through addressing the most sensitive use.

This TMDL document does not formally list or delist waterbodies. It does provide information for Montana's listing process which is conducted biannually. The next 303(d) list that will reflect information provided in this document will be published in 2006.

Table 3-5. Montana's 1996 303(d) Listing Information for the Sun River Basin.

Segment Name	Waterbody Number	Estimated Length or Area (miles) or (acres)	Probable Cause	Probable Source
Upper Sun River (Gibson Dam to Muddy Creek Confluence)	MT41K001_010	77	Thermal modification Siltation Suspended solids Nutrients Flow alteration	Agriculture[1] Flow regulation/modification Irrigated crop production
Lower Sun River (Muddy Creek Confluence to Mouth)	MT41K001_020	17	Nutrients Salinity/TDS/Sulfates Flow alteration Suspended solids Habitat alterations Thermal modification	Agriculture[1] Flow regulation/modification Hydromodification Irrigated crop production Natural sources Range land
Muddy Creek	MT41K002_010	36	Nutrients Salinity/TDS/Sulfates Flow alteration Suspended Solids Habitat alterations Thermal modification pH	Agriculture[1] Flow regulation/modification Irrigated crop production Natural sources Range land
Ford Creek (Lowest 4 Miles)	MT41K002_020	4	Flow alteration Nutrients	Agriculture[1] Irrigated crop production Off-farm animal holding area
Freezeout Lake	MT41K004_030	3500	Metals Organic Enrichment/DO Salinity/TDS/Chlorides	Agriculture[1] Irrigated crop production Nonirrigated crop production
Gibson Reservoir	MT41K004_020	1282	Flow alteration Siltation Suspended solids	Agriculture[1] Irrigated crop production Natural sources
Willow Creek Reservoir	MT41K004_020	1356	Flow alteration	Irrigated crop production

1 – Agriculture is a category in 303(d) source listing that contains irrigated crop production, nonirrigated crop production, range land, grazing related sources, riparian range grazing, crop-related sources and off-farm animal holding area subcategories. When lists are compiled, all categories and subcategories are listed.

Table 3-6. Montana's 2002 303(d) Listing Information for the Sun River Watershed.

Segment Name	Waterbody Number	Estimated Length or Area (miles) or (acres)	Probable Cause	Probable Source
Upper Sun River (Gibson Dam to Muddy Creek Confluence)	MT41K001_010	80.3	Phosphorus Thermal modification Dewatering Habitat alteration Bank erosion Riparian degradation Nutrients Flow alteration	Irrigated crop production Riparian pasture grazing Channelization Flow regulation/modification Agriculture Crop-related sources Grazing related sources Hydromodification
Lower Sun River (Muddy Creek Confluence to Mouth)	MT41K001_020	17.1	Nutrients Siltation Salinity/TDS/Sulfates Flow alteration Suspended solids Bank erosion Habitat alterations	Agriculture Irrigated crop land Riparian range grazing Channelization Crop-related sources Grazing related sources Hydromodification
Muddy Creek	MT41K002_010	31.8	No causes listed because of use classification	No sources listed because of use classification
Ford Creek (Lowest 2 Miles)	MT41K002_020	2.0	Siltation Bank erosion Channel incisement Riparian degradation Fish habitat alteration Habitat alteration	Riparian pasture grazing Hydromodification Agriculture Grazing related sources
Freezeout Lake	MT41K004_030	3500	Selenium Sulfates Nutrients Noxious aquatic plants Metals	Agriculture Irrigated crop production Crop-related sources
Gibson Reservoir	MT41K004_020		Did not meet SCD*.	
Willow Creek Reservoir	MT41K004_020		Did not meet SCD*.	

*SCD = Sufficient and Credible Data as identified in 75-5-702, MCA.

Table 3-7. Waterbodies on Montana's 303(d) List of Impaired Waters and their Associated Level of Beneficial Use Support.

Waterbody & Stream Description	Waterbody ID #	Use Class	Trophic level	Year	Aquatic Life	Fisheries-cold	Fisheries-warm	Drinking Water	Swimmable (Recreation)	Agriculture	Industry
Gibson Reservoir	MT41K004	B-1	O	1996	P	P					
				2002	X	X		X	X	X	X
Willow Creek Reservoir	MT41K004	B-1	M	1996	P	P					
				2002	X	X		X	X	X	X
Freezeout Lake	MT41O002	B-1	E	1996	P	N		N	P	P	F
				2002	P	N		N	P	P	F
Sun River-from Gibson Dam to Muddy Creek	MT41K002	B-1		1996	P	P			P		
				2002	N	N		F	F	F	F
Ford Creek- from mouth 2 miles upstream (Smith Cr-Elk Cr-Sun R)	MT41K002	B-1		1996	P	P			P		
				2002	P	P		F	F	F	F
Muddy Creek-from headwaters to the mouth (Sun R)	MT41K003	I		1996	N	N		P	N	P	
				2002	N	N		P	N	P	F
Sun River- From Muddy Creek to the Mouth (Missouri River)	MT41K003	B-3		1996	N		N	P	N	P	
				2002	N	N	N	F	P	P	P

Legend
F= Full Support; P= Partial Support; N= Not Supported; T= Threatened; X= Not Assessed (Insufficient Credible Data); E= Eutrophic; M= Mesotrophic; D= Dystrophic; O= Oligotrophic

3.5 Point Source Summary

There are three types of permitted point sources in the watershed. Wastewater treatment plants (POTW), confined animal feeding operations (CAFO) and industrial stormwater sites all have potential discharge into state waters (Map 1-1, Table 3-8). Wastewater treatment plants with NPDES permits are considered as sources and have data to identify loading rates to surface waters for nutrients and total suspended solids (TSS). Stormwater permits are not considered in source assessments because they discharge sporadically and are thought to be a small contributor of all pollutants addressed in this document when compared to other sources. Permitted CAFOs should not discharge unless there is a 25 year, 24 hour storm event. If a storm of this magnitude occurs, other nonpoint sources and natural sources would likely contribute nutrient and sediment at orders of magnitude higher than the CAFOs. The conclusions stated above about CAFOs and stormwater sources are purely based on professional judgment. Current water quality and quantity data for CAFOs and stormwater sources is not robust, and could not contribute to a reasonable assessment of these sources. Future TMDL reviews should consider these sources if there is data to support the assessment.

Table 3-8. Permitted Point Sources in the Sun River Watershed.

Permit	Permit #	Type	Waterbody
Great Falls International Airport Authority	MTR000015	Stormwater	Lower Sun River
CF Motorfreight	MTR000276	Stormwater	Lower Sun River
United Materials of Great Falls	MTR300211	Stormwater	Lower Sun River
Perry Merkel Shop	MTR000413	Stormwater	Lower Sun River
Vaughn Sewer District	MT0021440	WWTP	Lower Sun River
Sun Prairie Water and Sewer District	MT0028665	WWTP	Upper Sun River
Sterling	MTG010111	CAFO	Upper Sun River
Steinback Cattle Co	MTG010130	CAFO	Upper Sun River
Broken O Ranch	MTG010147	CAFO	Upper Sun River
AB Cobb	MTG010038	CAFO	Ford Creek
Town of Fairfield	MTG580003	WWTP	Freezeout Lake

3.6 Impairment Status

Impairment discussions about listed waterbody and pollutant combinations are presented in the beginning of each of the pollutant sections. Categories of 303(d) listings are grouped together in this document according to Table 3-9. Some of Montana's 303(d) listings pertain to sources of pollutants, also called pollution, and are addressed as sources of a pollutant in this document. For example: riparian degradation and bank erosion are sources of sediment and thermal input to a stream.

Table 3-9. Grouping of 303(d) Listings into the Following Sections of this Document.

Section	303(d) listings addressed
4.0 Flow/Discharge	A brief review of water budget and in-stream flow assessment is presented in this section.
5.0 pH	pH
6.0 Salinity	Salinity/TDS/Sulfates Sulfates Salinity/TDS/Chlorides
7.0 Selenium	Metals (primary category for selenium) Selenium
8.0 Nutrients	Nutrients Phosphorus Bank Erosion (Nutrient Source) Noxious Aquatic Plants (Effect of Nutrients) Organic Enrichment/DO (Effect of Nutrients)
9.0 Sediment	Siltation Suspended Sediment Channel Incisement (Habitat/Sediment Source) Fish Habitat Alteration (Habitat) Bank Erosion (Habitat/Sediment Source) Habitat Alteration (Habitat/Sediment Source) Riparian Degradation (Habitat/Sediment Source) Flow Alteration (Habitat/Sediment Source)
10.0 Temperature	Thermal Modification Habitat Alteration (Thermal Impacts) Riparian Degradation (Thermal Impacts) Flow Alteration (Thermal Impacts)

SECTION 4.0
IN-STREAM FLOW/DISCHARGE CONDITIONS

In-stream flow conditions are an important consideration for water quality restoration planning in the Sun River watershed. Restoration strategies will have to address flow conditions to restore water quality. In-stream minimum flows in the Sun River and maximum flow durations on tributaries are crucial for meeting water quality targets and supporting in-stream beneficial uses. Stream discharge is a factor in loading calculations and is an essential part of a holistic watershed planning process. The balance of water use for all expected beneficial uses continues to be a controversial issue in the watershed, but coordinated efforts by stakeholders and water users can achieve more efficient and balanced use of the water.

Under Montana's Administrative Rules, TMDLs cannot diminish, divest or imperil water rights. Most of the Sun River watershed is currently a closed basin to new in-stream water rights due to the over allocation of water, thus restricting acquisition of any future surface water rights. Limited surface water rights may be allocated in Muddy Creek. New groundwater rights are available and may have an impact on in-stream flow. The use of existing water rights also has an impact on water in the river. Modified irrigation methods can impact the amount of acreage that can be cultivated under a water right. The water usage can become more efficient with more acreage under irrigation but more water evaporates or transpires and less returns to streams via the groundwater after use on fields. Therefore, restoring in-stream flows to the Sun River under existing water right law must be voluntarily achieved through locally coordinated efforts and irrigation water management initiatives.

4.1 Existing Flow Conditions

In-stream discharge data exists for 26 USGS discharge measurement sites in the watershed, but only 4 are currently active (Table 4-1). Continuous summer flow measurements have been collected for irrigation management studies during 2001 and 2002 in various locations in the Muddy Creek watershed (Verbal comm. Bauder, 2002). Instantaneous stream flow data is associated with water quality grab samples at various monitoring sites. Discharge monitoring occurred at many sites along the Sun River and at tributary confluences during July and September of 2004. The Sun River Watershed Group and MT DNRC are currently assessing data from this monitoring. Data from this assessment is depicted in Section 11.0 of this document.

Flow alteration in the Sun River watershed is primarily associated with the diversion of water for irrigation (Figure 4-1). Irrigation return flows from surface and groundwater pathways impact water quality in many areas of the watershed. Much of the water from Gibson Reservoir is diverted for use on the Greenfields Bench and Fort Shaw irrigation districts. A portion of the water from the Greenfields Irrigation District returns to Muddy Creek, Freezeout Lake, Mill Coulee and Big Coulee through direct surface wasting and groundwater flow. Installation of Gibson Reservoir in 1929 has changed the stream flow conditions of the Sun River (Figure 4-2). Discharge data indicate that stream flows in the Sun River fall below levels recommended by MFWP for maintaining a healthy fishery near Simms (Figure 4-3; MFWP, 1989). Elk Creek near Augusta and Sun River from the Sun River Diversion to Fort Shaw are on the MFWP

Chronically Dewatered List (MFWP, 1997b). Because of irrigation practices, there is very little inter-annual variation of stream flow in Muddy Creek when compared to the Sun River (Figure 4-4). The Lower Sun River recovers a significant amount of irrigation water via Muddy Creek (Figure 4-5). Other Sun River tributaries that receive substantial inter-basin transferred irrigation water are Duck Creek, Big Coulee, and Adobe Creek.

4.2 Discharge Indicators

General flow targets for the survival of aquatic communities were established using MFWP wetted perimeter data for the upper and lower Sun River and Ford Creek (Table 4-2, MFWP, 1989). MFWP recommended a minimum in-stream flow of 100 cfs on the Sun River from the Diversion Dam to the Elk Creek confluence, a minimum flow of 130 cfs from the Elk Creek confluence to the mouth, which are established as aquatic life survival flows. These flows produce a low level of aquatic habitat potential. MFWP also calculated flow measurements on the Ford Creek, upper and lower Sun River for normal and near optimal conditions for fisheries, at 12, 360 and 220 cfs respectfully. The previously identified basin-wide water budget should assess if and how easily these flow criteria can be achieved or exceeded. For the interim, FWP's flow recommendations are the absolute low flow criteria used for both the upper and lower Sun River and Ford Creek.

MFWP fisheries biologists collected measurements of discharge and wetted perimeter at selected cross riffle sections on each Sun River segment. The discharge and wetted perimeter data were then used in the WETP model to develop a wetted perimeter versus discharge curve. The recommended in-stream flows were derived from the upper and lower inflection points on the WETP discharge vs. wetted perimeter curve. Below the lower inflection point, fish riffle habitat rapidly diminishes and food production rapidly declines with decreasing flows. Above the upper inflection point, food is produced at or near optimum rates regardless of increases in flow. The target value chosen falls within the range of flows that are critically important to food production (Figure 4-2; McDonald, 2000). MFWP flow recommendations are a starting point for restoring in-stream beneficial uses.

Any in-stream discharge requirements above 100 cfs during all but high water years will have significant impacts to existing irrigation system management practices (Ed Everaert, 2001). The USBR requirement for flow over the Sun River Diversion dam is 50 cfs during drought years, as identified by the USBR Standing Operation Procedures Manual (USBR, 2001). The flows at 50 cfs will have impacts to fisheries and aquatic life (MFWP, 1989). Flows sustained at only this minimum level of aquatic habitat function will not achieve full support of the designated beneficial use of cold-water fishery.

Sediment, temperature, selenium, salinity and nutrient impairments in the Sun River and a number of tributaries are directly related to flow conditions or water flow paths. The general flow recommendations proposed by MFWP using wetted perimeter techniques should be considered at a minimum as a starting point when considering discharge criteria that supports beneficial uses. MFWP recommended minimum in-stream flows are used as discharge criteria in this section. More detailed linkage between flow and each pollutant will be assessed in following pollutant TMDL sections if it is possible with existing data. In some cases, discharge modification is identified in a source assessment and subsequently allocated to in the associated TMDL.

4.3 Water Budget Study

Because water quality in the Sun River watershed is very closely tied to in-stream, irrigation, and groundwater movements, a watershed-wide water budget study is important component of a monitoring strategy. Many smaller studies have investigated certain aspects of water movement within the Sun River watershed, but a holistic water budget has not been completed to date. The water budget should have enough detail so that it can be used to guide implementation of reasonable irrigation water management (IWM) practices, make predictions of IWM impacts to in-stream flow, and assess the best options to save water for in-stream use. The water budget should identify the type and location of irrigation efficiencies that will improve in-stream flow during critical times of the year. The analysis should consider both environmental and economic impacts and provide a cost-benefit analysis. The beginning of this water budget assessment occurred during the summer and fall of 2004, but it is unlikely that the data collected this past year is sufficient to meet the goals stated in this paragraph.

Figure 4-1. Diagram of Major Water Flow Paths for Water Use in the Sun River Watershed.

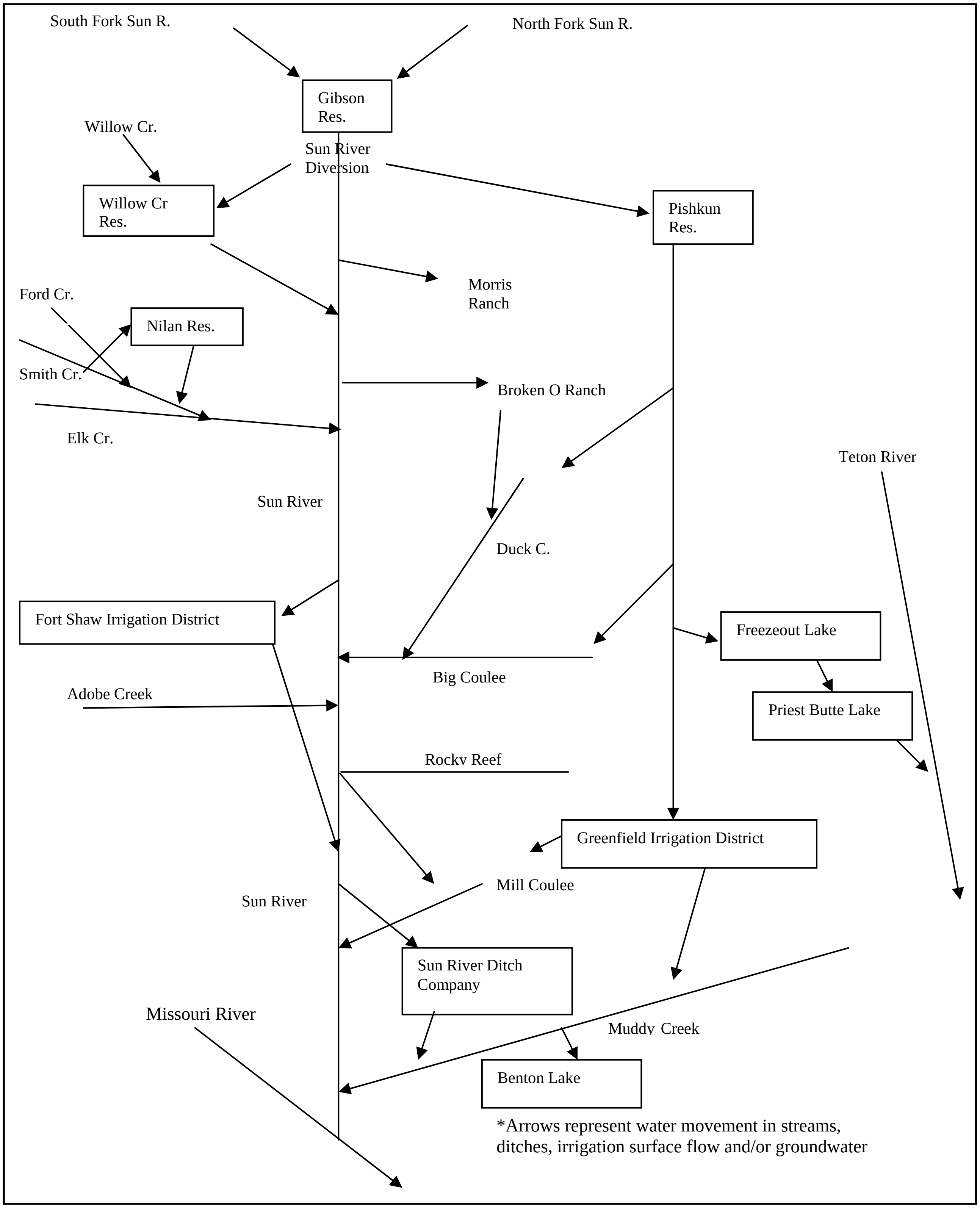
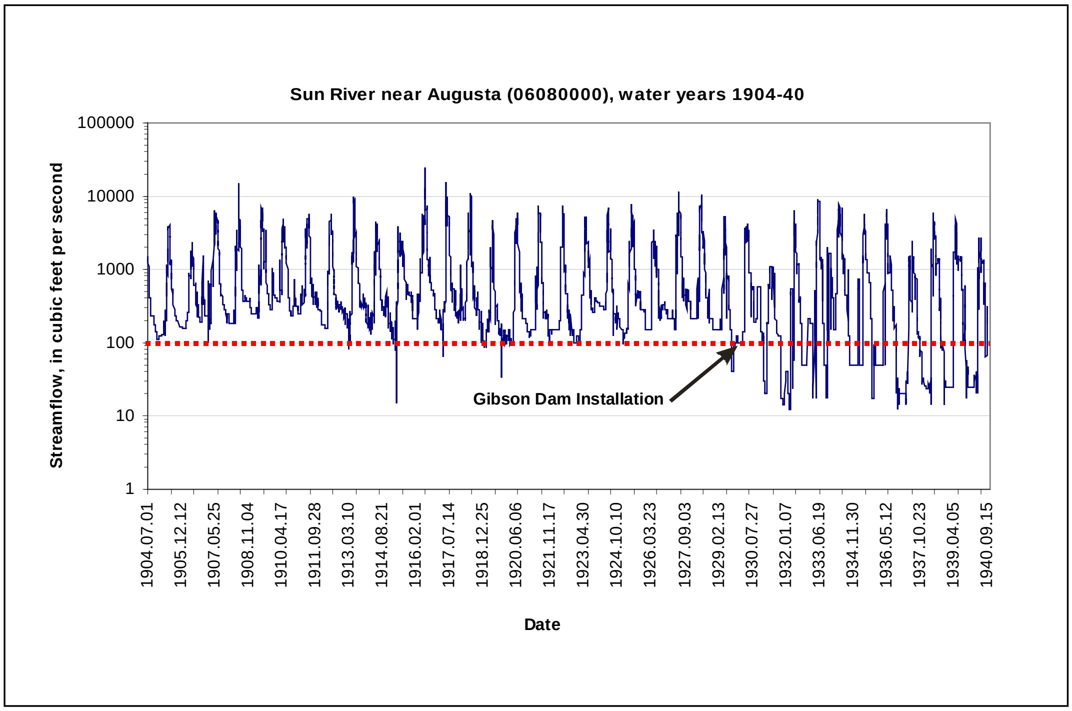
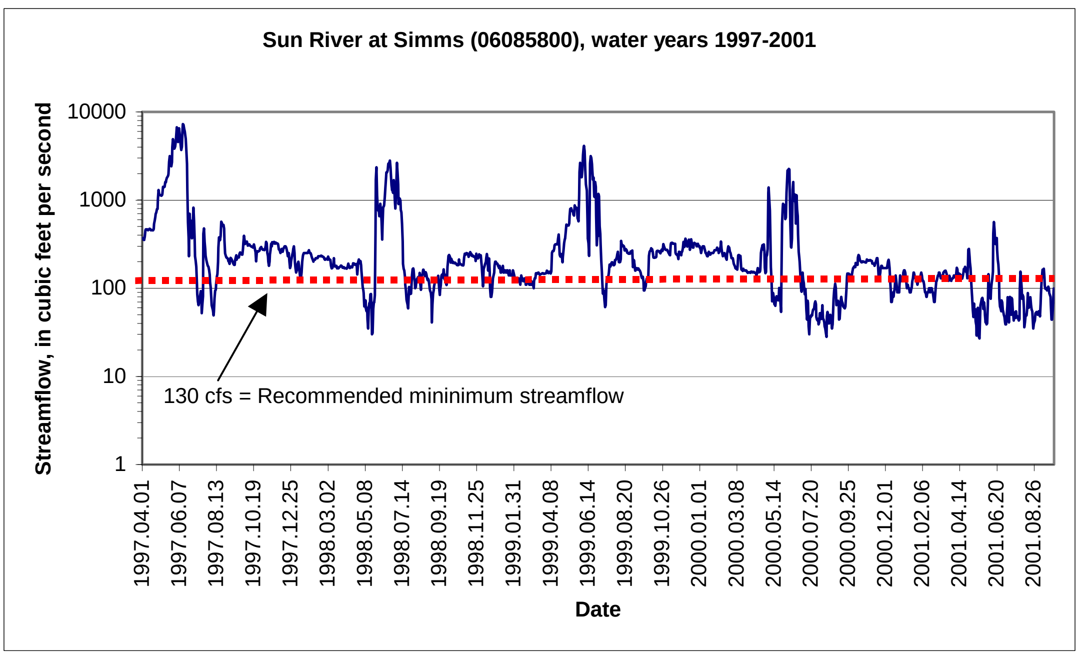


Figure 4-2. Hydrograph Illustrating the Effect of the Gibson Dam Installation in 1929 on Stream Flow Conditions in the Sun River.



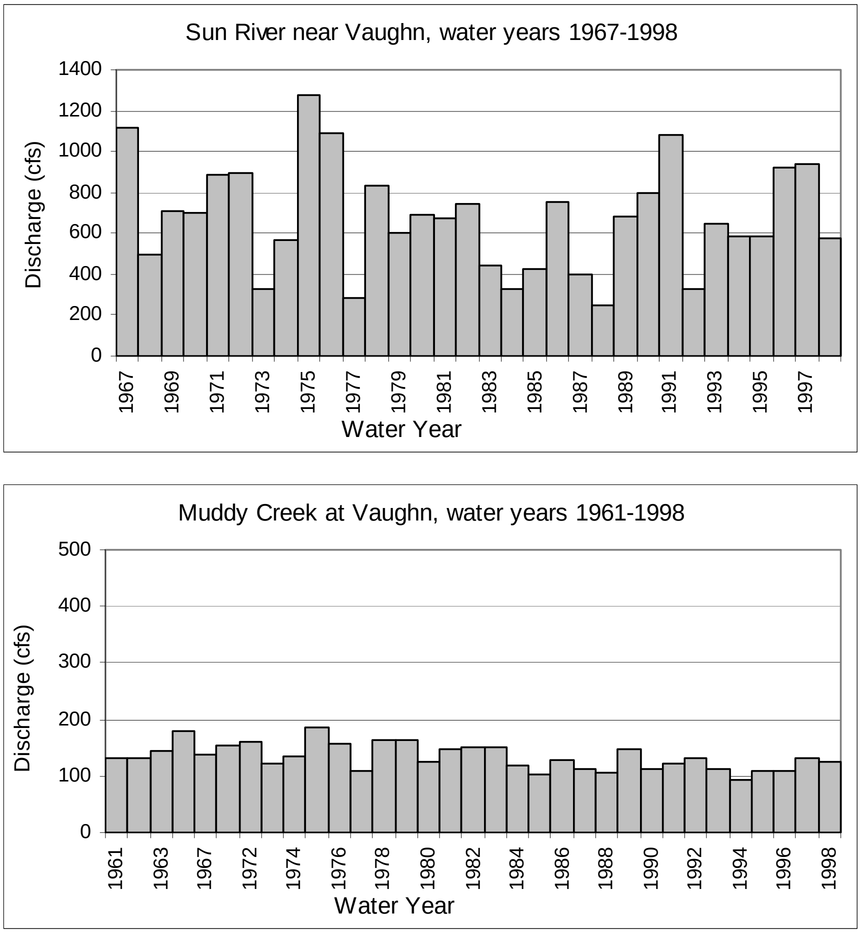
(modified from McDonald, 2000)

Figure 4-3. Sun River Discharge at Simms.



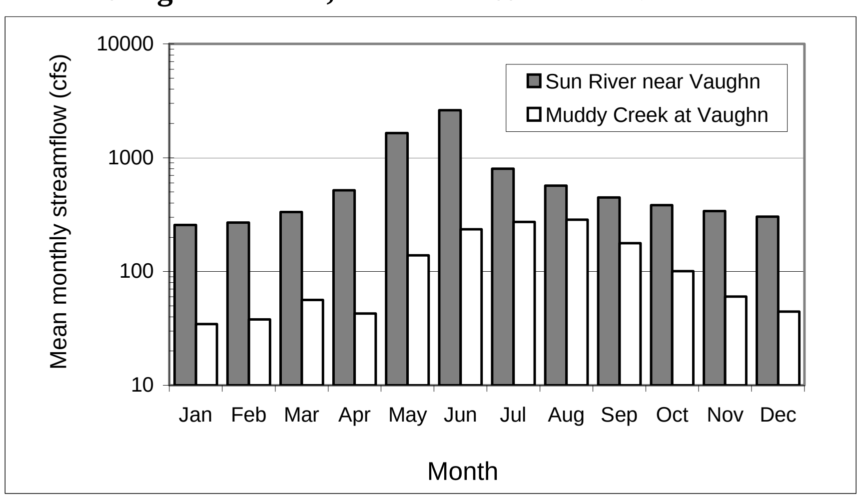
*Flows are compared to in-stream targets derived by MFWP for preserving a healthy fishery.

Figure 4-4. Annual Mean Stream Flow at the Sun River Near Vaughn and Muddy Creek at Vaughn Stations in the Sun River Watershed.



(from McDonald, 2000)

Figure 4-5. Comparison of Mean Monthly Stream Flow for the Sun River Near Vaughn and Muddy Creek at Vaughn Stations, Sun River Watershed.



(from McDonald, 2000)

Table 4-1. USGS Discharge Measurement Stations.

Site Number	Station Name	Latitude	Longitude	Elevation	Drainage Area (Mi^2)	Currently Active?
6087000	Sun River Canal at Vaughn MT	47.567	-111.554			No
6085500	Crown Butte Canal near Simms MT	47.508	-112.026			No
6085000	Crown Butte Canal at Riebeling MT	47.508	-112.143			No
6086500	Sun River Canal near Sun River MT	47.539	-111.740			No
6081000	Floweree Big Canal near Augusta MT	47.550	-112.351			No
6080700	Spring Valley CA bl S V D nr Fairfield MT	47.592	-112.179			No
6080800	Spring Valley CA ab U T D nr Fairfield MT	47.611	-112.138			No
6088100	Spring Coulee near Power MT	47.663	-111.705	3590	30.4	No
6088200	Tank Coulee near Power MT	47.643	-111.680	3510	31	No
6079000	South Fork Sun River near Augusta MT	47.633	-112.868	4730	252	No
6088000	Muddy Creek near Power MT	47.713	-111.723	3640	137	No
6082500	Smith Creek near Augusta MT	47.417	-112.651	4600	25	No
6083500	Ford Creek near Augusta MT	47.433	-112.668	4760	19.4	No
6084000	Smith Cr bl Ford Cr nr Augusta MT	47.433	-112.518	4300	74	No
6082200	Sun River bl Willow Cr nr Augusta MT	47.547	-112.368	3957	827	No
6087500	Sun River at Sun River MT	47.536	-111.717	3400	1454	No
6080900	Sun River bl Diversion Dam nr Augusta MT	47.619	-112.692	4370	609	No
6086000	Sun River at Fort Shaw MT	47.519	-111.815	3465	1417	No
6085800	Sun River at Simms MT	47.502	-111.932	3570	1320	Yes
6081500	Willow Creek near Augusta MT	47.550	-112.468	4150	96.1	No
6084500	Elk Creek at Augusta MT	47.483	-112.384	4070	157	No
6088300	Muddy Creek near Vaughn MT	47.625	-111.636	3442	282	Yes
6078500	North Fork Sun River near Augusta MT	47.641	-112.860	4786	258	No
6080000	Sun River near Augusta MT	47.621	-112.707	4474	609	No
6088500	Muddy Creek at Vaughn MT	47.561	-111.538	3331	391	Yes
6089000	Sun River near Vaughn MT	47.527	-111.486	3317	1854	Yes

Table 4-2. Fish, Wildlife, and Parks Wetted Perimeter Discharge Requirements for Survival of Aquatic Communities.

Stream	Discharge
Ford Creek	12 cfs
Sun River	Drought minimum - 100 cfs above Elk Creek Drought minimum - 130cfs Below Elk Creek Non Drought minimum – 220 cfs
Muddy Creek	None – see Muddy Creek Sediment TMDL for flow duration curve target linked to sediment production from bank erosion

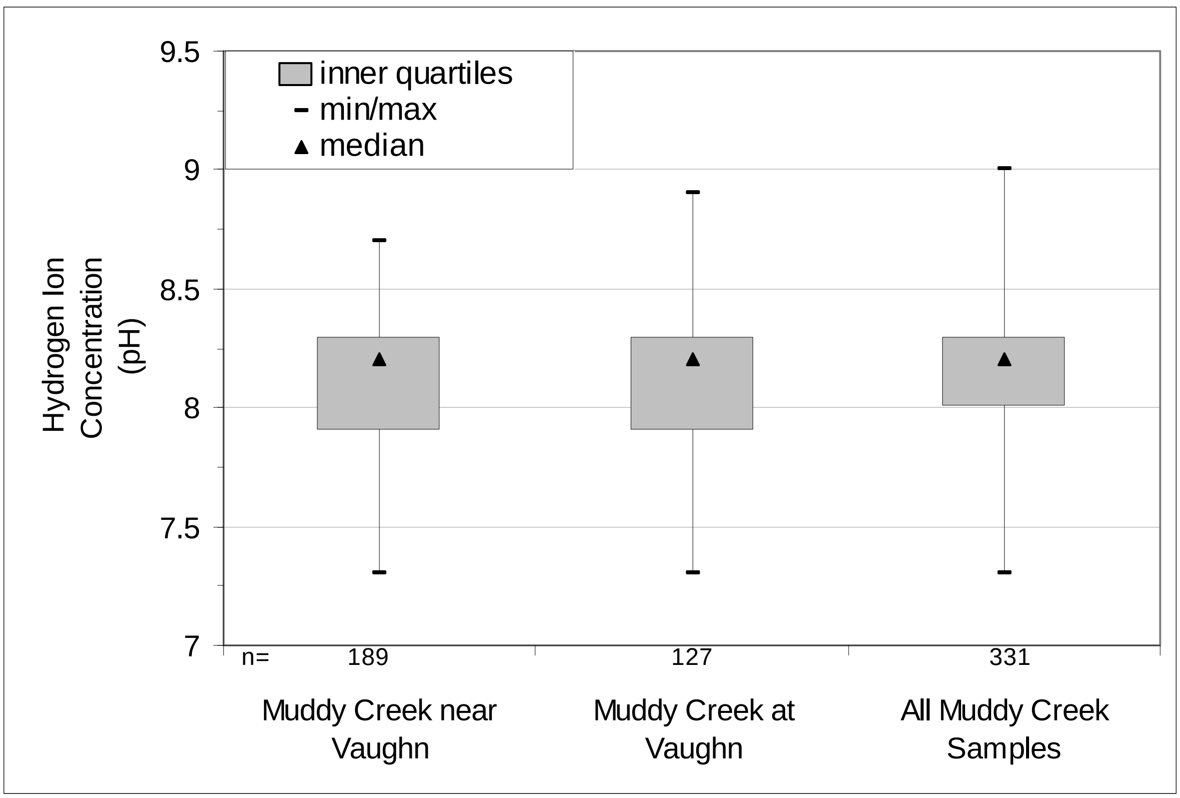
SECTION 5.0
HYDROGEN ION CONTENT (pH)

303(d) listed waterbodies: Muddy Creek.

5.1 Hydrogen Ion Concentration Existing Conditions

Hydrogen ion concentration standards for I classified waterbodies indicate that pH of the water should fall within the range of 6.5 – 9.5 units. Of the 331 pH samples collected in Muddy Creek, no exeedance of standards can be found in existing data to justify the 1996 303d pH listing. All samples are at or below 9.0 units (Figure 5-1). The only significant source of human caused pH change within the watershed is an increase in groundwater flow from irrigation and fallow cropping practices. These practices increase the amount of alkali constituents in surface waters, but usually do not affect pH to the extent that it affects beneficial uses. There are no hard rock or other types of metal mining in the Muddy Creek watershed that influence pH levels.

Figure 5-1. Hydrogen Ion Concentration in Muddy Creek at USGS Stations.



SECTION 6.0 SALINITY

This section of the Sun River Water Quality Restoration Plan focuses on salinity related pollutants. Salinity refers to the total amount of salts that are dissolved in water. Table 6-1 provides a list of waterbodies within the Sun River TPA that appear on either the 1996 or 2002 303(d) list for salt related pollutants. Water quality standards that relate to salinity are reviewed in Section 3.2.2.

Table 6-1. Waterbodies Listed for Salt Related Pollutants in the Sun River Watershed.

Water Quality Limited Segment	1996 303(d) List	2002 303(d) List
Freezeout Lake	Salinity/TDS/Chlorides	Sulfates
Lower Sun River (Muddy Creek Confluence to mouth)	Salinity/TDS/Sulfates	Salinity/TDS/Sulfates
Muddy Creek	Salinity/TDS/Sulfates	No causes listed because of use classification

Some waterbodies are listed for specific ions such as sulfate, chloride, or both. The ion related listings are provided on Montana's 303(d) list to provide the major ion type that contributes to Total Dissolved Solids (TDS) found in the water. TDS is a measure of all the salts dissolved in the water. In the Sun River watershed, beneficial use impacts from salts dissolved in water relate to the overall TDS in the water. All salt related listings, including the specific ions, are addressed in salinity TMDLs for each waterbody by dealing with the total salt content (TDS or Specific Conductance) that affects in-stream biology or irrigation uses. If salts are likely to have an impact on agricultural uses, specific fractions of salts that relate to the sodium adsorption ratio (SAR) of the water are also used as targets in this document.

Specific Conductance is a measure of how easily water can carry an electrical current. If the water has more salt in it, it conducts electrical current more efficiently. Specific conductance and total dissolved solids are highly correlated in the Sun River watershed ($y = 0.6742x$; $R^2 = 0.9785$; $n=177$). Because of the strong relationship between SC and TDS, all SC data was converted to TDS for a more robust analysis. With the exception of figures and tables derived from other documents, all further reference will be to TDS concentrations and will include transformed SC data. Likewise, all narrative reference to figures generated from other studies that use SC as an indicator, will convert the SC data into TSS using the Sun River's coorelation.

The remainder of this section presents all of the required salinity TMDL elements for each of the above listed waterbodies, one waterbody at a time. The salinity impairment status for the lower Sun River indicates that salts do not impair uses and provides rationale that a TMDL is not needed.

6.1 Freezeout Lake

See Section 2.8.6 for a description of the Freezeout Lake watershed.

6.1.1 Salinity Targets and Current Water Quality Status

Targets

Because Freezeout Lake appears to be misclassified, the salinity targets presented in this document are provided as interim targets and will be revised according to results of a use support analysis (see Section 3.2 for further details). If needed, all targets and TMDLs for Freezeout Lake will be revisited after considering reclassification. Beneficial uses associated with Freezeout Lake are primarily for aquatic life that supports the propagation of waterfowl (Verbal Comm. Mark Schlepp, 2002). Salinity targets for Freezeout Lake are designed to protect these beneficial uses.

The Freezout Wildlife Management Area (WMA) salinity in-lake beneficial use target is a TDS concentration of 5,000 mg/L. Both Priest Butte and Freezeout Lake are in the Freezeout WMA. Freezeout Lake and Priest Butte salinity targets are based on the effects of salinity on waterfowl rearing. Priest Butte Lake already has an EPA approved TMDL with this target.

Teal species, gadwall, northern shoveler, lesser scaup and mallard ducks dominate the waterfowl population in the Freezout Lake WMA (Nimick et al., 1996). Of the duck species present in the WMA, mallards had the most salt toxicity information available and were used to set targets. If more robust saline toxicity references for other, more appropriate, duck species become available, targets could be reassessed using the new references in future TMDL reviews. The salinity target is set to protect reproduction and food sources of resident waterfowl species. If the use attainability analysis indicates that more stringent salinity requirements are needed relating to more sensitive uses, future target revisions will be based upon the most sensitive use.

Acclimation of ducklings to salt water is age dependent and ducklings are more sensitive at young life stages (Barnes and Nudds, 1991). Mitcham and Wobeser (1998) indicate that there are no apparent effects in 14 day exposures of mallard ducklings to water in the 2,156-5,147 mg/L TDS range. Growth may have been slowed during long laboratory exposures exposures at 2,904 mg/L TDS concentration (Table 6-2). Swanson et al. (1984) found that drinking water in the range of 11,000 mg/L TDS was fatal to young mallard ducklings (Table 6-2). Another study indicates that 9,000 mg/L TDS had no effect on mallards (Nystrom and Pehrsson, 1998). The target for waterfowl rearing is based on the variable results from laboratory toxicity studies outlined in the National Irrigation Water Quality Program Information Report No. 3, which is summarized in Table 6-3 of this document. Note that the different rows in Table 6-3 are reports from different toxicity experiments and do not always confirm a common conclusion. The use based target is based upon these varying studies and is set at a level that that will likely support a healthy waterfowl population. The existing salinity and waterfowl population condition of Freezeout Lake support this target. Existing salinity conditions are below this target and a healthy resident waterfowl population exists (Nimick et al., 1996). But this isn’t the end of the story.

Table 6-2. Effects of Naturally Saline Drinking Water on 1-day-old Mallard Ducklings

Test Water Conductivity (µS/cm)	Equivalent Sun River Watershed TDS (mg/L)	Length of Exposure	Effects
3,750-7,490	2,717-5,513	14d	No apparent effect
4000	2,904	28d	Poor growth in last 2 weeks
7,720	5,685	14d	Poor growth
20,000	14,868	14d	6 of 10 died, poor growth
21,500	15,990	14d	7 of 9 died
35,000	26,085	60h	100% mortality
67,000	50,015	30h	100% mortality

(Mitcham and Wobeser, 1998)

Table 6-3. Summary of Comprehensive Biotic Effects of Salinity From Different Toxicity Studies.

Species	Salinity Concentration (mg/L TDS)	Effects
Mallard duck	~11,000	Reduced growth; fatal to young ducklings
	8,800-12,000	100 percent mortality
	10,000-15,000	Level of concern
	15,000	100 percent mortality (7-day-old ducklings)
	9,000	Threshold level for adverse effects
Mottled duck	12,000	Reduced growth, 10% mortality
	15,000	90% mortality
	18,000	100% mortality
	20,000	Level of concern

(Modified from Table 30 in USGS, 1998)

Most of the water in the Freezeout Lake Watershed originates from irrigation in the Greenfield's irrigation district. Water moves through Freezeout Lake and then enters Priest Butte Lake. Water from Priest Butte Lake flows into the Teton River. All water movement from Freezeout Lake, Priest Butte Lake and into the Teton River is highly regulated for wildlife management and salt content purposes.

A TMDL is already in place for Priest Butte Lake that considers the in-lake waterfowl rearing use target (5,000 mg/L TDS). Current TDS levels in Priest Butte Lake need to be reduced by 34 percent to meet this target. An assumption in the Priest Butte Lake TMDL is made that there is a directly proportional, positive relationship between Priest Butte in-lake TDS concentrations and loading to the lake. Thus, the Priest Butte Lake TMDL allocation identifies a 34% reduction in load from Freezeout Lake water releases entering Priest Butte Lake. See page 74 of *Water Quality Management Plan and TMDLs for the Teton River Watershed* for further details about Freezeout Lake's existing load to Priest Butte Lake and pages 86-87 for Priest Butte Lake's loading allocation methods. An assumption is made for Freezeout Lake that if concentrations are reduced by 34% and the water budget is static, a 34% loading reduction from Freezeout lake would be achieved. Where the existing TDS concentration in water exiting Freezeout Lake is calculated as a mean of 3,430 mg/L, the 34% reduction target level is 2,264 mg/L TDS. Setting this lower mean target of 2,264 mg/L TDS for Freezeout Lake water releases also drives the in-lake and Freezeout Lake water release target to this lower concentration because in-lake and discharge concentrations are approximately the same (Figure 6-1; Table 6-4).

Table 6-4. Freezeout Lake Targets and Existing Conditions.

Freezeout Lake	Target	Existing Condition
	TDS (mg/L)	
In-lake	< 2,264	mean of 3,430
Water Releases to Priest Butte Lake	< 2,264	mean of 3,338

Assumptions are made for calculating Freezeout Lake's target based upon loading to Priest Butte Lake. The first is that discharge estimates provided by MFWP (1997a) are representative of yearly discharge from Freezeout Lake to Priest Butte Lake. The second is that the water budget of Freezeout and Priest Butte lakes would not change, but the concentrations of salts exiting Freezeout Lake would change due to conservation practices identified in the salinity restoration plan for Freezeout Lake. Given these assumptions, the target calculation is a simple 34% reduction of TDS concentration in water exiting Freezeout Lake. A restoration approach is provided that considers this last assumption.

Existing Conditions and Impairment Status

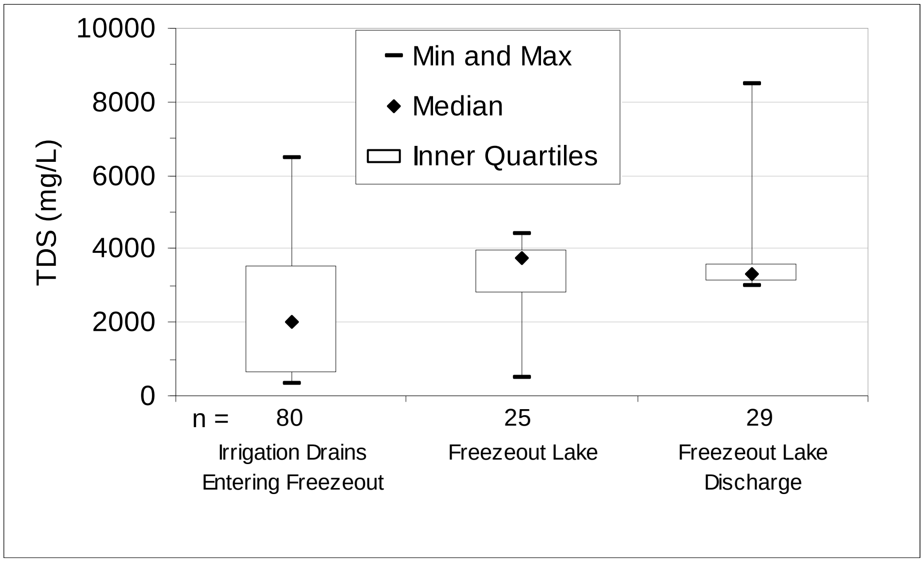
Freezeout Lake was listed in 1996 for Salinity/TDS/Chlorides as a single pollutant category. The 1996 listing indicates that chlorides were the major ion contributing to salinity, which is incorrect. Sulfates are the major ion contributing to TDS in Freezeout Lake. The 2002 303(d) list indicated probable causes of impairment related to sulfates only. This is also incorrect as the listing category should be Salinity/TDS/Sulfates to indicate that salinity and TDS are the major issues impacting beneficial uses and that sulfate is the major contributing ion.

Freezeout Lake was a small, closed basin that historically had fluctuating water levels depending upon variations in weather. Imported irrigation water from the Sun River began to raise water levels in Freezeout Lake and now lake levels are managed. Freezeout Lake water flows through a canal to Priest Butte Lake and ultimately flows into the Teton River. The imported irrigation water is flushing salts out of the saline soils and geology found in the Freezeout Lake watershed, thereby contributing TDS loads to Freezeout Lake and downstream waters.

Mean TDS in Freezeout Lake and the discharge to Priest Butte Lake are 3,338 mg/L and 3,430 mg/L respectively (Figure 6-1). Only one sample from Freezeout Lake or Freezeout Lake discharge exceeds the 5,000 ug/L target value. Mean TDS in water entering Freezeout Lake from irrigated areas is approximately 2,150 mg/L but varies greatly depending upon source area and time of year (Figure 6-1). When comparing existing water quality conditions to targets based upon beneficial uses within Freezeout Lake, it appears the lake is either minimally impaired or not impaired. This water quality based assessment falls in line with a waterfowl study that was conducted on Freezeout Lake indicating a healthy resident waterfowl population (Nimick et al., 1996).

Conditions in Freezeout Lake meet saline water quality goals intended to protect avian populations identified in the section above, but loading to downstream areas is an environmental problem. Freezeout Lake water flows into Priest Butte Lake and subsequently into the Teton River, which are both impaired by salt conditions and have existing salinity TMDLs. The Priest Butte Lake TMDL identifies the Freezeout Lake watershed as contributing 85% of Priest Butte Lake's identifiable salt load and allocates a 34% reduction in load to salts contributed by the Freezeout Lake watershed. Because of this allocation, Freezeout Lake's target is based upon reduction of loads to Priest Butte Lake and meeting waterfowl and associated aquatic life beneficial uses in the lake. A TMDL and further allocation to salt sources within the Freezeout Lake watershed is provided to reduce salt concentrations in Priest Butte Lake. Thus, this TMDL is in reality a further source load assessment for Priest Butte Lake.

Figure 6-1. Total Dissolved Solid Concentrations in Surface Water Irrigation Return Flow to Freezeout Lake, Freezeout Lake, and Freezeout Lake Discharge.



6.1.2 Source Assessment

Sources of salts within the watershed are geologic. Specific soils and geology in the area have high salt content. Soils formed by glacial lake deposits have the highest soil salt content in the watershed and are located around Freezeout Lake (Maps 2-4,6-1). Surficial glacial drift deposits also contain a high salt content and are located northeast of Freezeout Lake. These two geologic sources are moderately permeable and allow water to move through them. Porous formations allow water to move through at a faster pace and thus salts can be leached from these sources. Colorado shale contains high salt concentrations and underlies the eastern half of the watershed but is less porous than the previous glacial lake deposits and glacial drift.

Increased salinity, above natural conditions, in surface water, is caused by significant changes in groundwater flow volume. Activities in Freezeout Lake watershed that increase groundwater volume above natural conditions include irrigated cropping and fallow cropping practices. If these activities exist on porous geology or soils with high salt content, a significant amount of salts can easily dissolve from soils and geology and be transported to state waters. The combination of saline sensitive soils and geology and land use that facilitates salt movement occurs to the south, east and northeast of Freezeout Lake (Map 6-2). The largest human caused contributor of salts to Freezeout Lake is irrigation occurring on glacial lake deposits. The second largest human caused contributor of salts is fallow cropping small grain production on glacial lake deposits, glacial drift, and Colorado shale.

6.1.3 TMDL and Allocations

As stated in the analysis in Section 6.1.1, the major salinity concern in the Freezeout Lake watershed is exportation of salt loads that contribute to downstream impairments. Thus, the targets are based upon loading to downstream waterbodies. The allocation for the Freezeout Lake watershed is a 34% reduction in TDS loads to Priest Butte Lake. Current Freezeout Lake TDS load estimates are calculated in the Priest Butte Lake TMDL using MFWP (1997a) estimates of concentration and discharge. The current estimated daily TDS surface load exiting Freezeout Lake is 83,591 lbs/day and the reduction needed to meet the allocation for the Priest Butte Lake TMDL of 55,170 lbs TDS/day is 28,421 lbs TDS/day. The current load exiting Freezeout Lake is calculated using Equation 6-1 and inserting values from Freezeout Lake discharge, where $Q_{af/yr}$ = 2,790 ac-ft and C = 4,028 mg/L TDS (MFWP, 1997a). Dry land and irrigated area source loads entering Freezeout Lake are calculated using the same equation with the discharge and concentration values indicated in Figure 6-2.

$$Load(lbs/day) = Q_{af/yr} * CF_Q * C * 5.39$$ **Eq. 6-1**

Where:
- $Q_{af/yr}$ = average annual discharge in acre-feet/year
- CF_Q = 0.00138 (conversion factor for discharge from af/yr to cfs)
- C = mean concentration of TDS in mg/L
- 5.39 = conversion factor from mg/L to lbs/day

The USGS estimated that 92 percent of the surface water entering Freezout WMA is derived from irrigation activities (Table 6-5: Nimick et al., 1996). Data from STORET and USGS indicates that the average amount of water entering Freezeout Lake from irrigation activities has a TDS concentration of 2,150 mg/L. Total dissolved solids surface water loading from irrigated lands is estimated at 92.5 percent of total TDS loads entering Freezeout Lake (Table 6-5). USGS estimates that eight percent of the surface water entering Freezout WMA is derived from dry land areas such as grazed lands and fallow cropping areas (Nimick et al., 1996). Limited data is available from STORET and USGS for dry land tributaries entering Freezeout Lake but indicates an average TDS of approximately 1,969 mg/L. Total dissolved solids surface water loading from dry land sources are estimated at seven percent of total TDS loads entering Freezeout Lake. Fairfield TDS load is calculated using one sample of TDS in their effluent measured during 2004 that is assumed to be a constant concentration in their effluent discharge from 1997-2001. Fairfield contributes an estimated 0.5% of the total TDS load to Freezeout Lake.

The TMDL for Freezeout Lake is calculated by adding all source loads from the three sources together and reducing the overall source loads entering the lake by 34%. It is assumed that a 34% reduction in source loads will equate to a 34% reduction in loads exiting the lake. The allocation strategy applies an overall 5% margin of safety when applying allocations to sources within Freezeout Lake. An equal 37.5% source reduction is applied to the fallow-cropped areas and irrigated lands identified in Map 6.2 (Table 6-6). No reduction is needed from the waste load because it is such a minor source. Ultimately, the loading allocations to Freezeout Lake are based upon meeting a 5,000 mg/L TDS target in Priest Butte Lake.

Table 6-5. Estimated Average Annual Dissolved TDS Source Loading to Freezout Wildlife Management Area From Fairfield POTW, Irrigated and Non-irrigated Lands, Excluding the Seep East of Priest Butte Lake.

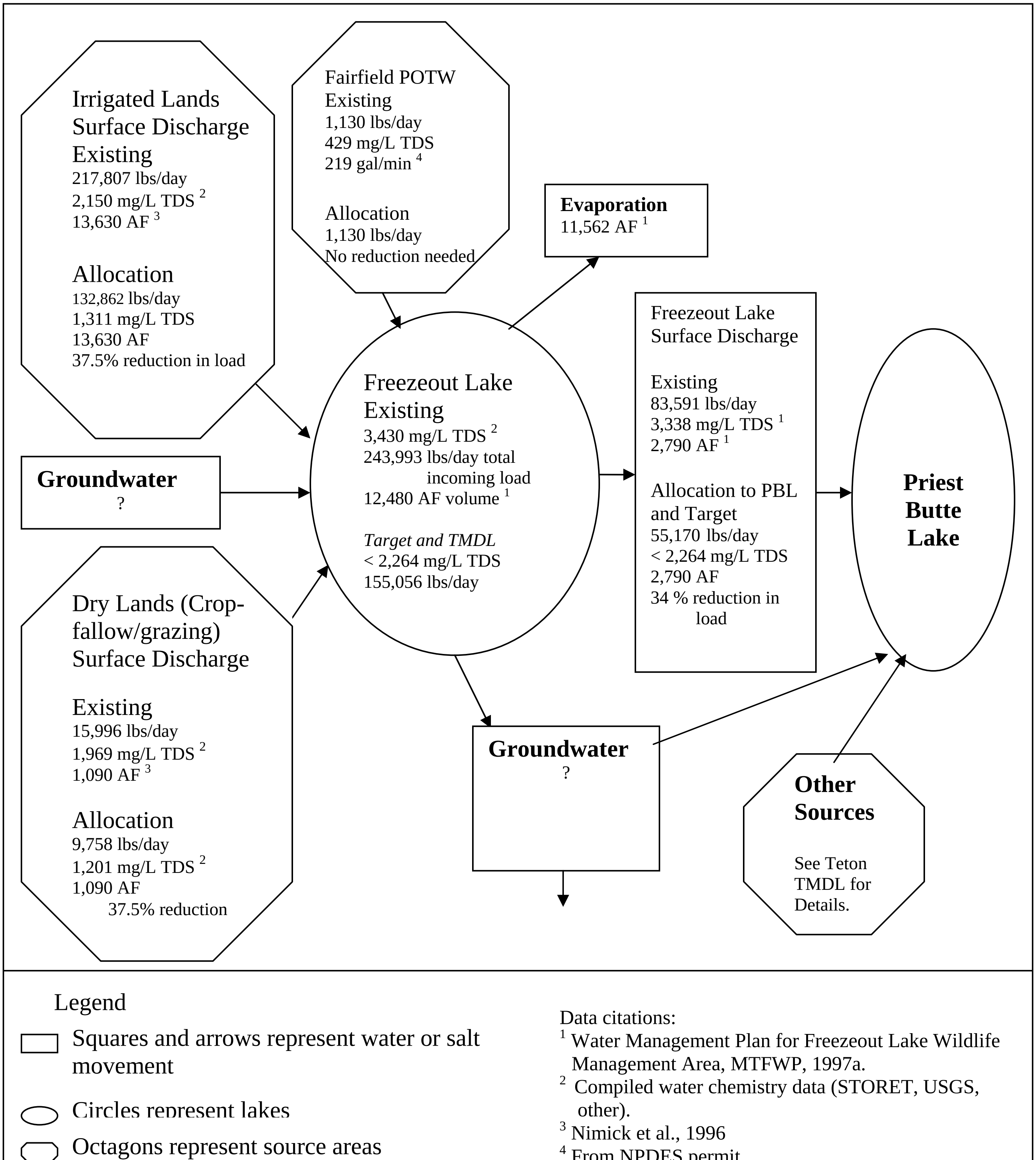
Location	Irrigated = I Non-Irrigated= NI	Underlying Geology	Drainage Area (acres)	Average Annual Flow	Average TDS Concentration (mg/L)	Average Load (lbs/day)	Percent of Current Load	Load per Acre (lbs/day)
Irrigated areas (Area 1 on Map 6-2)	I	Quaternary Gravel and Glacial Lake Deposits	5,732	13,630 AF 18.83 cfs	2,150	217,807	92.5	37.9
Dry land areas East and West of Freezeout Lake (Area 2 on Map 6-2)	NI (fallow cropping grains and limited grazing)	Upper Cretaceous Montana Group and Quaternary Glacial Deposits	69,400	1,090 AF 1.51 cfs	1,969	15,996	7.0	0.23
Fairfield POTW	NA	NA	NA	219 gal/min 0.59 cfs	429	1,130	0.5	NA

Available data are used to calculate TDS loads. A number of data limitations exist, so assumptions have to be made during for the source loading analysis. Limited data is used for calculating dry land source loads. Dry land sources include both fallow cropland and non-irrigated grazing land, but non-irrigated grazing land has a continual vegetation cover and is not considered a human caused source of salts in the watershed. The controllable salt loading from dry land areas originates on fallow crop fields. Another data limitation is that source loads and the Freezeout Lake discharge load are derived from data that represent different timeframes. All loading calculations are surface water loads but groundwater is likely a considerable TDS loading component in the watershed. It is likely that addressing surface water source loads will also address groundwater source loads because source activities affect both surface and groundwater loading.

Table 6-6. TDS Allocation to Sources.

Location	Existing Load (lbs/day)	Percent Load Reduction Needed to Meet Allocation	Allocated Load (lbs/day)	Percent Allocation of TMDL	Load per Acre Allocation (lbs/day)
Irrigated areas including NW portions of Greenfields Bench and off-bench area S&E of Freezeout Lake	217,807	37.5	136,229	87.9	23.7
Dry land areas (grazing/fallow crops)	15,996	37.5	9,945	6.4	0.14
Fairfield POTW	1,130	0	1,130	0.7	---
Margin of Safety	---	---	7,755	5.0	
Freezeout Lake TMDL	---	---	155,056	---	---

Figure 6-2. Estimated Existing TDS Loading, Targets, Allocation, and TMDL for Freezeout Lake.



Data citations:
[1] Water Management Plan for Freezeout Lake Wildlife Management Area, MTFWP, 1997a.
[2] Compiled water chemistry data (STORET, USGS, other).
[3] Nimick et al., 1996
[4] From NPDES permit

6.1.4 Restoration Strategy

The three unnatural sources of salts in Freezeout Lake watershed are Fairfield's POTW, irrigation, and fallow cropping practices. The POTW is not a significant source. Irrigation on sensitive soils and geology is the largest human induced salt contributor to Freezeout Lake. It is important to address this land activity with irrigation water management practices (IWM) because irrigated areas are estimated to contribute 93 percent of the salt loads to Freezeout Lake. Fallow cropping practices that occur on sensitive soils and geology are another source of salt loading in Freezeout Lake that should be addressed by dry land management practices. Map 6-2 provides two restoration areas for the Freezeout Lake watershed that relate to these two salt sources.

It is recommended that all irrigation activities in Area 1 of Map 6-1 be addressed using irrigation water management conservation practices. Addressing the identified irrigation areas with conservation practices is not likely to affect water levels in the Greenfields Bench aquifer, a drinking water source for the Town of Fairfield, because the saline sensitive glacial lake deposits are down gradient from the bench. The irrigation restoration area, between Freezeout Lake and the Greenfields Bench, is predominantly irrigated by water from Greenfield's Irrigation District through a canal system. Drainage ditches, not to be confused with the water delivery canals, have been dug in the glacial lake deposits to intercept shallow groundwater and drain the it from the irrigated soils into Freezeout Lake.

Possible BMPs for the specific irrigation restoration area:

1. **No new irrigated or fallow crop lands.** Given the type of soils, general geology, and existing salinity problems, the land in this area should not be converted to or placed under new irrigation or fallow crop.
2. **Continued improvements in irrigation water management using current hand line sprinklers.** This would mostly include water scheduling to only add water to meet plant needs. Less water would percolate down through salt and selenium rich soils in this area and discharge to the drainage system. This activity is somewhat unrealistic because irrigators would potentially have to move hand-line sprinklers during the middle of the night. This task requires significantly more time and effort from the irrigator at unrealistic scheduling times. This IWM activity will require long-term time and effort commitments from irrigators with limited benefits. It is unlikely this strategy would succeed in significantly reducing salt and selenium loading in the irrigation restoration area for Freezeout Lake.
3. **Switching from flood to pivot irrigation**. Switching to pivot irrigation from hand-lines reduces the effort needed from the irrigator to apply water appropriate to plant need. The unrealistic scheduling effort needed to meet IWM criteria for hand-line operation is automated with the pivot sprinkler system. This task requires a substantial initial financial investment by the irrigator that may be assisted through farm bill programs. Much of this area has already been converted to pivot. This IWM practice is likely to have benefit in reducing loads, but the degree of benefit is unknown.
4. **Canal water loss study/canal lining.** The canal system in this area has not been monitored closely enough to have a true understanding of canal leakage or how much

water canals introduce into the glacial lake deposits. However, lining is normally beneficial to irrigators because of water savings and would be useful in this situation to deter additional water from contacting glacial lake deposits. An irrigation ditch water loss study should be implemented as soon as possible for this area and ditches directly up gradient of the glacial lake deposits. Lining of ditches and canals to reduce water seepage and discharge through the aquifer should occur. There are varying types of lining options that should be explored while considering effectiveness, costs, and location restraints.

5. **Monitor pre and post IWM water budgets**. Freezeout Lake watershed MUST receive approximately same amount of water from the Greenfield Irrigation District as it does currently. All of the IWM practices identified above are directly related to decreasing water application rates to sensitive soils and geology. Any water savings from the IWM must be directly applied to Freezeout Lake through surface water pathways or Freezeout Lake will become saltier.

The irrigation water savings taken from the restoration alternatives identified above in the Freezeout Lake watershed should be applied to moving the saved water from the Greenfield delivery system to Freezeout Lake. Moving additional water from the Sun River is not an option for dilution in Freezeout Lake because the Sun River is currently chronically dewatered. Water is needed in the Sun River to meet in-stream beneficial uses. Water can be managed within the Greenfields Bench irrigation system for diversion to Freezeout Lake instead of discharging to Muddy Creek during high flow events to achieve Freezeout Lake salt targets through dilution.

If applying a combination of the irrigation restoration solutions does not meet salinity allocations for this area, future options become more costly and less desirable. Options may be to reevaluate targets, collect more data to pinpoint specific source locations within the irrigation restoration area, and/or to convert irrigated lands in this area to continual non-irrigated vegetative cover. The costs and benefits of these potential future alternatives should be considered prior to their pursuit.

Areas of fallow cropping occur in the Freezeout Lake watershed and contribute salt to surface and groundwater. Therefore, it is also important to address the fallow cropping that occurs on glacial drift and Colorado shale. BMP strategies on lands recommended for fallow cropping could include reduction in summer fallow acreage, flex cropping, conversion to alfalfa, or temporary inclusion into the Conservation Reserve Program (CRP). It is recommended that the CRP continue to address these areas. If additional resources for the area become available in the region from the CRP program, Area 2 identified in Map 6-2 should have priority for funding.

6.1.5 Margin of Safety, Seasonal Consideration, and Adaptive Management

Since Freezeout Lake is likely misclassified, an analysis of beneficial uses will be completed in the future and this interim TMDL will be reviewed and potentially revised according to outcome of the analysis.

Seasonality is considered by setting average annual allocations and setting targets to protect waterfowl use during all seasons. An overall 5% margin of safety is reserved in the allocation process. The margin of safety is provided because of uncertainties in data analysis that are described earlier in this document and because of variation in saline conditions that arise inter-yearly due to drought conditions in the arid west. The 5% MOS is derived by applying equal, increased reductions to source areas 1 and 2.

An adaptive management approach is being used for meeting salinity targets and TMDL within the Freezeout Lake watershed. Because the analysis cannot determine the actual amount of natural background TSS loading, an adaptive management strategy will be used in the future. If the outlined conservation practices do not achieve targets or load allocations in the watershed, further strategies to meet these goals should be developed in future planning. If the goals of this document appear to be unachievable after all reasonable land, soil, and water conservation practices are in place, targets, TMDL, and allocations may need revision.

6.1.6 Effectiveness Monitoring Plan

An essential component of the water quality monitoring plan for TDS in the Freezeout Lake watershed is continue to monitor Fairfield's NPDES discharge for TDS/SC to verify waste loading to Freezeout Lake. This monitoring requirement will be incorporated into Fairfield's next permit review by MDEQ. The data will then be used during future TMDL reviews to refine the waste load allocation. Currently the waste load allocation is based off of one effluent sample.

Refinement of load allocations may be warranted in the future if funding is available. Dry land TDS loads should be refined and possibly broken into fallow cropping areas and grazed areas. Groundwater loads are unknown at this point in time and may be a considerable component of TDS loading to Freezeout Lake. Groundwater monitoring to estimate groundwater salt loads entering Freezeout Lake from identified source areas is warranted in the future but may be quite costly. The monitoring identified in this paragraph can be thought of as a wish list; it is not essential for future TMDL reviews.

Tracking water quality changes due to restoration activities is an important component of a long term monitoring plan. All IWM and fallow cropping restoration activities in the source areas identified in Map 6-2 should be tracked in a spatial database on a 5-year basis. Loading studies should be conducted along with any IWM practices to observe if increased irrigation efficiency reduces surface water TDS loads to Freezeout Lake. All irrigation alternatives that go beyond conventional irrigation water management practices should be accompanied with monitoring wells to ensure that groundwater salinity loading and transport trends are improving.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Future monitoring activities should include the development of a detailed monitoring plan that includes a quality assurance project plan (QAPP) prior to fieldwork.

6.2 Muddy Creek

Muddy Creek's general watershed description is provided in Section 2.8.5.

6.2.1 Salinity Targets and Current Water Quality Status

Targets

Specific conductance (SC) is referenced in this section because other studies have linked SC to toxic effects on soils, crops, aquatic life and fish. The target justification discusses salinity in relation to SC, but the final targets presented in this section use the strong relationship between SC and TDS to derive targets in the form of TDS.

The technical basis for Muddy Creek's agricultural related salinity targets is contained in the water quality standards for SC and sodium adsorption ratio (SAR) developed for the Tongue and Power River watersheds (MDEQ) and is presented in summary here. The Tongue and Power River standards are intended to protect irrigated field crops and irrigated soils. Targets proposed for the irrigation season are intended to protect the crops growing in the watershed now and those that are likely to be grown in the future.

As the SC of the soil water increases in an irrigated field, a threshold is reached where further increases in SC cause decreases in plant growth. The SC of the irrigation water directly affects the SC of the soil. The SC of soil water may be higher than SC of the irrigation water because plants and evaporation remove water from the soil but do not remove salts. Unless salts are removed or leached from the soil by excess water, the concentration of salts in the soil will build up as irrigation water is added over time.

The water that is applied in excess of the plant use and evaporation to a given area of soil is termed the leaching fraction. This excess water may be supplied by irrigation and by precipitation. However, the portion of the water that is used by plants or which evaporates does not directly add to the leaching fraction. Precipitation or irrigation that occurs when the soils are saturated with water or that is stored in the soil when excess water is applied does directly add to the leaching fraction.

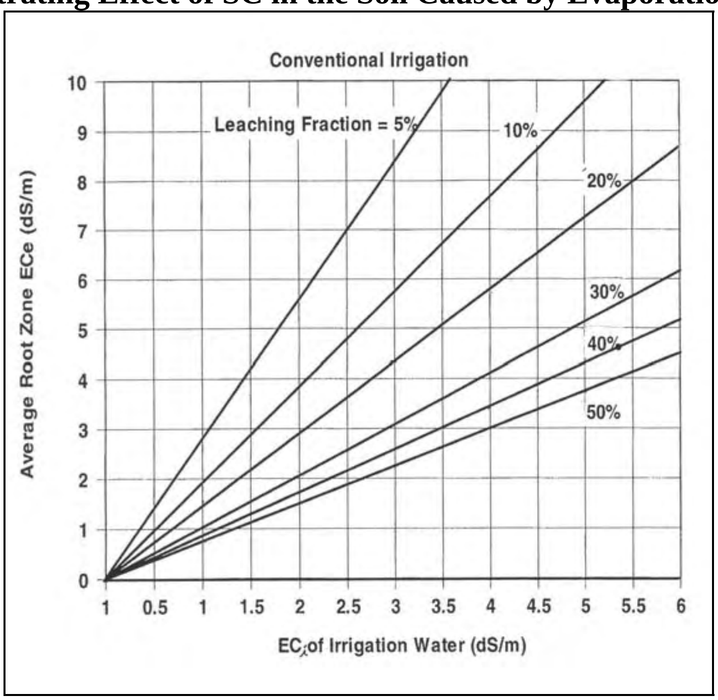
The sodium adsorption ratio (SAR) is a measure of the abundance of sodium relative to the abundance of calcium and magnesium in water. It is directly related to the amount of sodium that is adsorbed by soils. A high SAR in irrigation water has the potential to impair soil structure and thus the permeability of the soil leading to a lack of soil moisture. This is particularly so when the SC of the soil water or applied water is insufficient to counteract the negative effects of adsorbed sodium on soil structure. The SAR of irrigated soils equilibrates with the SAR and the SC of the applied irrigation water over time. That is, if the average SAR of the irrigation water is 5 and the SC is 1,500 μS/cm the SAR and SC of the soils at and near the soil surface will also be about 5 and 1,500 μS/cm within a few years.

Leaching of salts with excess irrigation water or from precipitation will lower the SC of the soil solution while its SAR will remain about the same. SAR of the soil water is controlled by the composition of the exchangeable ions (calcium, magnesium, sodium and potassium) adsorbed on the soil. The number of adsorbed ions is from 10 to 30 times greater than the number of ions dissolved in the soil water. Further, the total number of adsorbed ions does not change as a result of leaching. Consequently, the reduction in SC as a result of leaching can only have a small impact on the composition of the adsorbed ions and the SAR of the soil solution. Only a very small fraction of adsorbed sodium has to replace calcium, magnesium and potassium to maintain the SAR level in the soil water that was present before leaching occurred. As a result, leaching from natural rain can cause SAR problems in the surface soil because the stabilizing effects of other non sodium ions on aggregate stability is lost when the SC is reduced.

Targets for the irrigation season (May-September) are based on field crop irrigation. The techniques for target development for SC and SAR were first used in the Tongue and Powder watersheds of Montana. Sun River watershed salinity agricultural targets are based on crop type, rainfall, soil characteristics and other variables present in the Sun River watershed.

A leaching fraction of 15 percent is typical of conventional sprinkler and flood irrigation, which is used in the basin. Most of the irrigation in the basin is either sprinkler, conventional or modified flooding. The leaching fractions discussed are averages and it is assumed that leaching is uniform throughout a field. In practice, the leaching fraction is not uniform throughout a field and local impacts due to salinity can occur. Although these impacts cannot be quantified, they should be relatively minor. Garden grown crops are not considered because gardens are more closely managed. Plant symptoms of high soil SC and dehydration are the same. In a small garden area, water is easily applied when wilting occurs to overcome high soil SC. With more application of water, a larger leaching fraction is achieved, thus the targets based on a 15 percent leaching fraction are not applicable to gardens. If we assume that a 50 percent leaching fraction is the reasonable tolerance for water application in gardens and use the most sensitive garden crops (strawberries, beans, and carrots), the target would be about the same as that used for field corn. The concentrating effect of SC in the soil caused by evaporation and plant use are summarized in Figure 6-3.

Figure 6-3. Concentrating Effect of SC in the Soil Caused by Evaporation and Plant Use.



(from Hanson et al., 1999)

The diluting effect of precipitation must also be considered in order to correctly calculate SC values for irrigation water that will protect irrigated plants. If more rainfall is flushing through the soils, then higher salt content of irrigation water can be used without negatively affecting the soils and crops. The average annual total precipitation in Muddy Creek and lower Sun River areas is about 12 inches (Prism Precipitation Model, Map 2-1). Field corn is grown during various years in the eastern portion of the Sun River watershed, and is the most sensitive field crop in the Sun River watershed. Field corn requires about 30 inches of water for proper growth plus the 15 percent leaching fraction (34.5 inches total). The diluting effect of this precipitation is dependent on the amount of irrigation water that is applied. According to DeMooy and Franklin (1977), the effective infiltration of precipitation in the region is about 80 percent. That is, some of the precipitation simply runs overland to the nearest drainage without soaking into the soil. This is especially true during thunderstorms, which are common in the region. Therefore, an effective precipitation of 9.6 inches (0.8 X 12 = 9.6) is a reasonable value for calculating the infiltrating rainfall correction factor. The rainfall correction factor for the area is 1.4.

Equation 6-2 Rainfall Correction Factor Equation.

$$Rainfall\,CorrectionFactor = \frac{(Depth_{effectiveprecipitation} + Depth_{irrigationwater})}{Depth_{irrigationwater}} = 1.4$$

Where:

$Depth_{effectiveprecipitation}$ = *average of 12 inches of rainfall X 0.8 = 9.6 inches*

$Depth_{irrigationwater}$ = *total water for plant use and leaching (34.5) – effective rainfall (9.6) = 24.5 inches*

Salinity irrigation targets consider the type of plants being irrigated in the affected area, the sensitivity of those plants to SC, the leaching fractions that are occurring, and the precipitation correction factor. Corn is the most SC sensitive field crop that has been historically grown in Muddy Creek or the lower Sun River areas. The soil water SC threshold of corn is 1,750 uS/cm (Hanson et al., 1999). This is the point where corn productivity declines because of salts in the soil. Using an estimated 15 percent leaching fraction and the relationship between root zone and irrigation water salinity given in Figure 6-3 while applying a rainfall correction factor of 1.4 for increased leaching in the Sun River Watershed, irrigation SC can be 1,576 uS/cm (1,091 mg/L TDS) without affecting corn yields. The irrigation season absolute maximum target is 1,400 uS/cm (960 mg/L TDS). An additional margin of safety will be a target set at 1,000 uS/cm (660 mg/L TDS) average during the irrigation season. The margin of safety is provided because during drought years precipitation may not provide the leaching capacity needed to protect soils and crops. The average growing season TDS target is currently being met at all target sites. SAR should not exceed 4.5 for protecting soil cohesion and permeability properties. Given the current relationship between SAR, TDS and SC, SAR values of 4.5 will be met if the TDS target is met, unless new sources of salts occur in the basin such as coal bed methane or oil production.

Salinity also affects in-stream biological uses. Most freshwater fish, especially salmonids, have a higher salt tolerance than their primary food source, aquatic insects. Shifts in aquatic insect diversity are likely to impact a fishery's food source. Benthic aquatic insects are sensitive to elevated salinity levels in streams (Klarich and Regele, 1980). Although research is limited concerning the affect of salinity on aquatic life, one relevant study conducted in southeast

Montana indicates that as SC levels increase, sensitive macroinvertebrate species are eliminated while more SC-tolerant species increase in abundance (Klarich and Regele, 1980). Thus, while the overall abundance of macroinvertebrates may not change, the diversity, or taxa richness, of the aquatic biota shifts. A shift in the type of aquatic insects found in a stream is likely to affect the type or health of fish found within the stream because aquatic insects are a significant food source for many fish species.

Klarich and Regele (1980) also grouped macroinvertebrate data based on stream salinity values. Streams were segregated based on in-stream biotic reference criteria suggested by McKee and Wolfe (1963) at 2,400 µS/cm and by the National Technical Advisory Committee on Water Quality Criteria (NTAC, 1968) at 1,800 µS/cm. Klarich and Regele (1980) suggest that the 1,800 µS/cm criteria would be better at determining mild salinity stress in streams. The authors also developed a regression equation based on the relationship of mean Margalef Index diversity values and SC that indicated this value is within the low end of a range of slight biological effects. Mount et al. (1997) suggest that chronic toxicity to fresh water crustaceans and minnows can begin to occur with in the range of 1,200 to 1,800 µS/cm. The point at which toxicity manifests, however, is dependent on individual ionic concentrations of the water. MFWP conducted a detailed review of toxicity studies and found relevant toxicity studies for fathead minnows, freshwater crustaceans, walleye and northern pike. The draft review concluded that 1,500 uS/cm SC levels were protective of these species (Skaar, 2003).

A 1,500 µS/cm in-stream use criteria for the Sun River watershed was derived using the general mid-point of the available in-stream uses research for aquatic biota (Klarich and Regele, 1980; Mount et al., 1997; Skaar, 2003). Certain salt ions are more toxic than others and the exact ratio between ions can change over time, therefore a 100µS/cm margin of safety is applied to the criteria above to arrive at a 1,400 µS/cm (960 mg/L TDS) target for aquatic life use. Evaluating the needs of both irrigated agriculture and aquatic biota, a maximum in-stream SC target of 1,400 µS/cm (960 mg/L TDS) is proposed that would be applied to all monitoring stations at anytime of year (Table 6-7). This target should not be exceeded by more than 10% of samples during any month of the year over a 5 year timeframe. It is unknown if natural conditions may exceed this target. In addition, the in-stream salinity target of 1,000 µS/cm, (660 mg/L TDS) is maintained as the seasonal average measured from April 30 to September 30 to protect irrigated agricultural uses (Table 6-7).

Table 6-7. Muddy Creek Salinity Targets.

Waterbody	Targets	
	TDS (mg/L)	SAR
Muddy Creek	< 960 Year round	< 4.5 (May1-Sept 30)
	660 ave. (May 1-Sept 30)	

Impairment Status

TDS concentrations in Muddy Creek fluctuate seasonally and are discharge dependant (Figure 6-4 and 6-5). During low flows, most of the water in Muddy Creek is derived from groundwater that has ample time to dissolve salts from soils and geology. During spring and the irrigation season, more surface water runoff and irrigation to lower TDS concentrations. The average TDS concentration at Vaughn during the irrigation season is 484 mg/L and meets the 660 mg/L TDS average target for the irrigation season (Table 6-7). Fifteen percent of the samples at Vaughn are above the not to exceed target of 960 mg/L TDS. The majority of exceedances, 50 of 57, were during the non-irrigation season. Therefore, Muddy Creek is in need of a TDS TMDL that will protect irrigation and aquatic life based upon the absolute maximum TDS target.

Figure 6-4. Muddy Creek at Vaughn TDS Concentrations During Irrigation and Non-Irrigation Seasons.

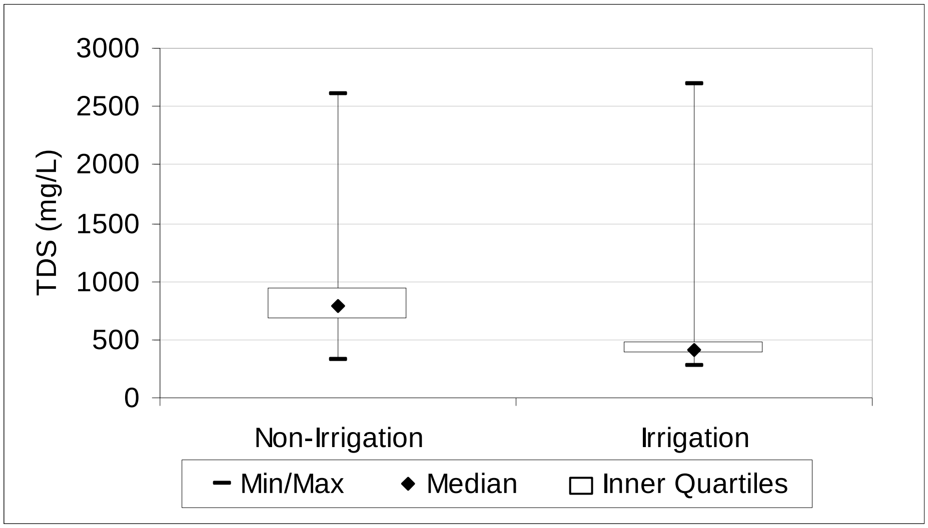


Figure 6-5. Muddy Creek at Vaughn TDS Concentration and Flow Correlation.

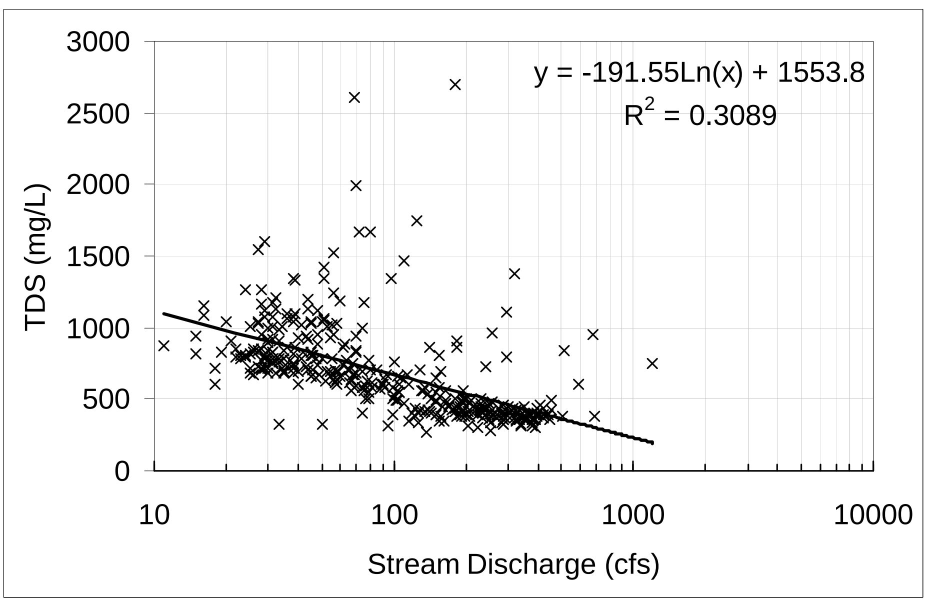
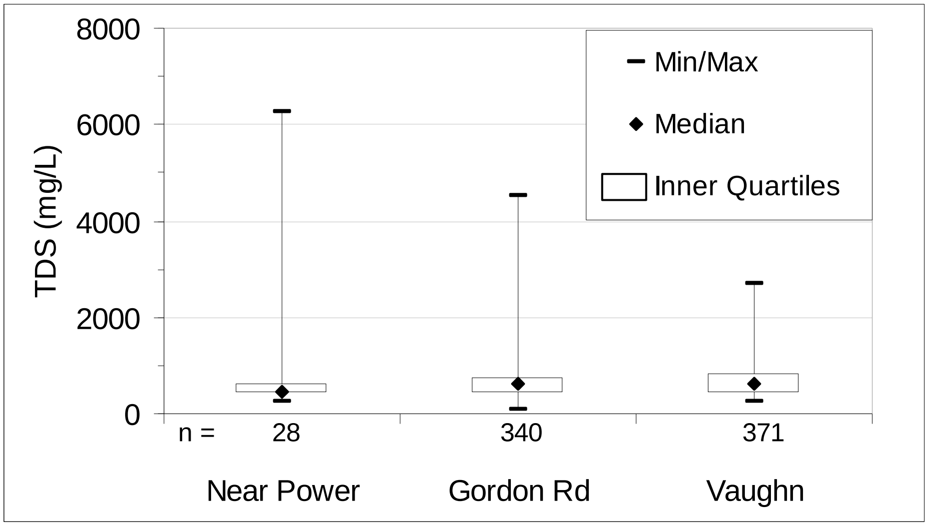


Figure 6-6. TDS Concentrations in Muddy Creek (Upstream to Downstream).



6.2.2 Source Assessment

Sources of salts within the watershed are geologic. Specific soils and geology in the area have high salt content. Glacial drift, present in much of Muddy Creek's watershed, is a deposit that has high salt content and has moderate porosity that allows water to move through it easily. Porous deposits allow water to move through at a faster pace and thus more salts can be leached from these sources. Colorado shale underlies the whole watershed and contains high salt concentrations, but is less porous than glacial drift and therefore likely contributes fewer salts to surface waters. When the water meets the horizontal Colorado shale formation it moves laterally and emerges as seeps and springs as the shale is exposed along the sides of the Muddy Creek valley.

Increased salinity, above natural conditions, in surface water is caused by significant changes in groundwater flow volume or pathways. Activities in the Muddy Creek watershed that increase groundwater volume above natural conditions include irrigated cropping and crop-fallow practices. If these activities exist on porous geology or soils with high salt content, a significant amount of salts can easily dissolve from soils and geology and be transported to state waters. Fallow cropping practices occur on glacial drift overlying Colorado shale in most of the watershed north and east of Muddy Creek. Irrigation occurs to the west of Muddy Creek on the Greenfield's Bench with a very porous gravel deposit that overlies Colorado shale. The gravel in this area has low salt content and the Colorado shale has low porosity.

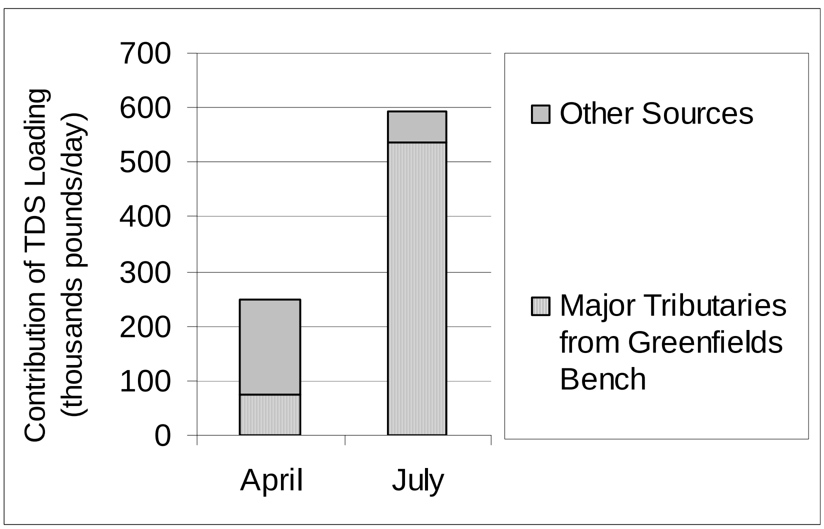
The Montana Bureau of Mines and Geology (MBMG) has collected water discharge and salinity data from Greenfields Bench major drainages during 1999. A gross estimation of salinity source assessment for Muddy Creek watershed is shown in Figure 6-7 using the limited data collected by MBMG during 1999 and USGS data at the Muddy Creek at Vaughn site. Other potential sources of salt loading in Muddy Creek are dry land agricultural runoff and groundwater discharge.

Major irrigation drainages from the Greenfields Bench appear to contribute approximately 90 percent of the total TDS loads to Muddy Creek during the summer irrigation season. It appears that they only contribute about 30 percent of the loads during the pre-irrigation, late winter/early spring, season, when most (50 of 57) target exceedances occur. Only one TDS sample from the Greenfields Bench drainages was above the maximum target concentration of 960 mg/L. Average TDS concentrations of the Greenfield's Bench drainages during the irrigation season were below the average TDS target of 660 mg/L. Other, non-irrigation sources appear to be significant contributors of TDS during the low flow period, when most target exceedances are found. Other sources include dry land areas.

The only other major man caused source is fallow farming. Currently, there is very little salinity or discharge data to assess the fallow crop areas of the Muddy Creek watershed. Gathering water quality data in intermittent or ephemeral streams in these areas poses a challenge. The few samples that have been gathered in the intermittent drainages draining fallow fields indicate that salt concentrations can fluctuate greatly in these areas. A map of irrigated lands, fallow farming, and soil electrical conductance has been compiled for basic source assessment in the Muddy Creek watershed (Map 6-3). The map indicates that the most saline soils, also called saline seeps, are found down gradient from fallow cropping areas.

There are no POTW NPDES sources in the Muddy Creek watershed.

Figure 6-7. Estimated TDS Loading in the Muddy Creek Watershed.



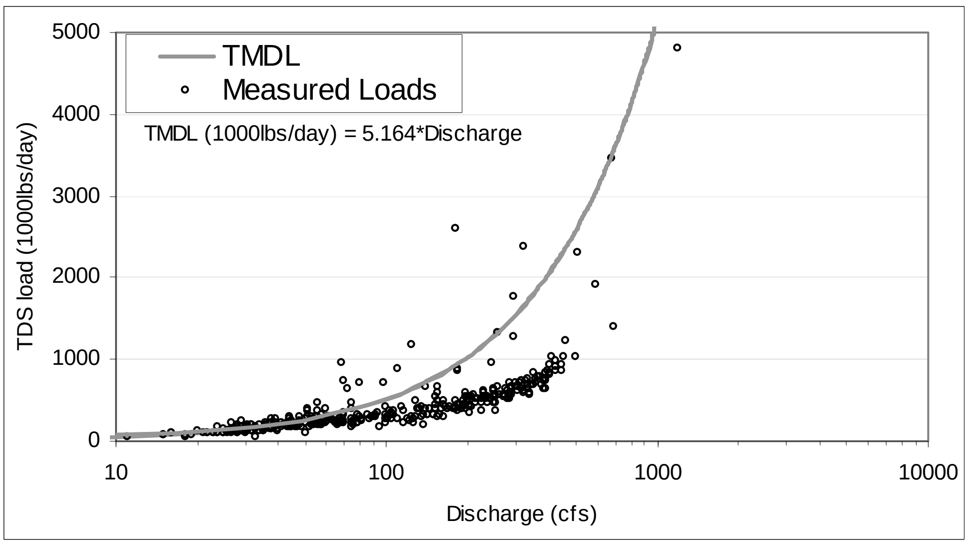
(Data from Miller, 2002 and USGS Muddy Creek at Vaughn Station)

6.2.3 TMDL and Allocations

Muddy Creek's TDS TMDL is based upon the maximum TDS target concentration of 960mg/L (Table 6-7). When the TMDL is exceeded, the targets are exceeded. The TMDL is expressed as a discharge dependant equation in Figure 6-8 and is compared to actual load measurements at Vaughn. Measured load points above and to the left of the TMDL line are exceedances of the TMDL. The figure shows that most of Muddy Creek's TDS TMDL exceedances occur between 25 and 100 cfs during lower flows. These lower flows usually occur during the non-irrigation season. The most sensitive time of the year is April, when the TMDL is exceeded about 60% of the time. Average April loads need to be reduced by 15%. The conversion factor of 5.164 in the TMDL equations is a combination of the TDS target, time, water volume, and mass factors.

Although there is limited direct evidence, strong indirect evidence indicates that areas of fallow farming have the most impact on dissolved salt concentrations during late winter and early spring when dissolved salt concentrations in Muddy Creek are of concern. Data described in the source assessment indicate that irrigation return flows from the Greenfields Bench are a diluting factor that usually contributes to lower in-stream TDS concentrations, and thus, would help meet the TMDL. Therefore, the allocation to irrigated agriculture in Muddy Creek's watershed is to not increase TDS loading. An allocation to fallow cropping will be to reduce April loads by 20%. Applying this allocation to loading during April will also address other less sensitive times of the year.

Figure 6-8. Muddy Creek TDS TMDL and Measured Loads at Vaughn.



6.2.4 Restoration Strategy

Areas of fallow cropping occur in Muddy Creek's watershed and contribute significant amounts of salt during low flow timeframes. Map 6-3 identifies areas of crop-fallow and shows saline seep areas in darker grays that are associated with crop-fallow fields. Therefore, it is important to address crop-fallow that occurs on glacial drift and Colorado shale. Lands recommended for crop-fallow BMPs could include reduction in summer fallow acreage, flex cropping, conversion to alfalfa, or temporary inclusion into the CRP. It is recommended that the CRP continue to address these areas. If additional CRP resources become available for the region, the crop-fallow areas in the Muddy Creek Watershed should receive funding priority.

6.2.5 Margin of Safety, Seasonal Consideration, and Adaptive Management

Explicit margins of safety are provided in the TDS targets. The not to exceed target of 960 mg/L TDS provides a 12% margin of safety when compared to the irrigation target analysis outcome.

The 960 mg/L TDS provides a 7% margin of safety when compared to the in-stream biological use target analysis outcome. Target analysis results for both uses were similar and the MOS was used to make the targets for both uses the same. Also, another margin of safety is an irrigation season average of 660 mg/L TDS and an SAR of 4.5 to ensure that soils are protected against degradation from salts.

Because the source assessment and loading analysis are somewhat weak, a 5% margin of safety is applied to the allocation process. The allocation process uses April loads, during the most sensitive month of the year, to assess load reductions needed from fallow crop areas to meet the TMDL. The 5% MOS is derived by adding an extra 5% reduction of April TDS loads to those called for from fallow crop areas.

An adaptive management approach is being used for meeting salinity targets and the TMDL within the Muddy Creek watershed. If identified conservation practices do not achieve targets or load allocations in the watershed, further strategies to meet these goals should occur in future planning. If the goals of this document appear to be unachievable after reasonable land, soil, and water conservation practices are in place; targets, TMDL and allocations may have to be revised.

6.2.6 Effectiveness Monitoring Plan

Refinement of loads for allocation may be warranted in the future if funding is available. Dry land TDS loads should be refined and possibly broken into fallow cropped and grazed areas. Groundwater loads are unknown at this point in time and may be a considerable component of TDS loading to Muddy Creek. Groundwater monitoring to estimate groundwater salt loads entering Muddy Creek from identified source areas is warranted in the future but may be quite costly. The monitoring identified in this paragraph can be thought of as a wish list; it is not essential for future TMDL reviews.

Tracking water quality changes due to restoration activities is an important component of a long term monitoring plan. TDS and SC trend monitoring should continue periodically at Vaughn. All crop-fallow restoration activities should be tracked in a spatial database on a 5-year basis. Gross groundwater TDS loading estimates from crop-fallow and irrigation sources could be used to shore up source assessment and allocations. Effectiveness studies should occur in coordination with crop-fallow restoration practices to observe if TDS load reductions result.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Future monitoring activities should include developing a detailed monitoring plan that includes a quality assurance project plan (QAPP) prior to fieldwork.

6.3 Lower Sun River

The Sun River's general watershed description is provided in Section 2.8.4.

6.3.1 Salinity Targets and Current Water Quality Status

Targets

The same targets outlined in Section 6.2.1 apply to the lower Sun River.

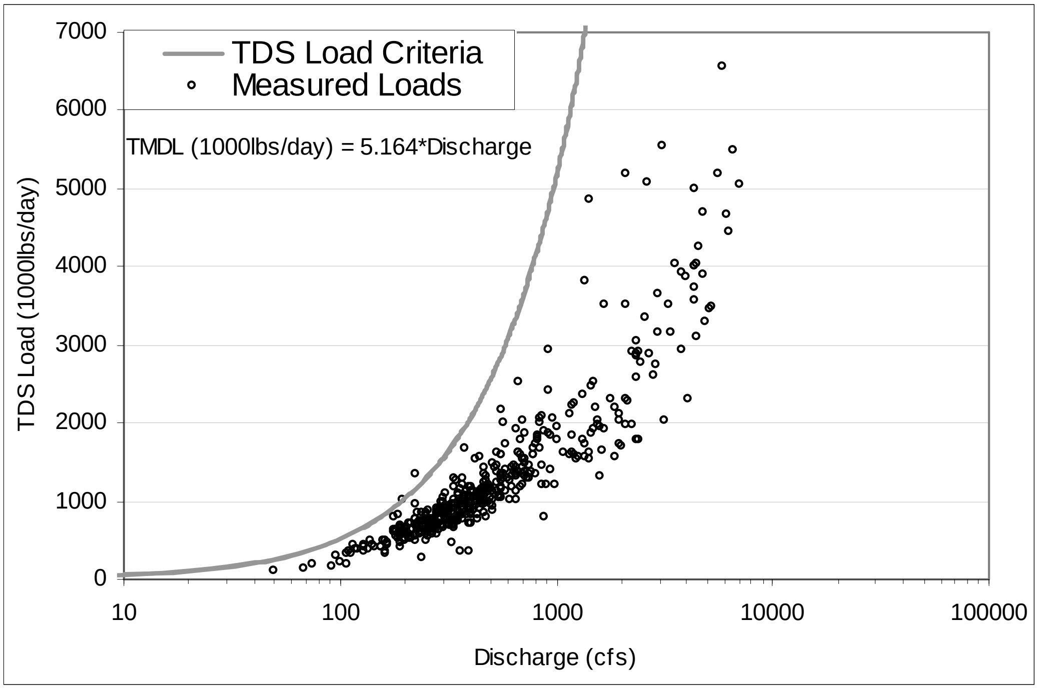
Impairment Status

Sampling on the lower Sun River indicates that targets have been exceeded in only 2 of 466 samples. The two exceedances were detected during 1973 and 1977. Thus, the lower Sun River is not impaired due to salinity. A loading assessment was completed on the Sun River to further demonstrate that there is no need for a TMDL.

Sun River TDS load critera is based upon the maximum TDS target concentration of 960mg/L (Table 6-7). When targets are exceeded, the criterion is exceeded. The loading criterion is expressed as a discharge dependent equation in Figure 6-9 and is compared to actual load measurements at the Vaughn USGS station. This figure shows that the criterion has been exceeded only twice. These exceedances were during the 1970s and do not reflect current conditions. The conversion factor of 5.164 is a combination of the TDS target, time, volume, and mass factors.

Muddy Creek contributes approximately 37 percent of TDS loading to the lower Sun River near Vaughn while the contributing land area of Muddy Creek is only 16 percent of the Sun River watershed. A salinity TMDL is previously provided for Muddy Creek. Section 6.2.3 allocates load reductions to fallow cropland within Muddy Creek.

Figure 6-9. Sun River TDS Loading Criteria and Measured Loads at Vaughn.



SECTION 7.0
SELENIUM

This section of the Sun River Water Quality Restoration Plan focuses on selenium and the toxicity associated with selenium. Selenium is a metal that can dissolve in water and is usually highly toxic to aquatic life at relatively low concentrations. Selenium is an essential trace nutrient for many aquatic and terrestrial species, but at higher concentrations becomes toxic. Selenium is used in photocopying, glass manufacturing, electronic devices, pigments, and insecticides (EPA-440/f-80-070). The largest source of selenium in the environment is weathering of rocks and soils, as is the case in the Sun River watershed. Humans can influence this weathering by increasing water contact with rocks and soils through farming practices and mining.

Complex selenium biogeochemistry cycles in the aquatic environment affect the toxicity of selenium. Selenium can exist in several different oxidation states in water, each with varying toxicities, and can undergo biotransformations between inorganic and organic forms. Currently water quality standards do not consider selenium's oxidation level, but they may in the near future. Selenium also has been shown to bioaccumulate in aquatic food webs, which makes dietary exposures to selenium a significant exposure pathway for aquatic organisms and birds that depend upon aquatic organisms for food sources (USEPA, 1998).

Table 7-1 provides a list of waterbodies within the Sun River TPA that appear on either the 1996 or 2002 303(d) list for metals or selenium. Selenium is the only 303(d) listed metal that is known to affect beneficial uses in the Sun River watershed. Freezeout Lake was listed for metals, with selenium being a subcategory of metals. Therefore, this section deals with both the selenium and metals listings for Freezeout Lake. Muddy Creek has experienced some limited selenium standard exceedances but was never listed for selenium or metals as a cause of impairment. A TMDL is also provided for Muddy Creek in this section of the document as a precautionary measure.

Montana's selenium standards are based on total recoverable analysis. Most samples from Muddy Creek were analyzed for total selenium while most samples from Freezeout Lake were analyzed for dissolved selenium. There currently is not enough total recoverable selenium data in the watershed to construct a relationship to either dissolved or total selenium analyses. The TMDL analysis for Freezeout Lake uses an EPA conversion factor to convert dissolved selenium concentrations to total recoverable concentrations (60 FR 15366).

Table 7-1. Waterbodies Listed for Selenium.

Water Quality Limited Segment	1996 303(d) List	2002 303(d) List
Freezeout Lake	Metals	Metals Selenium

The remainder of this section presents all of the required TMDL elements for each waterbody in need of a selenium TMDL, one waterbody at a time.

7.1 Freezeout Lake

7.1.1 Selenium Targets and Current Water Quality Status

Targets

Standards and targets for selenium are based on total recoverable selenium analysis. Currently, most data in the watershed has been analyzed using either total selenium or dissolved selenium. Problems occur when comparing standards based on total recoverable selenium to total selenium and dissolved selenium analyses. Total selenium analysis uses a more aggressive digestion technique than total recoverable selenium analysis, and the method extracts a larger portion of metals off of and out of the suspended solids in the water sample. Therefore, comparison of total selenium analysis to standards that are based on total recoverable selenium does not always indicate standards are exceeded. Total selenium data can be used as an indicator of metals problems in a watershed when comparing data to standards. It can be assumed that when a dissolved selenium sample exceeds a total recoverable standard, total recoverable selenium will also be above the standard because the dissolved analysis only detects a fraction of the total recoverable analysis. Use of current data in this document will adhere to the assumptions stated above or use the EPA conversion factor (60 FR15366).

Montana has 3 numeric standards for selenium, all of which are based upon total recoverable water chemistry analysis. Two of the standards are set to protect aquatic life use. The chronic aquatic life use standard is 5 µg/L and the acute aquatic life standard is 20 µg/L. A human health standard is set at 50 µg/L (Table 7-2).

Table 7-2. Montana's Water Quality Selenium Standards.

Standard	Total Recoverable Selenium
Chronic Aquatic Life (Not to exceed for longer than a 96hr duration)	5 µg/L
Acute Aquatic Life (Not to exceed)	20 µg/L
Human Drinking Water (Not to exceed)	50 µg/L

Selenium water column targets for Freezeout Lake and Muddy Creek are based on Montana's water quality standards (WQB-7; Table 7-2). Unlike many other metals, aquatic life selenium standards are not hardness dependant. The water column targets proposed for Freezeout Lake and Muddy Creek are based on Montana's chronic aquatic life standard. Acute aquatic life and human drinking water standards are currently being met in both Muddy Creek and Freezeout Lake.

Along with the potential for causing toxicity in the water column, selenium is also accumulating in bottom sediments and bioaccumulating in Freezeout Lake's food chain. Therefore, sediment targets have been identified based on a 4 ug/g recommendation by Lemy and Smith (1987) to curb food-chain bioaccumulation. All targets will be considered attained when there are no exceedances over a five-year period when following the monitoring guidance in Section 7.1.6.

Table 7-3. Selenium Targets.

Waterbody	Targets (total recoverable selenium)	Location
Muddy Creek	5 µg/L Water Column	Muddy Creek at Vaughn
Freezeout Lake	5 µg/L Water Column 4 ug/g Surficial Bottom Sediment	Composite sample of the 3 largest drains flowing from the eastern glacial lake deposits specified in Kendy et al. (1999).

Impairment Status

As stated above, the majority of selenium sampling in Freezeout Lake has been analyzed for dissolved selenium. Irrigation from areas just off of the Greenfields bench have increased groundwater tables and groundwater flow in a sensitive geologic area near Freezeout Lake. Irrigation drains that flow to Freezeout Lake have been installed in this area south and east of the lake (Figure 7-1). Dissolved selenium concentrations in these drains have been found above acute aquatic life standards as well as human health standards. The highest dissolved selenium concentrations in the watershed, as high as180 µg/L, have been measured in these drains.

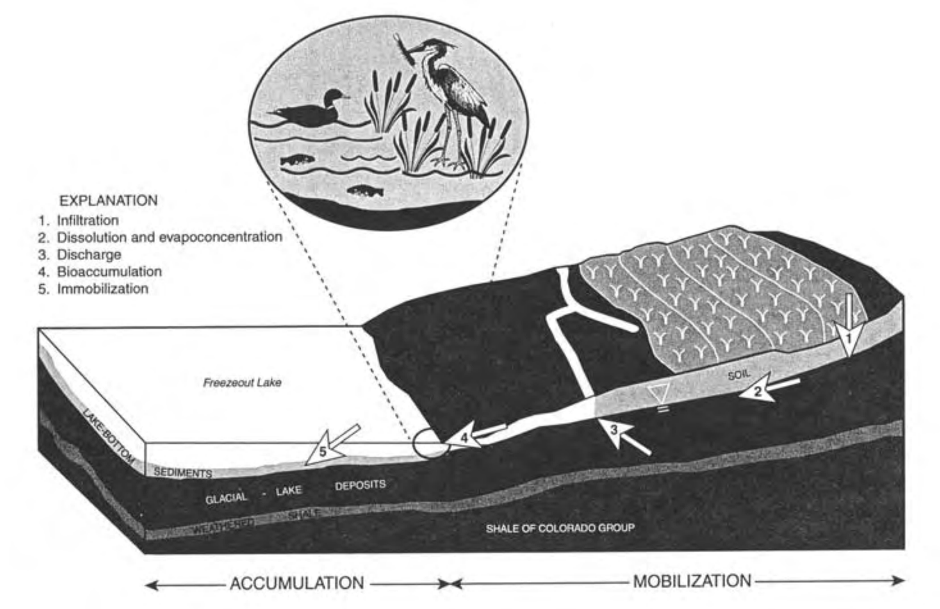
Although multiple samples have not targeted a short time frame to indicate if chronic standards have been exceeded, it is likely that chronic standards are exceeded in the drains as well as in areas of Freezeout Lake near the mouths of the drains. Approximately 9 percent of the dissolved selenium samples from Freezeout Lake are above 5 µg/L. Selenium concentrations above 5 µg/L occur only on the south and east margins of the lake near inflowing irrigation drains. The selenium is quickly adsorbed to sediment or incorporated into biota (Nimick et al., 1996). Water samples collected in the center of Freezeout Lake have lower dissolved selenium concentrations. No acute aquatic life or human health standards have been exceeded in Freezeout Lake samples. Selenium concentrations in lake-bottom sediment are above the limit for biological risk (Kendy et al., 1999) (Figures 7-2 and 7-3).

Minnows and macroinvertebrates are used as food sources for waterfowl in Freezeout Lake. Selenium levels in these food sources are greater than biological risk thresholds (Figures 7-4, 7-5, and 7-6) (Nimick et al., 1996; Kendy et al., 1999). The supply canals and drains of the Greenfields Irrigation District allow forage fish to move into Freezeout Lake during spring, summer and fall. However, the shallow wetlands of Freezeout Lake do not have sufficient depth to sustain a year-round population of forage fish (Nimick et al., 1996). All but a few of the fish samples collected by Nimick et al. (1996) were above the 4 ug/g dry weight concentration suggested by Skorupa and Ohlendorft (1991) as a critical dietary threshold for birds (Figure. 7-4). Almost all taxa of aquatic insects sampled from Freezeout Lake had exceedances of the 4 ug/g dry weight concentration identified as a critical dietary threshold for birds. Aquatic insects in the southern end of Freezeout Lake near irrigation drains had higher concentrations than those sampled in the northern end of the lake (Figure 7-4).

Surprisingly, no evidence of selenium toxicity was observed in Freezeout Lake's waterfowl population even though selenium concentrations in resident birds were above known toxicity thresholds (Nimick et al., 1996). In 1991 and 1992, Freezout WMA waterfowl breeding pairs were estimated at 300 pairs/mi2 and 269 pairs/mi2 respectively. Gadwall was the most numerous resident duck species in Freezout WMA (Figure 7-7). Breeding pair densities compared favorably to those reported for major breeding areas in a prairie setting (Pospahala et al., 1974). Eared grebe nests were monitored and mean clutch size was 2.82 (Nimick et al., 1996). Mayfield nest success and apparent nest success was 41-43 percent and 60-66 percent respectively (Nimick et al., 1996). Embryo viability and death rates at Freezout WMA were not abnormally high during this study (Nimick et al., 1996). The calculated number of ducklings produced at Freezout WMA was 24,281 in 1991 and 31,882 in 1992 (Nimick et al., 1996).

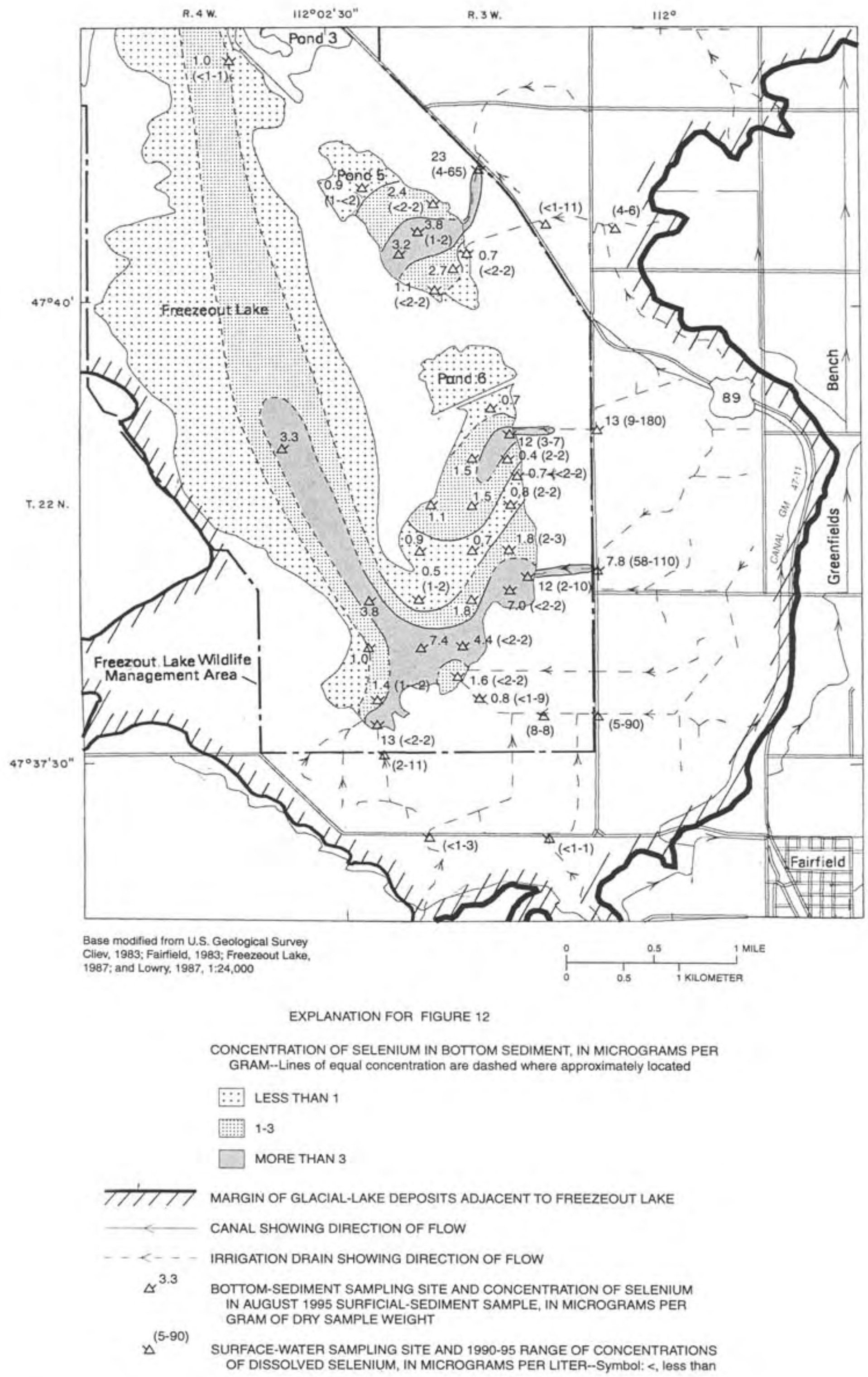
A selenium TMDL is needed because specific areas of Freezeout Lake do not meet Montana's selenium water quality standards and accumulation of selenium in animals and bottom sediments occurs within Freezeout Lake. Unlike salinity, selenium loading to Priest Butte Lake from Freezeout Lake is not a concern because the selenium is effectively trapped in Freezeout Lake by chemical and physical interactions. Selenium concentrations in Freezeout Lake discharge are generally low, between 1-2 μg/L.

Figure 7-1. Conceptual Diagram of Processes Affecting Selenium Mobilization from Irrigated Glacial-lake Deposits and Accumulation in Wetland and Biota of Freezeout Lake.



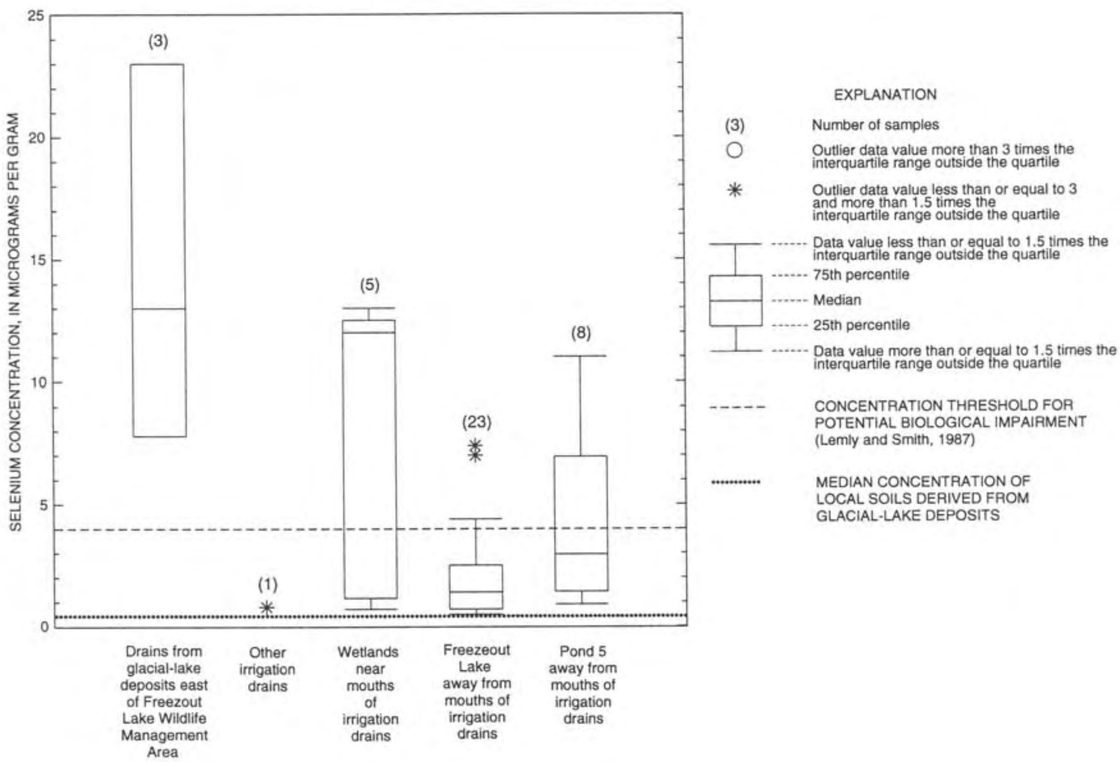
(from Kendy et al., 1999)

Figure 7-2. Selenium Concentrations in Surficial Bottom Sediment in August 1995 and Ranges in Surface Water Concentrations from 1990-1995.



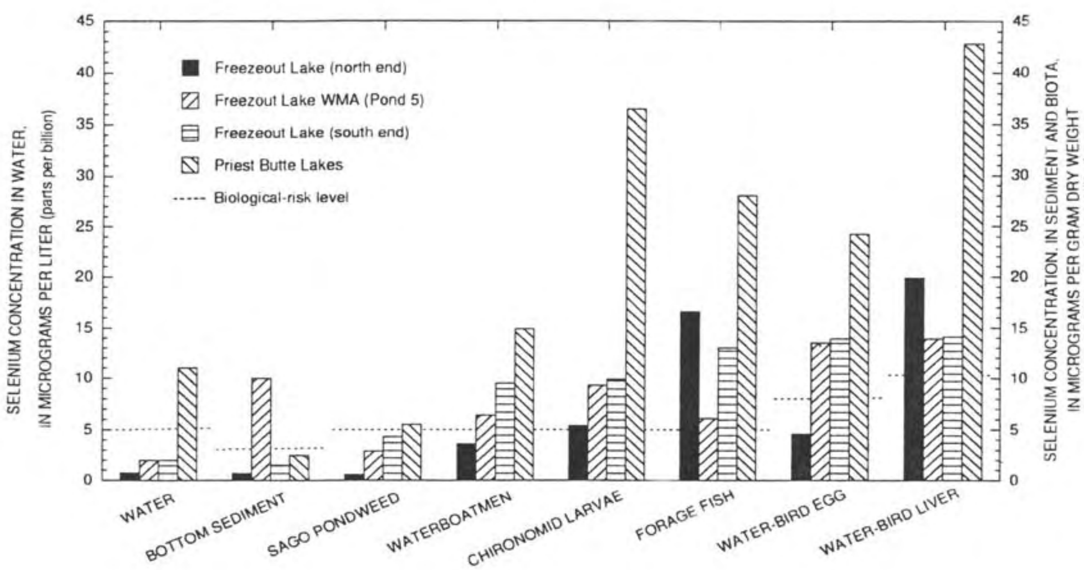
(from Kendy et al., 1999) Sediment samples were unsieved.

Figure 7-3. Distribution of Selenium Concentration in Surficial Bottom Sediment from the Southern Freezeout Lake Area.



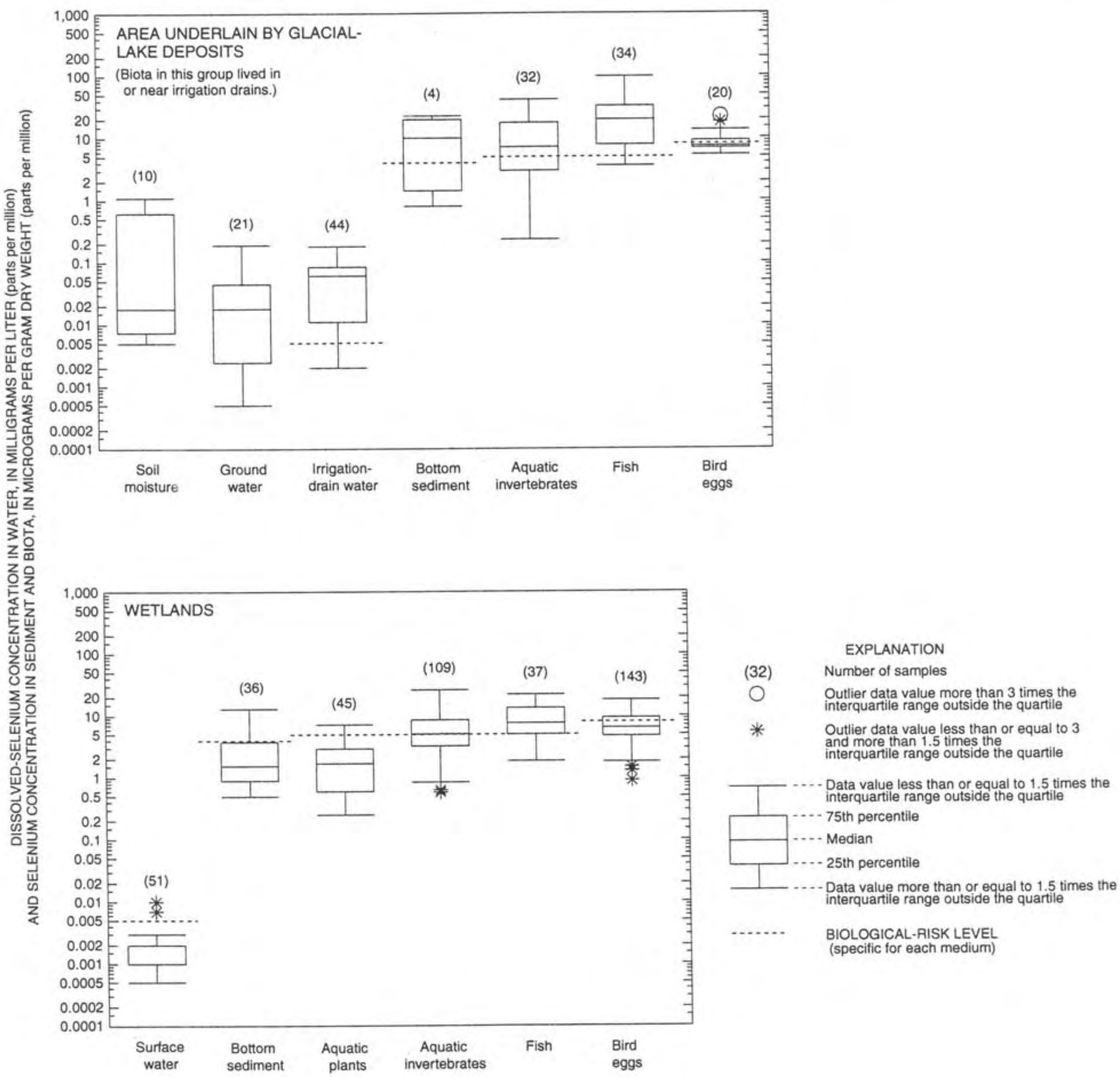
(data from Kendy and Olsen, 1997; figure from Kendy et al., 1999)

Figure 7-4. Mean Selenium Concentration in Water, Bottom Sediment, and Biota from Sites in Freezout WMA and Benton Lake WMA.



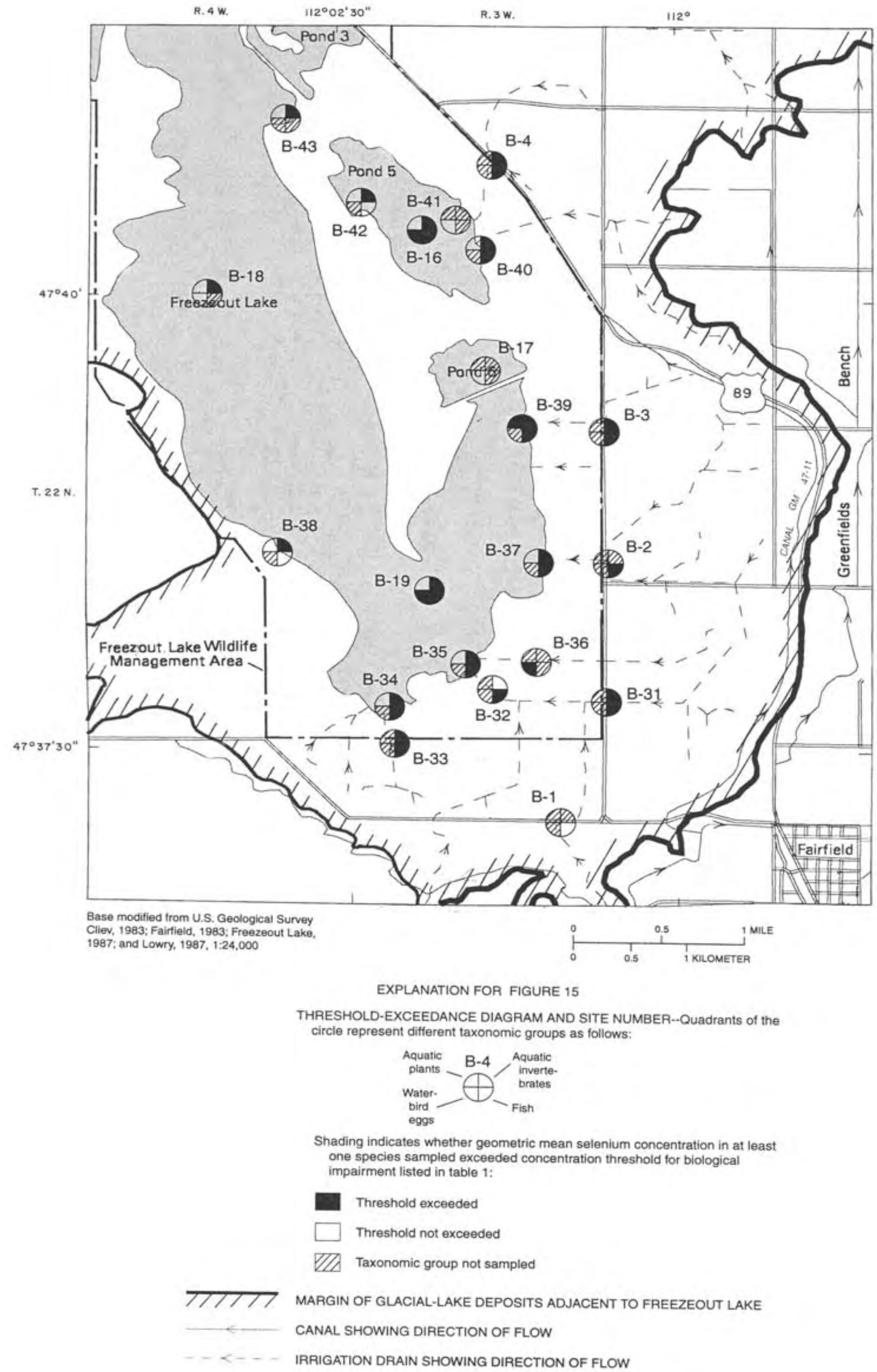
(from Nimick et al., 1996. Bird eggs for Freezeout Lake (north end) and Priest Butte Lake are for American avocets. All other water-bird data are for samples of eared grebes. (Toxicity thresholds are from Tables 1 and 3 in Nimick et al., 1996)

Figure 7-5. Distribution of Dissolved Selenium Concentrations in Water, Bottom Sediment, and Biological Samples from Southern Freezeout Lake Area.



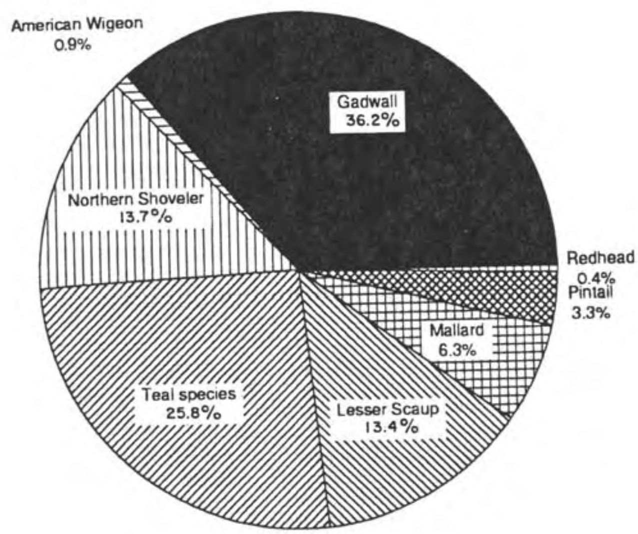
(from Kendy et al., 1999) Half detection limits used if sample was reported below a detection limit. Biological risk levels refer to total-recoverable selenium and are the same outlined for Figure 7-4.

Figure 7-6. Biological Sampling Sites where Geometric Mean Selenium Concentration in at Least One Species Exceeded the Concentration Threshold for Biological Impairment in the Southern Freezeout Lake Area.



(from Kendy et al., 1999)

Figure 7-7. Species Composition of Breeding Ducks Observed in 1991-1992 at Freezout Wildlife Management Area.



(from Nimick et al. 1996)

7.1.2 Source Assessment

Dissolved selenium entering Freezout WMA was grossly estimated by Nimick et al. (1996). Nimick et al. (1996) indicates that the most significant seasonal loading differences in the watershed occur between the irrigation and non-irrigation seasons. The assessment segregates data into these seasons: irrigation May –Sept; non-irrigation Oct-April. The source assessment segregated irrigated and non-irrigated lands and then further separated irrigated lands into sub-categories using underlying geologic attributes. The three sub-categories of irrigated land were: 1,820 acres in the SW corner of Greenfields Bench (GB) underlain by gravel, 2,140 acres in the NW corner of GB underlain by gravel, 3,580 acres in the off-bench area south and east of Freezeout Lake underlain by glacial deposits.

For TMDL use, loading from the seep east of Priest Butte Lake was subtracted from Freezout WMA loading calculations by Nimick et al. (1996) and is reported as Freezeout Lake's load in Table 7-4. Nimick et al. (1996) loading source estimates indicate that approximately 87 percent of the selenium loading to Freezeout Lake is derived from a 3,580 acre area of irrigated glacial deposits to the south and east of Freezeout Lake (Table 7-4). Other areas of selenium load contribution are the NW corner of Greenfields Bench and dry land cropping areas over glacial lake deposits and glacial drift (Figure 7-8).

Because Nimick et al. (1996) estimated most of the selenium loading to the lake came from irrigated glacial deposits; Kendy et al. (1999) further investigated this source for a more accurate estimate. Kendy et al. (1999) divided glacial lake deposit areas into two distinct units based on their relationship of discharge to selenium concentrations (Figure 7-9). The sub-area east of Freezeout Lake drains primarily westward from seleniferous glacial lake deposits and is represented by sites S-6, S-7, S-8 and S-11 in Figure 7-9. The sub-area south of Freezeout Lake drains northward and is represented by site S-52 in Figure 7-9. Loading calculations given in Table 8 of Kendy et al. (1999) were incorrectly calculated although the discharge and average dissolved selenium concentrations are correct (Pers. Comm. Nimick, 2003). The correct loading calculations for Kendy et al. (1999) are presented in Table 7-5 of this document. Loading from glacial lake deposits corrected from Kendy et al. (1999) are approximately 40 percent of those estimated in Nimick et al. (1996). If comparing Kendy et al. (1999) corrected glacial lake deposit selenium load estimates to Nimick et al. (1996) load estimates from other sources in the watershed, glacial lake deposits would contribute approximately 73 percent of the total dissolved selenium load to Freezeout Lake.

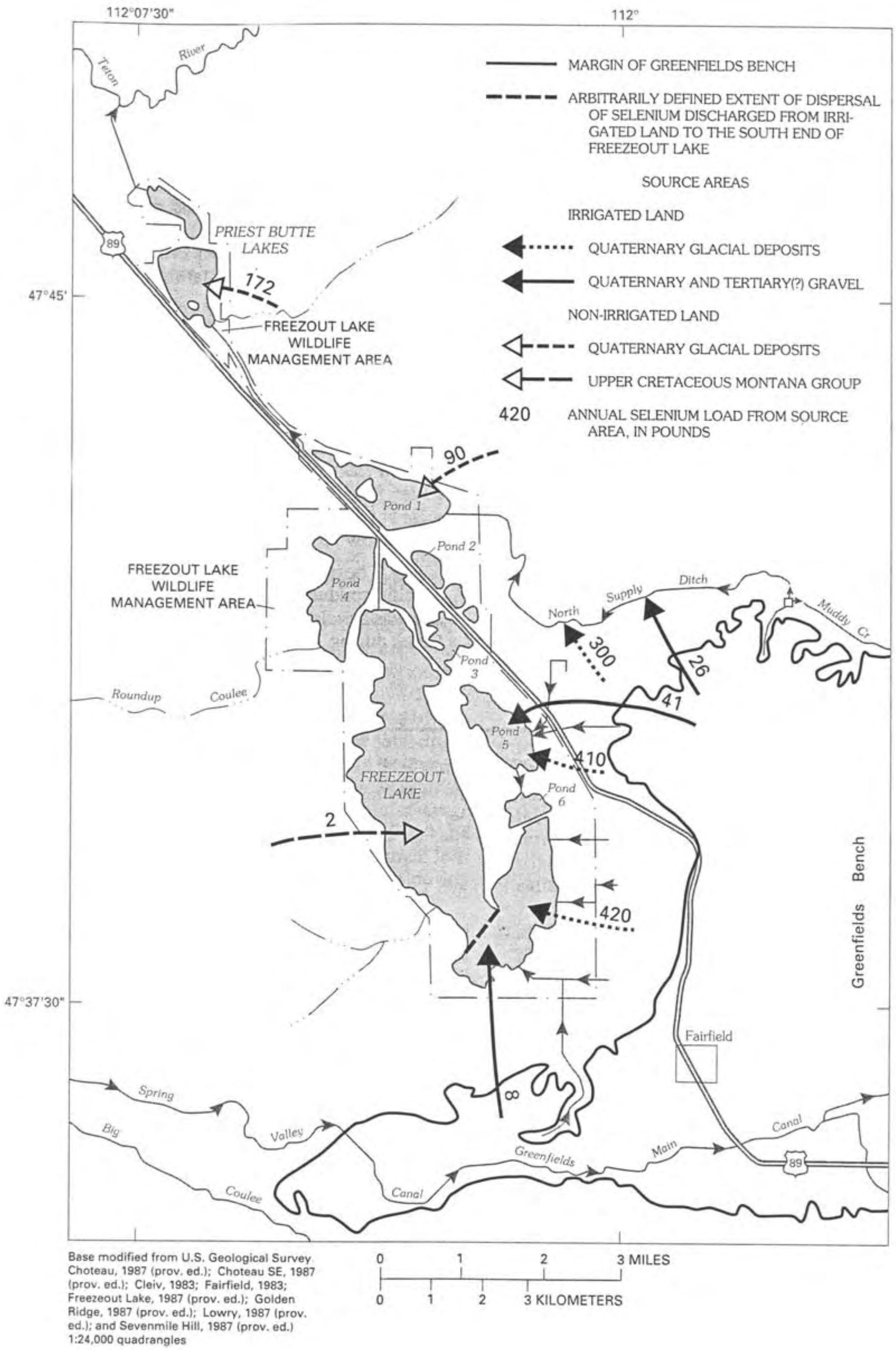
Fairfield's POTW has no associated selenium data. No loading estimates are available for this source. The allocation process uses reasoning that Fairfield's effluent is comparable to other POTW effluents across Montana that have associated effluent selenium data with the same levels of selenium in their source water. A phased monitoring approach will be used to validate this assumption.

Table 7-4. Estimated Average Annual Selenium Source Loading to Freezout Wildlife Management Area From Irrigated and Non-irrigated Lands, Excluding Seep East of Priest Butte Lake.

Location	Irrigated = I Non-Irrigated= NI	Underlying Geology	Drainage Area (acres)	Average Annual Flow (acre-ft)	Average Concentration (µg/L)	Average Annual Load (lbs/yr)	Percent of Total load	Area of Discharge
Greenfieldss Bench, SW corner	I	Quaternary and Tertiary (?) Gravel	1,820	IS = 2,480 NIS = 820	IS = <1 DS <1 TRS NIS = 2 DS 2.2 TRS	IS = 3 DS 3.3 TRS NIS = 4.5 DS 4.9 TRS	0.5	Main Freezeout Lake
Greenfieldss Bench, NW corner	I	Quaternary and Tertiary (?) Gravel	2,140	IS = 3,090 NIS = 770	IS = 6 DS 6.5 TRS NIS = 8 DS 8.6 TRS	IS = 50 DS 54 TRS NIS = 17 DS 19 TRS	5	Pond 1 Pond 5
Off-bench Area, S&E of Freezeout Lake	I	Quaternary Glacial Deposits	3,580	IS = 4,850 NIS = 1,620	IS = 49 DS 53 TRS NIS = 110 DS 119TRS	IS = 650 DS 705 TRS NIS =480 DS 521 TRS	87	South Freezeout Pond 1 Pond 5
West of Freezeout Lake	NI	Upper Cretaceous Montana Group	45,700	730	1 DS 1.1 TRS	2 DS 2.2 TRS	<0.5	Main Freezeout
East of Freezeout Lake	NI	Quaternary Glacial Deposits	23,700	360	91 DS 99 TRS	90 DS 98 TRS	7	Pond 1

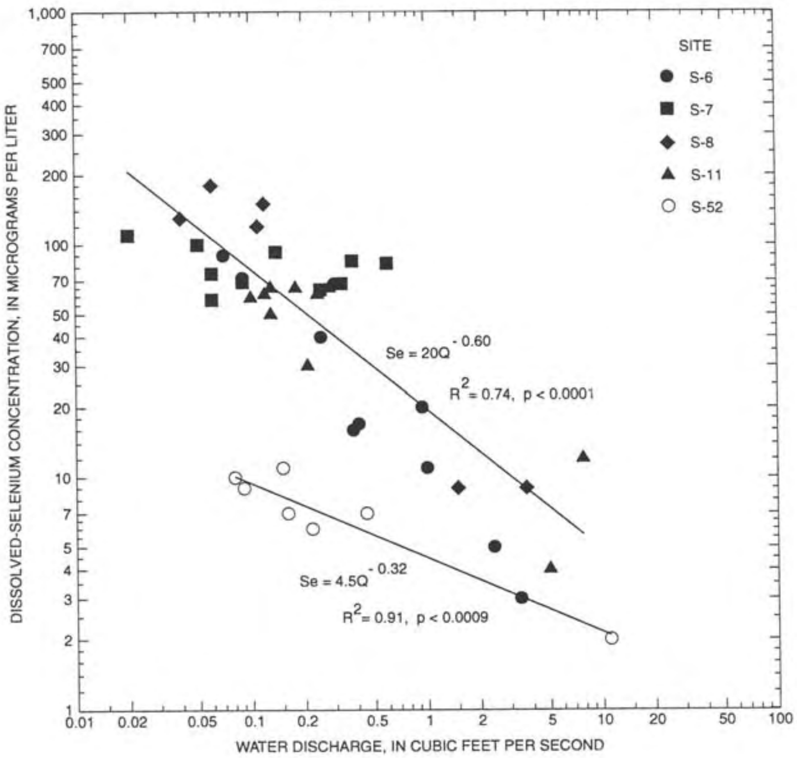
(loading data from Nimick et al., 1996)
Total recoverable selenium loads are based on converting dissolved selenium loads using a conversion factor from 60 FR15366.
IS = Irrigation season NIS = Non-Irrigation season
DS =Dissolved Selenium TRS = Total Recoverable Selenium

Figure 7-8. Spatial Representation of Estimated Average Annual Selenium Load Discharge to Freezout Lake WMA.



(from Nimick et al., 1996)

Figure 7-9. Relationship of Discharge to Dissolved-Selenium Concentration in Irrigation Drainage from Land Underlain by Glacial Lake Deposits in the Freezeout Lake Area.



(from Kendy et al., 1999) Even though all sites drain glacial lake deposits, Site 52, located south of Freezeout Lake, is in a distinctly different geological setting than other sites, which are located east of Freezeout Lake.

Table 7-5. Estimated Seasonal Selenium Loads From Irrigated Land Underlain by Glacial Lake Deposits to Freezeout Lake.
(data from Kendy et al., 1999- loads are corrected from original USGS document)

Sub-Area	Size (acres)	Estimated Seasonal Discharge[1] (acre-ft)		Average Seasonal Dis-Se [2] (µg/L)		Seasonal Dis-Se Loads (lbs)		Annual Dis-Se Load (lbs)	Estimated Annual Total Rec. Se Load [4] (lbs)
		I	NI	I	NI	I	NI		
1993									
East	3,570	2,460	610	42	83	281	138	419	455
South	500	420	110	5	9	5.71	2.69	8.4	9.22
Annual total	4,070	2,280	720	--	--	287	141	428	463
1994									
East	3,570	2,610	650	42	83	298	147	445	483
South	500	950	240	5	9	12.9	5.87	18.8	20
Annual total	4,070	3,560	890	--	--	311	153	464	503
1995									
East	3,570	2,600	650	42	83	297	147	444	482
South	500	670	170	5	9	9.11	4.16	13.3	14
Annual total	4,070	3,270	820	--	--	306	151	457	495
Average annual	4,070	3,40	810	--	--	301	445	447	485

[1] Discharge estimates are based on total volume of irrigation water delivered to farms within a subarea and corresponding irrigation-efficiency estimates; total volume of direct spills from canals and corresponding estimates of spill percentages to each subarea; total volume of canal deliveries and corresponding estimates of canal seepage to each subarea; and total annual precipitation (National Oceanographic and Atmospheric Administration, issued annually) and corresponding estimates of precipitation runoff and infiltration.
[2] Concentration estimates are based on samples collected during 1990-92 (Lambing and others, 1994, Table 14) and 1995 (Kendy and Olsen, 1997, Table 10).
[3] Sum of seasonal loads does not equal annual load due to rounding.
[4] Estimated using conversion selenium factor in 60 FR 15366.
I – Irrigation Season NI= Non-irrigation season

7.1.3 TMDL and Allocations

Freezeout Lake's TMDL is based upon all water entering the lake meeting total recoverable selenium, water column targets. The TMDL for Freezeout Lake is 0.55 lbs of total recoverable selenium per day. A conversion factor of 1.085 is used from 60 FR 15366 (March 23, 1995) to convert the measured dissolved selenium loads to total recoverable loads for comparison to the TMDL. While this conversion factor is designed for the Great Lakes Region, and there is probably a margin of error in using it in the arid western states, it is the best conversion tool in existence. Existing estimated total recoverable selenium loads entering Freezeout Lake are about seven times higher than the total recoverable selenium load allowed by the TMDL. The TMDL for Freezeout Lake is derived by applying target total recoverable selenium concentrations to USGS estimated flows entering the lake derived by Nimick et al. (1996).

Selenium data for POTW effluents in the Sun River watershed are not available. Most likely, selenium waste load allocations are low compared to the nonpoint sources. The town of Fairfield is the only NPDES POTW in Freezeout Lake's watershed. Source water sampling for the town of Fairfield has yielded selenium results below 5 µg/L (MDEQb). Effluent data from larger cities across Montana indicate that there are no detections of total recoverable selenium above the acute standard. Therefore, Fairfield's effluent concentration is likely below standards. There are no identified significant selenium sources between the Town's source water and effluent. The waste load allocation is to meet the selenium chronic aquatic life targets in Fairfield's effluent. At current discharge this would be 0.02 lbs/day (Table 6.7). Fairfield's current discharge rate is above their design capacity and the facility should stay below their design flow or upgrade the facility to treat higher discharges effectively.

Loading estimates indicate that irrigation on the glacial lake deposits between Freezeout Lake and the Greenfields Bench are contributing the majority of dissolved selenium loads along with high concentrations (Figure7-8). The area with crop-fallow activities northeast of Freezeout Lake and the North Supply ditch contributes high concentrations and a moderate load of selenium and thus should also be assessed an allocation. The allocations will focus on meeting the target of 5 µg/L total recoverable selenium for all water entering Freezeout Lake from these two areas. Existing load estimates from these two areas are compared to loads based on a 5 µg/L limit for water entering Freezeout Lake. Comparisons of current annual loads and allocated annual loads from each significant source area are provided in Table 7-6. Note that existing loads are for dissolved selenium and the TMDL is for total recoverable selenium so the actual reductions that are needed to meet the TMDL may be even higher than stated in Table 7-6.

Table 7-6. Total Recoverable Selenium Allocation for Freezeout Lake.

Area	Average Annual Discharge	Average Selenium Concentration (µg/L)	Average Annual Selenium Load (lbs/yr)	Allocation to Specific Sources (lb/yr)	Reduction Needed (%) ((Existing Load - Allocation)/ Existing Load)
Fallow Crop	360 AF [2]	99 [3]	97	5	95
Irrigated	2557 AF [1]	Irrigation 46 [1] Non-Irrigation 83 [1]	485	35	93
Fairfield	0.59 cfs	?	?	0.02	Likely no reduction needed. Phased waste load assessment.

[1]Calculated from east irrigation area from Kendy et al. (1999).
[2] From Nimick et al. (1996)
[3] From compiled Sun River watershed Database (USGS, STORET, MBMG)
A conversion factor of 1.085 (60 FR 15366; March 23, 1995) is used to convert the USGS estimated dissolved selenium loads to total recoverable loads for comparison to the TMDL in Table 7-6.

7.1.4 Restoration Strategy

Salinity and selenium sources are almost exclusively the same in the Sun River watershed. See the Freezeout Lake salinity restoration section (Section 6.1.4) for detailed restoration strategies that will reduce selenium loading to Freezeout Lake. Activities that introduce the most water into soils and geology that lie over the highest selenium holding soil and geologic groups are the highest priority for restoration. The priority for restoration is irrigated land on glacial lake deposits, fallow cropping on glacial lake deposits, irrigation on glacial drift, and then fallow cropping on glacial drift. Irrigation water savings from the watershed should be applied to Freezeout Lake. The TMDL assessment assumes no change in water budget so the water that would have seeped into the lake via field application should directly enter the lake via Greenfieldss Irrigation District. If this does not occur, the TMDL will not be attained.

7.1.5 Margin of Safety, Adaptive Management, and Seasonal Considerations

A number of approaches are incorporated into the Freezeout Lake selenium TMDL margin of safety. An inherent margin of safety is built into establishing metals standards and the targets are based upon standards. The water column targets set for Freezeout Lake are to be met at all locations within the lake, thus the most problematic areas of the lake should meet the selenium targets and other less sensitive areas are likely to fall below the target concentrations. Montana's selenium chronic aquatic life standard concentration is based on a "96 hour average", but the water column target concentration is a "not to exceed" target using the chronic aquatic life standard concentration. Selenium sediment targets are provided for Freezeout Lake to address accumulation of selenium in sediments. Selenium sediment targets also protect against excessive bioaccumulation in the food chain. Seasonality is considered by setting a target to protect waterfowl use during all seasons.

An adaptive management approach is being used for meeting selenium targets and the TMDL for Freezeout Lake. If identified conservation practices do not achieve targets or load allocations in the Watershed, further strategies to meet these goals should be developed in future planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place; targets, TMDL and allocations may have to be revised.

7.1.6 Effectiveness Monitoring Plan

Fairfield's next permit review by MDEQ will require two effluent sample analysis for total recoverable selenium during high and low effluent discharge conditions. This limited sampling should suffice if selenium is found below 5 ug/L in both samples. Fairfield's drinking water source has low selenium concentrations, below the chronic aquatic life standard. It is extremely unlikely that any significant selenium sources are present from municipal uses in Fairfield. A number of major cities in Montana have selenium sample results for their POTW effluents. There has been no selenium concentrations found in any of the tested effluents in Montana above the chronic aquatic life standard.

Tracking water quality changes due to restoration activities is an important component of a long term monitoring plan. All IWM and fallow crop restoration activities in the source areas should be tracked in a spatial database on a 5-year basis. Total recoverable selenium sampling should occur on the major irrigation drains that enter Freezeout Lake on the southern and eastern shorelines. Instantaneous discharge monitoring should accompany any water chemistry monitoring. Water quality conditions that are characterized by this monitoring can be compared to targets and allocations and can also be compared to the progress of restoration activities during TMDL review.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Future monitoring activities should include the development of a detailed monitoring plan that includes a quality assurance project plan (QAPP) prior to fieldwork.

7.2 Muddy Creek

7.2.1 Selenium Targets and Current Water Quality Status

Targets

Water column targets set for Muddy Creek are based on the same rationale as provided in Section 7.1.1. The water column target for total recoverable selenium is 5 μg/L. Targets need to be met in 90% of the samples for any given month over a 5 year timeframe. No sediment targets are provided for Muddy Creek because it is a stream. Selenium is more likely to be transported in the water instead of stored in sediments in streams because of biological and physical processes that differ from lakes and wetlands.

Impairment Status

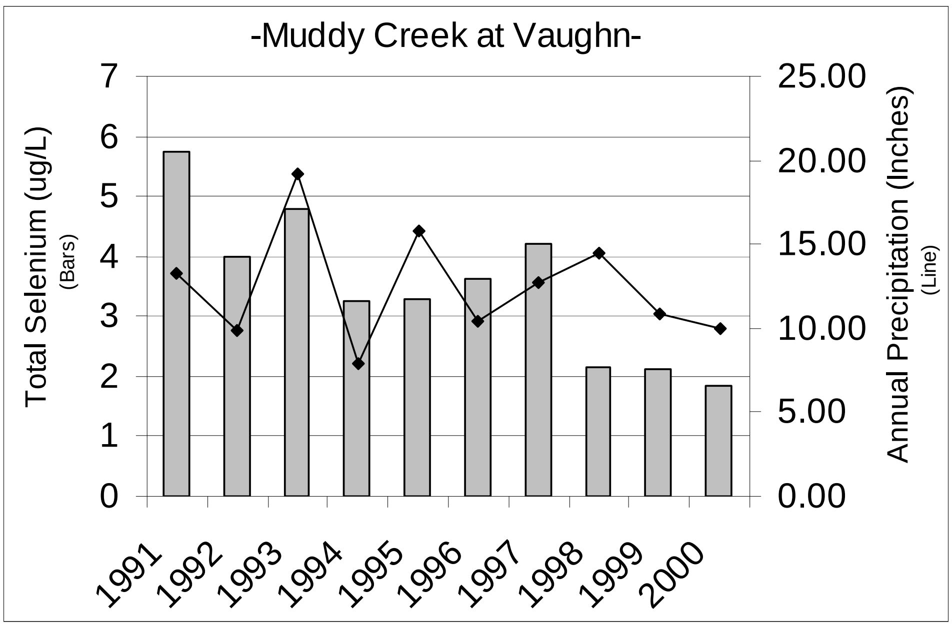
As stated at the beginning of the selenium section (Section 7.0), the majority of selenium sampling in Muddy Creek has been analyzed for total selenium. Caution should be used when discussing total selenium in that it cannot be easily compared to Montana's selenium standards. Selenium was not a cause listed on Montana's 1996 or current 303(d) list for Muddy Creek, but total selenium concentrations indicate that standards based upon total recoverable analysis may be exceeded during low flow periods. Thus, selenium threatens Muddy Creek's in-stream uses. Montana's chronic aquatic life selenium standard indicates that a total recoverable selenium concentration of 5 μg/L should not persist for a 96-hour duration. Total selenium concentrations were higher than 5 μg/L in approximately twenty-three percent of samples (McDonald, 2000). Although this doesn't necessarily mean that standards are exceeded, it indicates that they are likely exceeded. The highest total selenium concentration detected at the Muddy Creek at Vaughn site was 13.8 μg/L. Total selenium samples as high as 180 μg/L have been found in intermittent or ephemeral tributaries and coulees in the Muddy Creek watershed.

During the past 10 years there has been general decreases of total selenium concentration in Muddy Creek (Figure 7-10) although there has not been a large change in land use or restoration practices during this timeframe. Average monthly concentrations are highest in March and April during low flow conditions when a majority of the samples are above targets (Figure 7-11). There is an inverse relationship between flow and total selenium concentrations, which indicates that selenium sources are associated with geology or soils (Figure 7-12). Groundwater has a more influential impact on water chemistry during low flow periods because it composes most of Muddy Creek's flow during base flow. During low flow conditions in the fall, winter and early spring, there is little to no surface water runoff derived from rainfall, snowmelt or irrigation that dilute groundwater influence in Muddy Creek.

Because there have been exceedances of chronic aquatic life standards during the past decade and there has been little change in activities that mobilize selenium in the Muddy Creek watershed other than weather conditions, a TMDL will be constructed for selenium. There is potential that drought conditions are contributing to lower selenium concentrations in Muddy Creek.

Drought conditions may reduce selenium movement from crop-fallow areas because less water moves through the soil profile in fallow fields during these times than during wet weather conditions. During wet weather, more water moves through the soil in fallow fields and dissolves selenium and other salts, move to saline seep areas and from these areas are conveyed into state waters more easily.

Figure 7-10. Average Annual Selenium Concentrations in Muddy Creek and Average Annual Precipitation.



Precipitation is an average of Fairfield and Power data.

Figure 7-11. Monthly Total Selenium Concentrations in Muddy Creek at Vaughn Gauging Station (1991-2000).

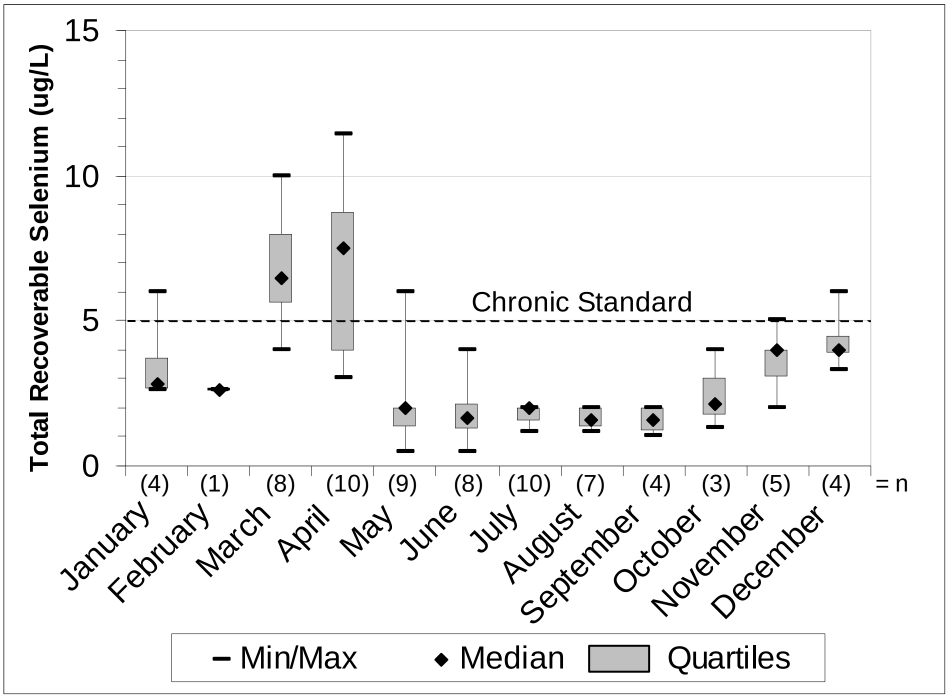
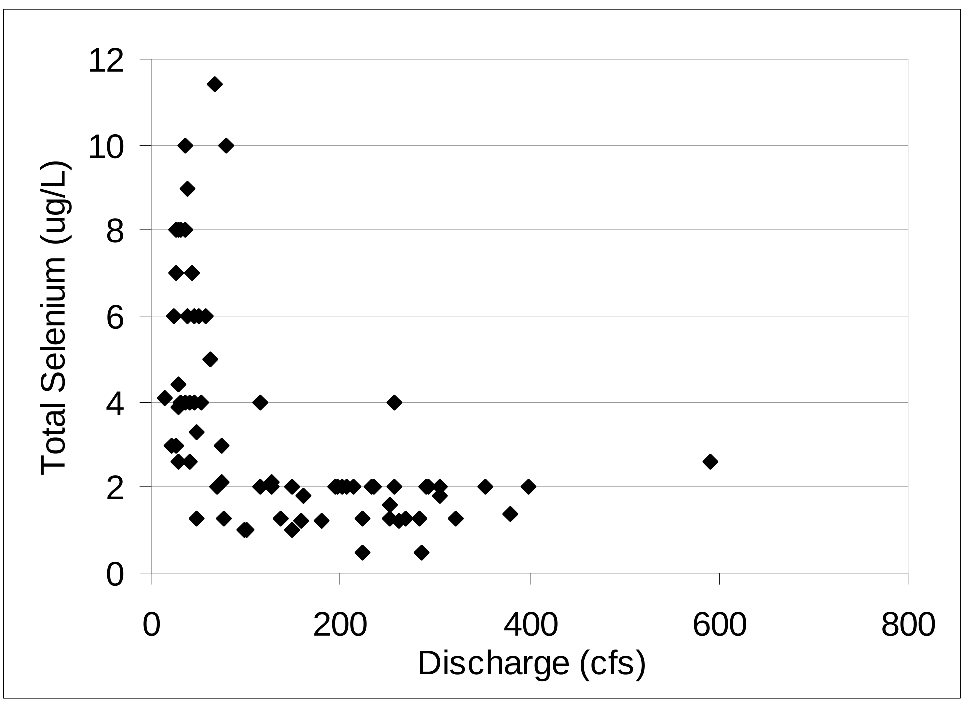


Figure 7-12. Relationship Between Total Selenium Concentrations and Flow in Muddy Creek (1991-2000).



7.2.2 Source Assessment

Measured selenium concentrations in irrigated drainages on the south and east portions of the Greenfields bench are below chronic aquatic life standards (Figure 7-13). Limited sampling in crop-fallowed areas of the watershed indicate variable, but potentially high concentrations of selenium (2-180µg/L, n=2). Further analysis of selenium in runoff and groundwater in the dry land farming areas of Muddy Creek should be conducted to further the understanding of how these areas contribute to Muddy Creek selenium loads and concentrations.

Loading calculations from three sample events during 1999 on five of the major Greenfields Bench drainages were compared to selenium loads at the Muddy Creek at Vaughn gauging station for the same year (Figure 7-14). The available Muddy Creek at Vaughn total selenium data is compared to dissolved and total recoverable selenium analyses from Greenfields Bench drainage samples. Therefore, loading from these five Greenfields Bench drainages may be slightly underestimated on a percentage comparison. Nevertheless, using this analysis, selenium loads from the Greenfields Bench appeared to contribute 10 percent of loading during the non-irrigation season and 20 percent of the selenium loading during the irrigation season to the Muddy Creek at Vaughn site. Other anthropogenic sources may include smaller Greenfields Bench drainages, groundwater entering directly into the stream from irrigation and fallow cropping, and surface water runoff from fallow cropping.

The relationship between precipitation and selenium concentrations should be further investigated. There is potential for increased selenium flushing from fallow cropping areas by higher annual precipitation. Loads from fallow cropping areas likely have a larger influence on the fluctuation of selenium concentrations in Muddy Creek because discharge from these areas is mostly intermittent and inconsistent. Higher selenium concentrations are likely to be found in groundwater in fallow cropping areas, when compared to irrigated fields because fallow cropping areas have inconsistent and less water flowing through root zones from precipitation only. Groundwater from irrigated lands in the Muddy Creek watershed is likely to produce a more consistent load with concentrations that are likely to be below standards (Figure 7-13). Inter-yearly consistency in irrigated area selenium load and concentration is likely because of a more consistent and higher water application rate from year to year when compared to precipitation rates on fallow cropped fields.

There are no NPDES POTW permits in the watershed.

Figure 7-13. Average and Maximum Selenium Concentrations in Water Draining from the East and South Portions of the Greenfields Bench.

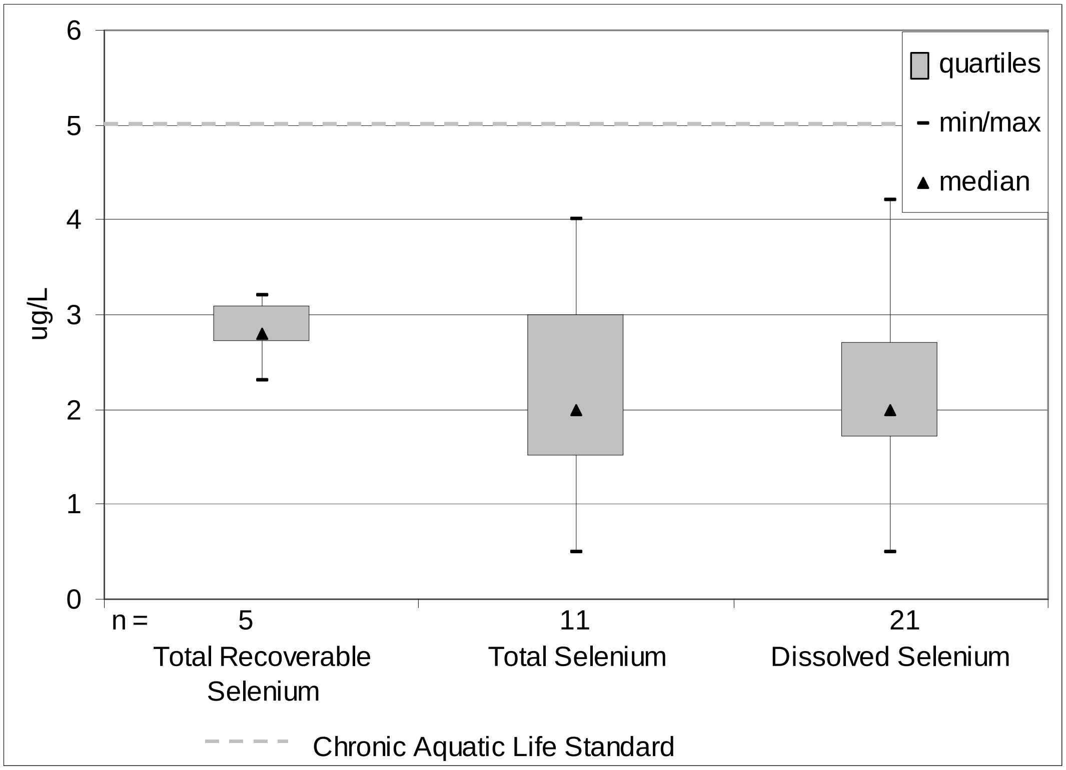
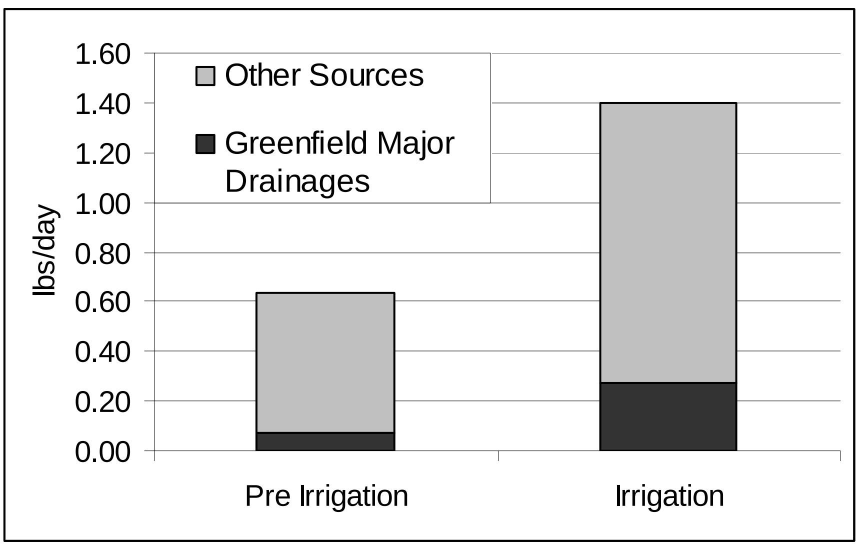


Figure 7-14. Estimated Selenium Loading in the Muddy Creek Watershed (1999).



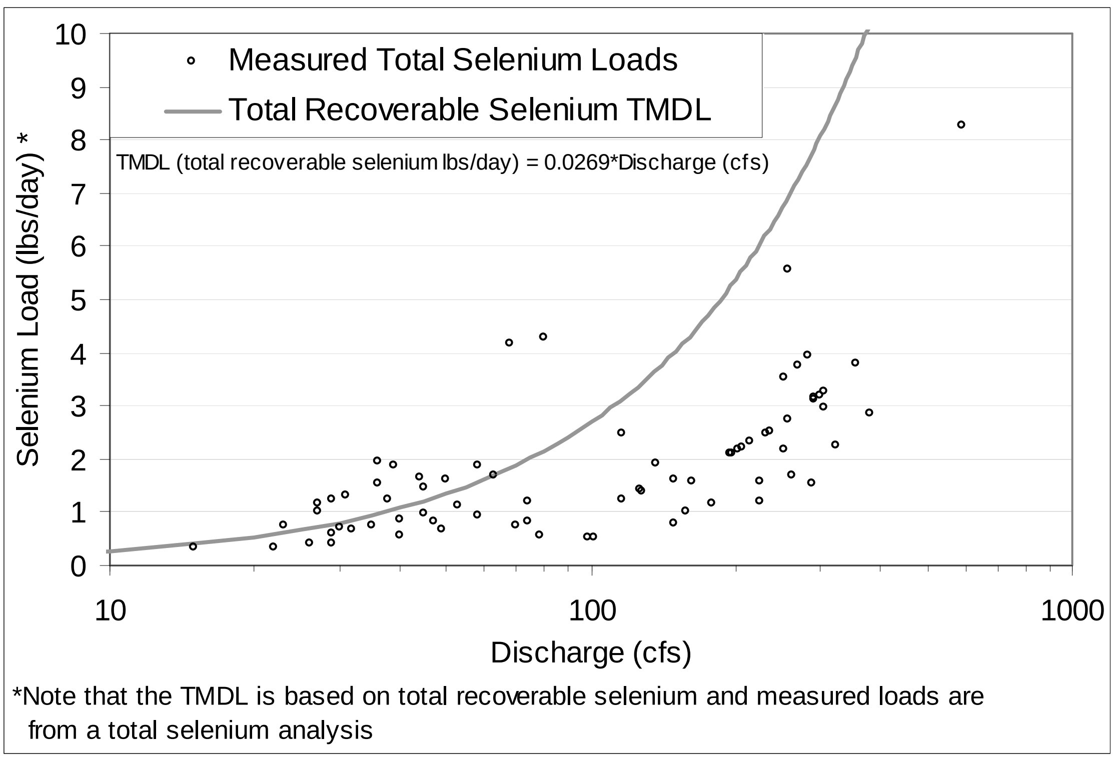
(data from Miller, 2002 and USGS Muddy Creek at Vaughn Station).
Pre Irrigation data from April and early May. Irrigation data is from July.

7.2.3 TMDL and Allocations

Selenium TMDL

Muddy Creek's selenium TMDL is based upon the target concentration of 5 μg/L total recoverable selenium. When targets are exceeded, the TMDL is exceeded. The TMDL is expressed as a discharge dependant equation in Figure 7-15 and is compared to measured total recoverable loads at Vaughn from 1991-2000. Measured load points above and to the left of the TMDL line are probable exceedances of the TMDL. The figure shows that most of Muddy Creek's TMDL exceedances occur between 25 and 100 cfs, during lower flows. The lower flows that produce target exeedances usually occur during late winter and early spring (Figure 7-11). For this reason, the load reduction is based upon February-April loads. When comparing the 1991-2000 measured loads to the TMDL, an average load reduction of 36% is needed to meet the TMDL during February-April. The conversion factor of 0.0269 is a combination of TDS target, time, water volume, and mass conversion factors.

Figure 7-15. Muddy Creek Selenium TMDL and Measured Loads from 1991-2000.



Allocation

Limited sampling indicates that water entering Muddy Creek from the major drainages on the Greenfields Bench meets the selenium chronic aquatic life standard and contributes an estimated 20% or less of the loading to Muddy Creek (Figure 7-13,7-14). Also, irrigation water dilutes selenium concentrations in the Muddy Creek. Very little irrigation on glacial lake deposits or glacial drift occurs in the Muddy Creek watershed, and thus selenium concentrations in water derived from irrigation return flows are relatively low. For these reasons, irrigated areas are not allocated a load reduction.

Limited data suggest that fallow cropping areas are sources of high selenium concentrations, but have great temporal variation in producing selenium loads. Because of limited direct evidence and convincing indirect evidence, fallow cropping areas are given a 100% allocation of selenium reduction needed to meet the TMDL at this time. This allocation will be based on the most sensitive months of the year when selenium concentrations are the highest, February through April. When comparing the 1991-2000 measured loads to the TMDL, an average load reduction of 36% is needed to meet the TMDL during February-April. Loads from fallow crop areas during this timeframe need to be reduced by 41% to likely meet the TMDL during this timeframe. A 5% MOS is applied to this allocation. By applying this allocation, other less sensitive times of the year will also meet the selenium TMDL. Fallow cropping fields are the only other significant source of human caused increase in water contacting soils and geology in the Muddy Creek watershed other than the irrigated areas discussed previously.

No waste load allocations are necessary at this time because there are no NPDES POTWs in the watershed.

7.2.4 Restoration Strategy

Salinity and selenium sources are almost exclusively the same in the Sun River watershed. See the Muddy Creek salinity restoration section (Section 6.2.4) for detailed restoration strategies that will reduce selenium loading to Muddy Creek. Activities that introduce the most water into soils and geology that lie over the highest selenium holding soil and geologic groups are the highest priority for restoration. The priority for restoration is fallow cropping on areas of glacial drift.

7.2.5 Margin of Safety, Seasonal Considerations and Adaptive Management

A number of approaches are incorporated into the Muddy Creek selenium TMDL margin of safety. An inherent margin of safety is built into establishing metals standards and the targets are based upon standards (EPA 440/5-80-070). The water column targets set for Muddy Creek are to be met at all locations in the stream, thus the most problematic areas of the lake should meet the selenium targets and other less sensitive areas are likely to fall below the target concentrations. Montana’s selenium chronic aquatic life standard concentration is based on a “96 hour average”, but the water column target concentration is a “not to exceed” target using the chronic aquatic life standard concentration. Seasonality is considered by setting a target to protect aquatic life use during all seasons. The TMDL reduction is set for the months of February through April when selenium concentrations are at their highest.

An adaptive management approach is being used for meeting selenium targets and the TMDL within the Muddy Creek watershed. If identified conservation practices do not achieve targets or load allocations in the watershed, further strategies to meet these goals should be developed in future planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place; targets, TMDL and allocations may have to be revised.

7.2.6 Effectiveness Monitoring Plan

Future selenium data should be analyzed using a total recoverable technique for easier comparison to Montana's water quality standards. Synoptic selenium sampling for toxicity studies should also consider dissolved selenium concentrations because dissolved selenium is one of the more toxic and transient forms of selenium. Monitoring of selenium in saline seep areas and areas of fallowed wheat production would be able to further characterize the dry land sources of selenium in Muddy Creek's watershed. Load monitoring should be conducted 3 times per year, once in February, March, and April at the Muddy Creek at Vaughn USGS station to determine if targets and TMDL are being met during the most sensitive time of the year.

SECTION 8.0 NUTRIENTS

This section of the Sun River Water Quality Restoration Plan focuses on nutrients and other physical and biological factors affected by nutrients. Nutrients can affect the fishery and associated aquatic life, aesthetics, agricultural and drinking water uses. Algal mats, decaying algal clumps, odors, low dissolved oxygen levels and discoloration of water are adverse environmental effects associated with excessive nutrients. These conditions may interfere with recreational uses or affect the aesthetic value of the stream. Excessive algae can interfere with irrigation systems and pose problems for public water supply use by fouling intake structures. Aquatic life and fish can suffer from depleted dissolved oxygen as a result of plant respiration at night. In extreme cases, surface waters may exceed drinking water nitrate standards.

The analysis for the nutrient TMDLs relies on existing nutrient data. Nutrient concentrations in the Sun River Watershed have been analyzed and reported using a number of different methods. Nitrogen or phosphorus data that are reported as TN, TP, TKN, NO_2, NO_3, or PO_4 were converted to equivalent concentrations as N or P using methods described in Mueller et al., (1995).

Impairment listings covered in the nutrient section are noxious aquatic plants, organic enrichment/dissolved oxygen, nutrients, and phosphorus. Table 8-1 provides a list of waterbodies within the Sun River TPA that appear on either the 1996 or 2002 303(d) list for nutrient related pollutants. This chapter addresses Ford Creek, the upper Sun River, Muddy Creek, the lower Sun River, and Freezeout Lake. TMDLs will be presented for all of these waterbodies except Freezeout Lake and Ford Creek. Limited nutrient and vegetation data for Freezeout Lake does not allow for TMDL development at this time. A TMDL development strategy will be provided in this chapter for guidance to complete the Freezeout Lake nutrient TMDL planning by 2007. There is no need for a Ford Creek nutrient TMDL. Conclusions from a Ford Creek nutrient impairment review indicate a nutrient TMDL is not necessary.

Table 8-1 Waterbodies Listed for Nutrient Related Listings.

Water Quality Limited Segment	1996 303(d) List	2002 303(d) List
Freezeout Lake	Organic Enrichment/DO	Nutrients, Noxious aquatic plants
Muddy Creek	Nutrients	No causes listed because of use classification
Upper Sun River	Nutrients	Nutrients, Phosphorus
Lower Sun River	Nutrients	Nutrients
Ford Creek	Nutrients	No nutrient related pollutant listings

The remainder of this section presents all of the required TMDL elements for each waterbody, one waterbody at a time.

8.1 Nutrient Target Setting Criteria

Nutrient targets are based upon Montana's narrative standards and regional nutrient criteria. The standard pertaining to nutrients indicates that, "surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: create conditions which produce undesirable aquatic life" (ARM 17.30.637 (1)(e)). Montana's standards that relate to nutrient enrichment are described in slightly more detail in Section 3.2. The undesirable aquatic life most commonly associated with elevated nutrient concentrations in streams are excess benthic algae and aquatic vascular plants. Aquatic plant growth becomes a nuisance when it adversely affects beneficial uses of a stream. Fisheries, recreation and aesthetics are usually the most sensitive beneficial uses of streams in Montana when considering nutrient enrichment. In shallow riffles, benthic algal chlorophyll *a* concentration is commonly used to measure the amount of aquatic plant growth on the stream bottom. Therefore, TMDL water chemistry and benthic chlorophyll *a* targets are based upon preventing excess growth of benthic algae.

Plants require a balance of nutrients for growth. Most aquatic algae contain nitrogen, phosphorus and carbon in a ratio by weight of 41/7/1 (Redfield, 1958; Chapra, 1997). Increases in plant production may occur if the limiting nutrient is elevated. Most aquatic plants are not limited by carbon, however, either nitrogen or phosphorus can limit growth. A nitrogen to phosphorus (N/P) ratio of around 7 is generally thought to be optimal for algae growth. Therefore if a N/P ratio is lower than 7 the stream is most likely limited by nitrogen, if the ratio is higher than 7 it is most likely to be limited by phosphorus. Conditions may change in streams daily or seasonally that affect the nitrogen to phosphorus ratio, and either nutrient may be limiting at times. The N/P ratio can be used as a general indicator of which nutrient is most likely limiting algae growth in a stream. The N/P ratio is 66 in Muddy Creek, 34 in the upper Sun River, and 100 in the lower Sun River. Therefore, all three stream sections appear to be limited by phosphorus. Although phosphorus is likely the limiting nutrient in these waterbodies, both nitrogen and phosphorus are addressed in this document because of the effects of downstream nitrogen loading. Also, the limiting nutrient may change as restoration occurs.

Benthic algal chlorophyll *a* is usually the most useful indication of nutrient impairment. Currently, two factors hinder the use of benthic algal chlorophyll *a* as an indicator of nutrient enrichment in Muddy Creek and the lower Sun River. The first factor is elevated sediment levels in both streams. In the Sun River, median nutrient and suspended sediment concentrations increase two to three times downstream of the Muddy Creek confluence (McDonald, 2000). Even though high nutrient concentrations exist, aquatic plants cannot grow efficiently because of high water column suspended sediment and unstable stream bottom. Thus, plants cannot use much of the available dissolved nutrients and loads are transported downstream. Second, there is a lack of benthic algal chlorophyll *a* data for Muddy Creek and the lower Sun River. For these reasons, both nutrient concentration and benthic algal chlorophyll *a* targets are presented.

Chlorophyll *a*

The CFR Nutrient Standards and MDEQ data for prairie regions were used to guide professional judgment on appropriate chlorophyll *a* targets for the Sun River TPA. Detailed analysis of the relationship between benthic algal chlorophyll *a* concentrations and nutrient concentrations has been conducted in the Clark Fork River, Montana. The algal and nutrient standards for the Clark Fork River are comparable to the Sun River watershed because portions of the Clark Fork River watershed and the Sun River watershed lie within the same ecoregion. Delineation of ecoregions is based upon climate, geology, physiography, soils, land use, hydrology and wildlife. Benthic algal chlorophyll *a* standards for the Clark Fork River are 100 mg/m^2 mean summer concentration and 150 mg/m^2 maximum summer concentration. The Clark Fork River chlorophyll *a* standards are proposed as targets in the Sun River Watershed.

Portions of the Sun River TPA also lie within the periphery of the northwestern glaciated plains ecoregion. MDEQ has conducted sampling for setting algal biomass and nutrient standards in wadeable streams of the northwestern glaciated plains ecoregion (Suplee, 2002). Preliminary results from reference site monitoring in this region indicate mean summer algae and macrophyte chlorophyll *a* concentrations for slightly entrenched Rosgen classified C channeled streams are in the range of 8.44-590 mg Chl a/m^2. It appears that reference sites in the northwestern glaciated plains ecoregion that produced chlorophyll *a* levels above 150 mg Chl a/m^2 had larger quantities of macrophytes. Macrophytes are rooted plants that can use nutrients in stream bottom sediments thus they do not always indicate nutrient enrichment of the stream water. The CFR standards of 150 mg/m^2 maximum and 100 mg/m^2 mean benthic algal chlorophyll *a* concentration appear to be appropriate for the northwestern glaciated plains ecoregion. Nutrient concentrations may be naturally higher in the northwestern glaciated plains ecoregion, but algal chlorophyll *a* concentrations do not appear to increase with the higher nutrient concentrations. All guidance pointed to a similar range of values for setting benthic algal chlorophyll *a* targets across a relatively broad range of stream and region types.

Nutrient Chemistry

Nutrient targets are based upon the Clark Fork River (CFR) numeric nutrient standards (ARM17.30.631), MDEQ prairie stream data, and EPA's Ambient Water Quality Criteria Recommendations for nutrient ecoregions (Table 8-2). Portions of the Sun River TPA are located in the Northwestern Glaciated Plains, Canadian Rockies, Montana Valley and Foothill Prairies, and Northwestern Great Plains EPA nutrient ecoregions (Woods et al., 1999). The criteria used from each of these ecoregions are also provided in Table 8-2 (Map 8-1). Similarities and differences between the ecoregions are explained in Appendix A and were considered in setting the nutrient concentration targets in each of the following waterbody nutrient TMDLs.

Table 8-2. Nutrient Criteria Used to Derive Sun River Nutrient Targets.

Location*	Criteria	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Benthic Chl *a* (mg/m^2)
Clark Fork River	Standards#	39	300	100 ave. 150 max.
EPA Nutrient Ecoregion II/16	Median summer concentration	30	350	---
EPA Nutrient Ecoregion VI/43	Median summer concentration	100	900	---
EPA Nutrient Ecoregion V/42	Median summer concentration	180	1370	---
MDEQ Data From Nutrient Ecoregion V/42	Median summer concentration	113	713	See text.

Clark Fork Nutrient Standards Downstream of Missoula

II/16 - ***Montana Valley and Foothill Prairies***
This ecoregion is used in EPA nutrient criteria guidance but has been incorporated into other ecoregions in the latest ecoregion delineation effort.

VI/43 - ***Northwestern Great Plains***
Data used for deriving EPA nutrient criteria in this region is limited. (TP-n=111/ /TN- n=21)

V/42 - ***Northwestern Glaciated Plains***
Data used for deriving EPA nutrient criteria in this region is very limited. EPA cautions use of the criteria (TP-n=50/ /TN-n=13)

V/42 -MDEQ - ***Northwestern Glaciated Plains*** (Milk River Watershed)
(TP-n=98/ /TN-n=98)

The Clark Fork Nutrient Standards and median summer concentrations for EPA nutrient ecoregions II/16, V/42 and VI/43 were used to guide professional judgment on appropriate nutrient targets for each waterbody. When regional nutrient criterion are refined for the northwestern glaciated plains ecoregion, more detailed reference data for the Sun River Watershed becomes available, or the state of Montana adopts numeric nutrient criteria, the targets presented in this document should be updated to reflect attainment of acquired knowledge.

Additionally, a new nationwide modeling approach using data from least impacted watersheds in each EPA nutrient ecoregion has estimated background nutrient conditions slightly lower than the targets presented for each nutrient listed waterbody (Smith et al., 2003). Background nutrient conditions are not necessarily the goal of Montana’s water quality standards, but are useful in identifying nutrient conditions that would likely support all designated uses.

Other environmental factors may affect algal production in streams. This section does not address the specific linkage of algal production to stream discharge, temperature, and shading. These influences on algal conditions are dealt with indirectly in the temperature and sediment TMDLs (Sections 9.0,10.0).

8.2 Ford Creek

8.2.1 Water Quality Status

Montana's 1996 303(d) list indicates that nutrients are a probable cause of impairment in Ford Creek. A feedlot located on the stream was the reason for the nutrient listing. Aerial photo assessment indicates no other concentrated sources of nutrients in this watershed. The animal feeding operation is located about 9.75 miles upstream of the confluence with Smith Creek. In the early 1990s the animal feeding operation was permitted as a CAFO, moved off stream and animal waste drainage was modified. During 1998, nutrient and benthic algal chlorophyll *a* samples were collected from Ford Creek above and below the feedlot area (Table 8-3). The animal feeding operation is located between sites F-9 and F-17. Data from 1998 indicates that restoration strategies have achieved nutrient and chlorophyll *a* criteria in Ford Creek (Table 8-3). Benthic algal chlorophyll *a* and nutrient concentrations during 1998 were below all proposed nutrient targets presented for the upper Sun River in Section 8.3.1, which also apply to Ford Creek. Periphyton analysis of samples collected during 1998 indicates full support of use at each site listed in Table 8-3 (Bahls, 1999). Nutrients were not listed as a probable cause of impairment for Ford Creek on Montana's 2002 303(d) list. A nutrient TMDL/Water Quality Restoration plan is not presented for Ford Creek because the 1998 data indicates non-impairment and previous land use changes.

Table 8-3. Ford Creek Nutrient and Chlorophyll *a* Data.

Sample ID (River Miles from Mouth)	Ortho-phosphorous (µg/L)	NO_2+NO_3 (µg/L)	Total Kjeldahl Nitrogen (µg/L)	Benthic Chl. *a* (mg/m^2)
F1 (17.24)	< 1	120	< 100	5.56
F-5 (15.20)	< 1	120	< 100	73.0
F-9 (10.57)	< 1	50	< 100	25.1
F-17 (8.04)	< 1	40	< 100	20.2
F-30 (1.09)	< 1	30	< 100	28.9

8.3 Upper Sun River (Gibson Dam to Muddy Creek Confluence)

8.3.1 Nutrient Targets and Current Water Quality Status

Targets

Nutrient targets for the upper Sun River are based on the Clark Fork River nutrient standards and EPA ecoregion II/16 criteria that are presented in Table 8-2. The targets are set for the summer months, May through September, when nutrients are likely to increase algal production. Nutrient targets for the upper Sun River are 39 µg/L total phosphorus, 350 ug/L total nitrogen, 100 mg/m^2 benthic algal chlorophyll *a* mean and 150 mg/m^2 maximum. Both the Clark Fork River and upper Sun River fall within the U.S. EPA Montana Valley and Foothill Prairie nutrient ecoregion.

Nutrient criteria for Mill Creek, Big Coulee, Duck Creek, and Adobe Creek are higher than the upper Sun River target because their watersheds are more comparable to prairie, plain areas, than mountain foothill areas. These specific upper Sun River tributary nutrient concentration criteria are indicated in Figure 8-1 and 8-2 for guidance and are based upon the same premise as Muddy Creek and the lower Sun River nutrient targets (see Section 8.4.1). Elk Creek and Smith Creek watersheds are in mountain foothill areas and therefore have the same nutrient concentration criteria as the upper Sun River nutrient target.

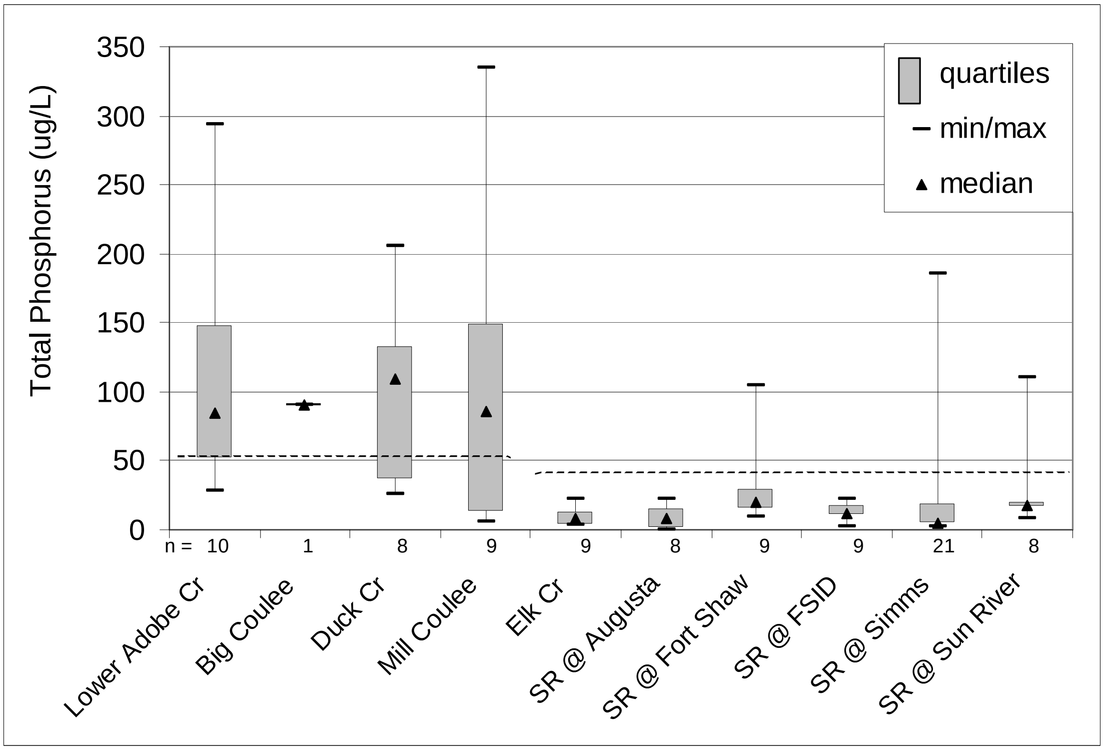
Impairment Status

Recently collected summer nutrient chemistry data for the upper Sun River indicates potentially elevated levels of total phosphorus and elevated nitrogen concentrations. In the upper Sun River, three of 55 total phosphorus water sample results from 1996-2004 are above water quality targets. The highest total phosphorus concentration detected in the upper Sun River, 186 µg/L, was detected at Simms (Figure 8-1). This exceedance is 377% of the target concentration but was during a flood when total phosphorus levels can be high naturally. Two out of the three exceedances of the total phosphorus target were during flood events of 3000 cfs or higher when high phosphorus levels are expected. Floods do not usually produce conditions that favor benthic algal production because of natural stream scour and turbidity. Therefore, these higher phosphorus concentrations are not likely to promote algal growth.

Thirty of 58 total nitrogen samples were above targets but nitrogen is not limiting algal production in this segment. Phosphorus limits algal production in this segment (Section 8-1). The highest total nitrogen concentration sampled in the upper Sun River exceeds targets by 683% (Figure 8-2). TMDLs for the lower Sun River and Missouri River should deal with transported nitrogen loads from this area if nitrogen is limiting algal production downstream.

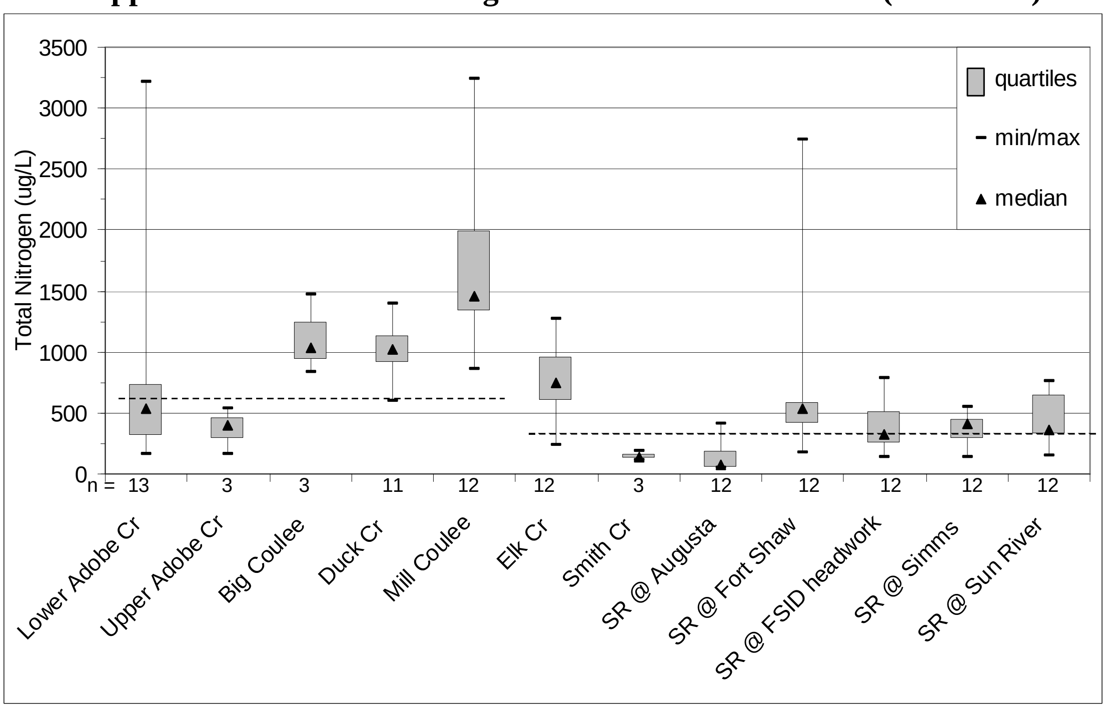
Phosphorus is the limiting nutrient in this section of the Sun River. Phosphorus levels in the upper Sun River segment do not appear to be an environmental problem because concentrations are low to moderate when conditions are suitable for benthic algal growth. Some of the tributaries to the upper Sun River do have higher total phosphorus concentrations than criteria that are presented and may be investigated further, but the upper Sun River appears to dilute the phosphorus loads from these tributaries.

Figure 8-1. Upper Sun River Total Phosphorus Summer Concentrations (1996-2003).



-The total nitrogen target for the upper Sun River is indicated as a dashed line.
-Nutrient criteria for tributaries are also included as dashed lines.

Figure 8-2. Upper Sun River Total Nitrogen Summer Concentrations (1996-2003).



-The total nitrogen target for the upper Sun River is indicated as a dashed line.
-Nutrient criteria for tributaries are also included as dashed lines.
SR = Sun River, FSID = Fort Shaw Irrigation District

Benthic algal chlorophyll *a* and dissolved oxygen levels are key indicators for determining if high nutrient concentrations are affecting beneficial uses. The following pictures of stream bottom provide some insight into the amount of benthic algae growth in this stream segment (Figure 8-3). Additionally, benthic chlorophyll *a* concentration was measured in the Sun River near the town of Sun River, on the lower end of this segment. An average of 71.3 mg/m^2 was found in three summer samples from 2001-2003. The minimum and maximum concentrations found were 69 and 74 mg/m^2. The chlorophyll *a* data indicate that nutrients do not impact beneficial uses in the upper Sun River.

Figure 8-3. Pictures of Algae Growth on the Stream Bottom in Shallow Glide Areas of the Upper Sun River, September 9th, 2004.

Near Augusta　　Near Simms

Recently collected data indicates that Montana's dissolved oxygen standards are met (Figure 8-4). Dissolved oxygen concentrations were lowest during the morning hours in the heat of the summer (Figure 8-5). The dissolved oxygen levels during these timeframes are just above Montana's dissolved oxygen standards (Section 3.0).

Figure 8-4. Dissolved Oxygen Concentrations in the Upper Sun River 2001-2003.

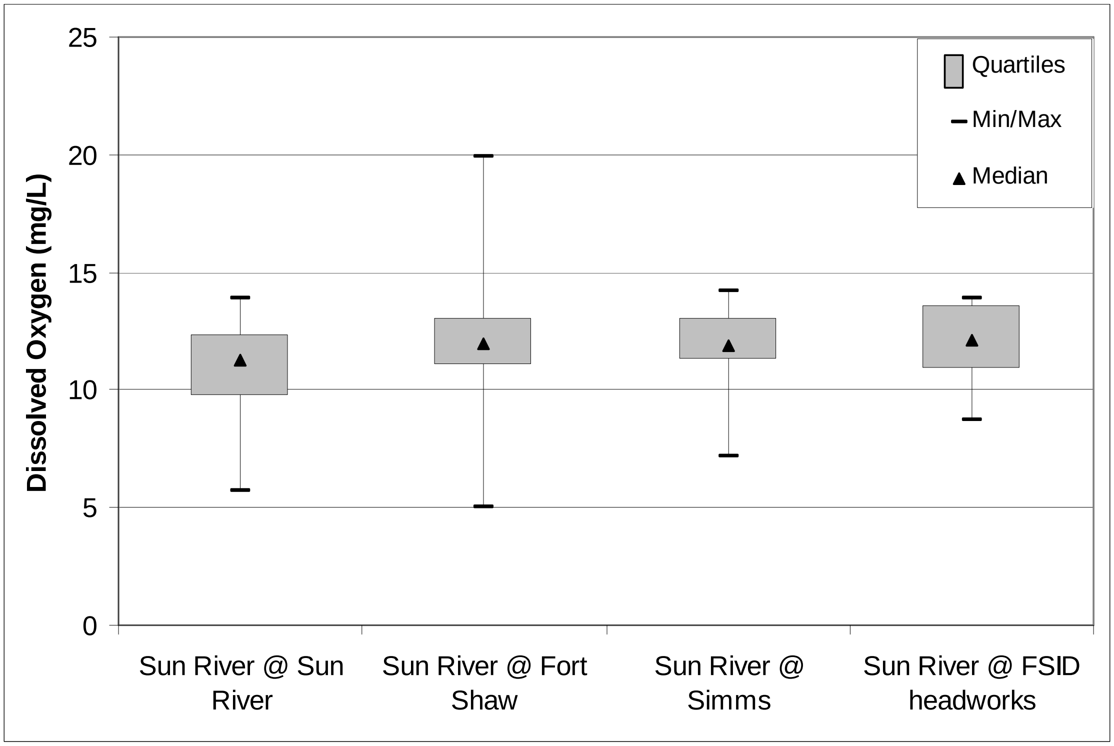
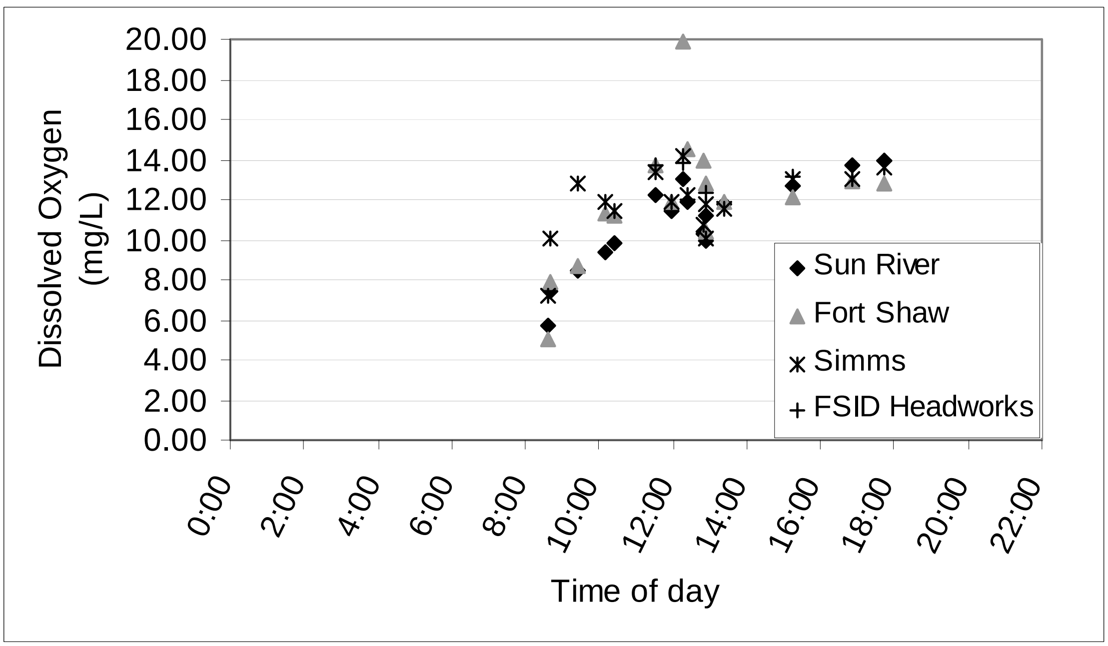


Figure 8-5. Dissolved Oxygen Concentrations and Time of Day Sample was Collected in the Upper Sun River 2001-2003.



A single macroinvertebrate sample was collected August 2001 near the town of Sun River (Bollman, 2001; Bollman, 2002). The biotic index for macroinvertebrates used in Montana is a slight derivation from the Hilsenhoff biotic index and is used to determine if nutrient enrichment affects the aquatic insect community. Mayfly taxa richness is also used as an indicator of nutrient enrichment. The biotic index was 4.83 and the mayfly taxa richness was high (7), suggesting little effect of nutrients on the aquatic insect community (Bollman, 2001; Bollman, 2002).

Assessing tributaries by comparing their existing water quality to nutrient criteria indicates a number of tributaries are sources of human caused nutrient loads. Nutrient concentrations in Adobe Creek, Mill Coulee, Elk Creek, Big Coulee, and Duck Creek are above nutrient criteria (Figures 8-1 and 8-2). Human influenced, nutrient producing activities such as irrigation, grazing and fallow cropping occur in these tributary watersheds.

8.3.2 Nutrient Conditions and Discharge Analysis

Nutrient loads were assessed for the upper Sun River. Phosphorus is assessed first because it appears to be the limiting nutrient that controls algae growth. Upper loading criteria that are likely to control algal growth are based on the nutrient targets presented in Section 8.3.1. The upper Sun River summer TP upper loading criteria that are likely to control algal growth are based upon maximum target concentrations of 39 µg/L. When targets are exceeded, the loading criteria are exceeded. Measured loads above and to the left of the load criteria line in Figure 8-6 are likely to create conditions that promote excessive benthic algal growth during mid and low discharges.

The Simms monitoring station was the only station on the upper Sun River with TP and associated discharge data. This site is used to compare existing TP loads to the upper loading criteria based on targets. The conversion factor of 0.2098 for the load criteria equation presented in Figure 8-6 is a combination of the TP target, time, water volume conversion, and mass conversion factors. Figure 8-6 shows that there are only three exceedances of the TP load criteria at Simms and two of these exceedances were during high flow. On average, the loading criteria are not being exceeded except during very high flow events when phosphorus levels are expected to be quite high. During mid and low range flow conditions that provide an optimal environment for benthic algal growth, only one of 23 samples exceeds the loading criteria. This evidence along with biological and dissolved oxygen data indicate that the total phosphorus conditions during mid and low range flows are controlling the algal growth in the upper Sun River to a point that uses are being met. Therefore, total phosphorus load reductions are not needed, but no increases in TP concentrations or loads should occur.

The Simms monitoring station was the only station on the upper Sun River with TN monitoring and associated discharge data. This site is used to compare existing TN loads to the loads that are likely to produce benthic algal conditions that support beneficial uses in the upper Sun River. The conversion factor of 1.883 for the loading criteria equation presented in Figure 8-7 is a combination of the TN target, time, water volume conversion, and mass conversion factors. Figure 8-7 includes nitrate loads because they indicate that nitrogen loading in the dissolved form is high and because there is not a robust TN data set at Simms. Nitrate is only a portion of TN. Actual associated TN loads would be higher than the measured nitrate loads. Most measured TN load criteria exceedances occur between flows of 50 and 150 cfs but higher discharges have not been sampled. The TN loading criteria are exceeded by 77 % of the samples, <u>but nitrogen is not the limiting nutrient in the upper Sun River</u> and is therefore not controlling benthic algal growth. Therefore, a TN TMDL is not needed. If nitrogen TMDLs are needed downstream of this segment, load reductions for this area may be called for in the future.

Estimated background concentrations ranges are derived from a study by Smith et al. (2003). Information from studies identified in Section 8.1 guided the selection of a background concentration from the range provided in Smith et al. (2003). The background concentration was then converted into a load equation in the same fashion as the TMDL targets were converted to the TMDL and is provided on the TMDL graphs below. Smith et al. (2003) modeled background TN and TP concentrations on a broad scale using reference watersheds in each EPA nutrient ecoregion. The background loads are modeled estimates and are provided as guidance on potentially achievable nutrient levels. Background levels are not necessarily the objective of a TMDL. The TMDLs are based on protecting in-stream beneficial uses. The background loads do coincide well with the State of Montana's water quality law because the modeling uses a reference watershed approach and extrapolates to impacted watersheds. See Smith et al (2003) for methods and modeling assumptions.

Figure 8-6. Upper Sun River Total phosphorus Load Criteria, Estimated Background Loads, and Measured Loads at Simms.

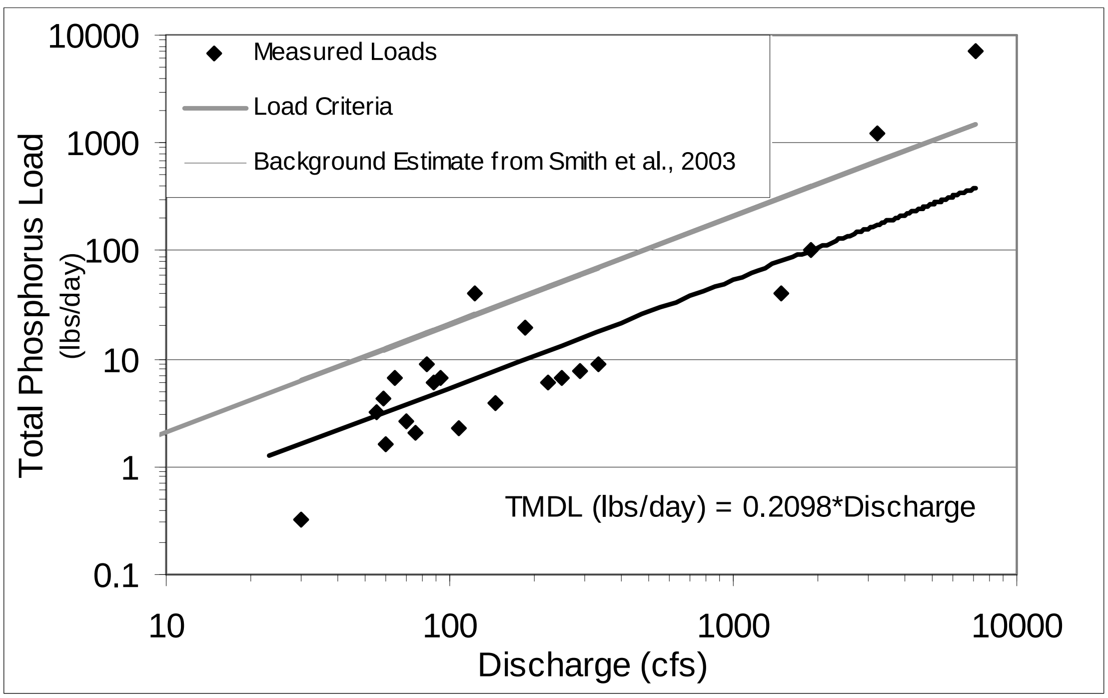
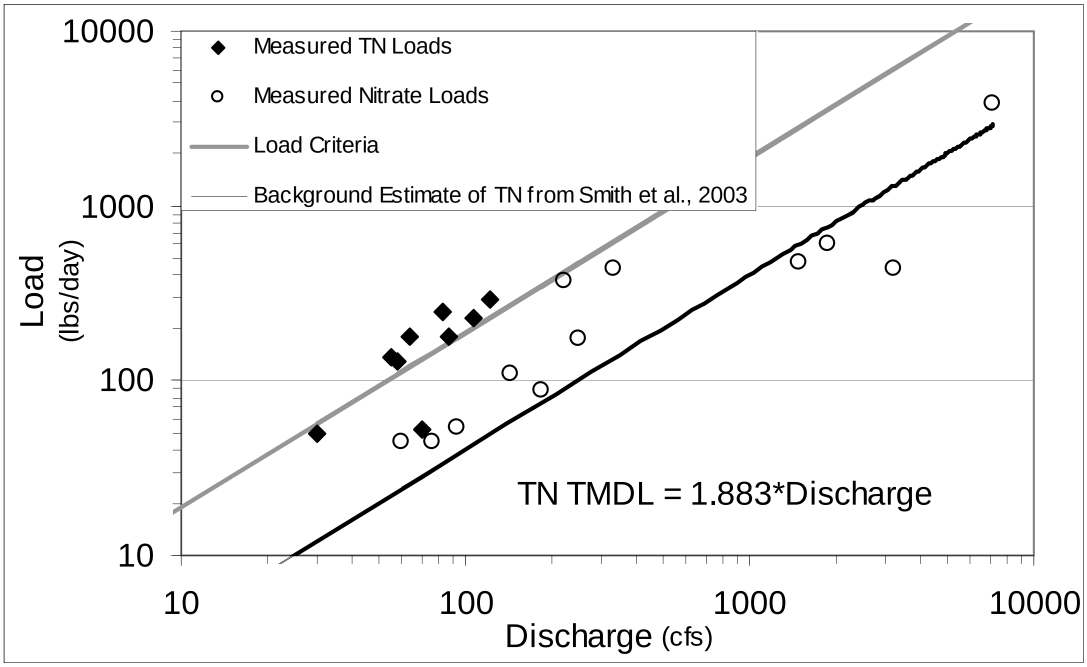


Figure 8-7. Upper Sun River Total Nitrogen Load Criteria, Estimated Background Loads and Measured Total Nitrogen and Nitrate Loads at Simms.



8.3.3 Monitoring Plan

Continuing a nutrient monitoring program is essential because TP concentrations are just below levels that could cause impairment. The follow up monitoring strategy is an essential part of an adaptive management program. TP and TN monitoring should continue at Simms along with discharge measurements. TP and TN monitoring should also be conducted along with associated discharge measurements at the town of Sun River. Nutrient monitoring should be conducted monthly during the summer months at these sites. Chlorophyll *a* and dissolved oxygen monitoring should also occur at these sites twice per summer during late July and August for two years. Dissolved oxygen (DO) should be monitored during the early morning. The results of this monitoring will be used to refine understanding of existing conditions resulting from nutrient loading in the upper Sun River.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Monitoring resources are not defined at this time nor are stakeholder and agency monitoring responsibilities. Future monitoring activities should include developing a detailed monitoring plan, or quality assurance project plan (QAPP), prior to fieldwork.

8.4 Muddy Creek

8.4.1 Nutrient Targets and Current Water Quality Status

Targets

Nutrient targets for Muddy Creek are based on EPA nutrient ecoregion VI/43 and V/42 nutrient criteria and on recently collected MDEQ data from Ecoregion V/42 (see Section 8.1.1). Portions of the Muddy Creek watershed fall within EPA nutrient ecoregions VI/43 and V/42. The targets are set for the summer months, May through September when aquatic plant production affects in-stream beneficial uses. The targets for Muddy Creek are set at 50 µg/L total phosphorus and 650 µg/L total nitrogen, 100 mg/m^2 chlorophyll *a* mean and 150 mg/m^2 chlorophyll *a* maximum.

Impairment Status

Muddy Creek has elevated total phosphorus and nitrogen concentrations. Thirty-nine of 60 total phosphorus (TP) water samples from 1996-2000 were above targets. The highest TP concentration detected in Muddy Creek, 1710 µg/L, was detected at Vaughn (Figure 8-8). This exceedance is 3,320% of the target concentration. All of the 17 total nitrogen (TN) samples from Muddy Creek were above targets. The highest TN concentration sampled in Muddy Creek exceeds targets by 492% (Figure 8-9).

Benthic algal chlorophyll *a* is a key indicator for determining if high nutrient concentrations are affecting beneficial uses. Benthic chlorophyll *a* has not been assessed in Muddy Creek. Currently, low benthic chlorophyll *a* concentrations would be found in Muddy Creek. Elevated streambed and suspended sediment levels in Muddy Creek suppress the growth of benthic algae or macrophytes. Even though high nutrient concentrations exist, aquatic plants cannot grow efficiently because of poor habitat conditions due to high sediment yields and extreme flow fluctuations. Suspended sediment in the water column blocks light and a shifting stream bottom does not provide a stable place for plant growth. Thus, plants cannot use the available dissolved nutrients that are delivered to the stream. The nutrients are transported downstream.

Figure 8-8. Muddy Creek Total Phosphorus Summer Concentrations (1996-2003).

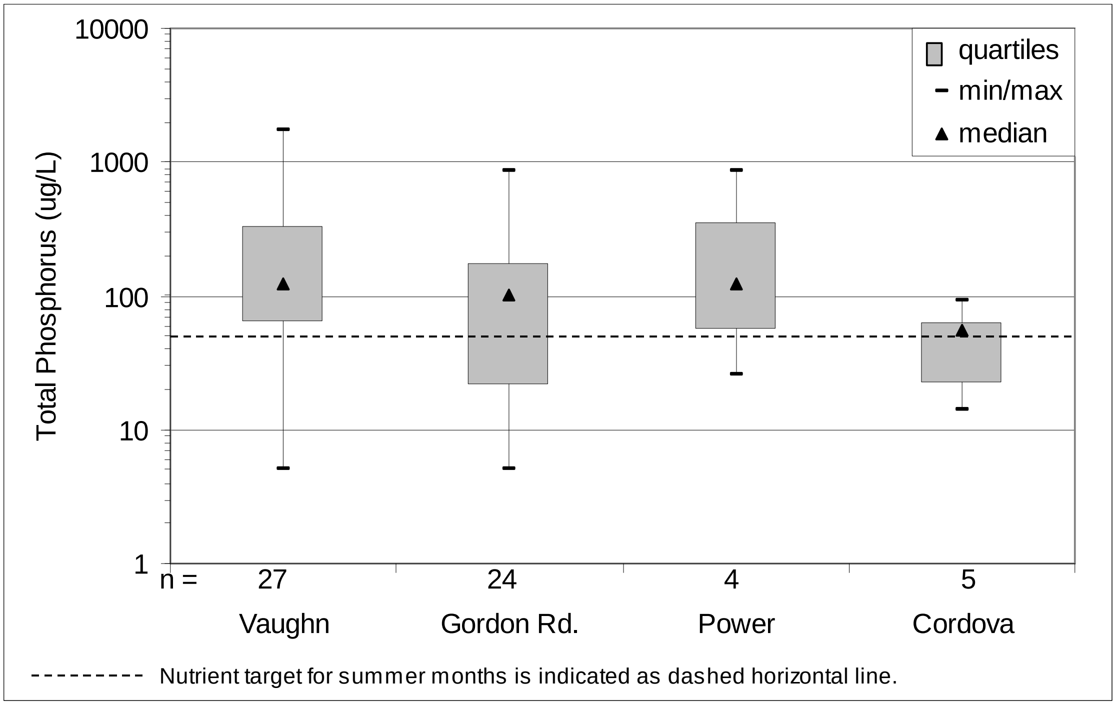
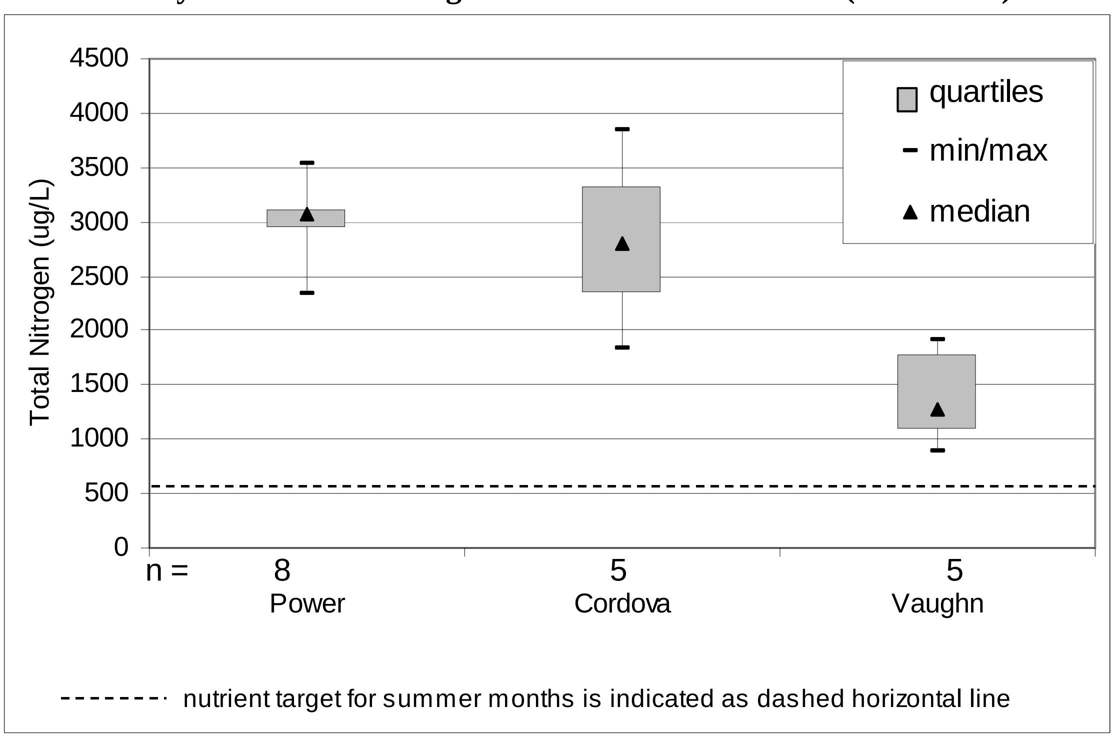


Figure 8-9. Muddy Creek Total Nitrogen Summer Concentrations (1996- 2003).



8.4.2 Source Assessment

Most of the source assessment monitoring in the Muddy Creek watershed has focused on nitrate analysis. Nutrients are transported, instead of being used by aquatic plants, in the Muddy Creek watershed. Therefore, nitrates are indicative of total nitrogen transport in the Muddy Creek watershed.

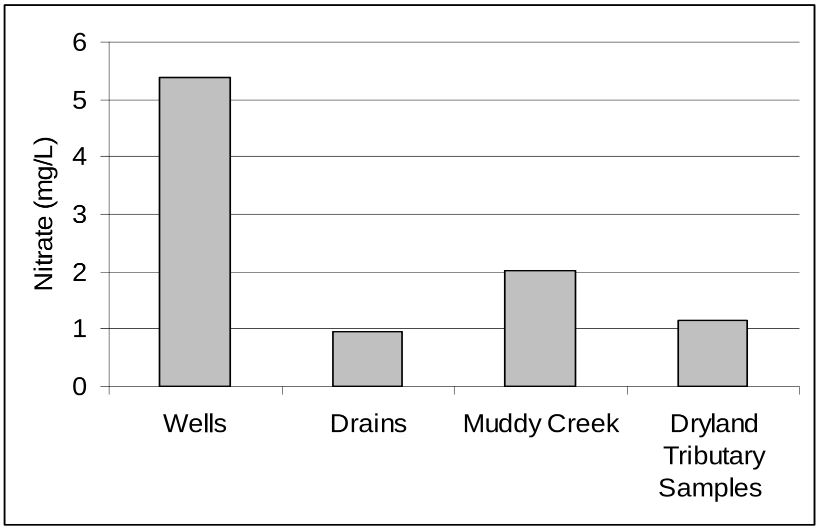
A 1980 study by Walther (1982) began to identify sources of nitrate in the Muddy Creek Watershed. Nitrate concentrations in Greenfields Bench groundwater, drainages from the Greenfields Bench, dry land drainages, and Muddy Creek were sampled (Figure 8-10). Walther (1982) rationalizes that lower nitrate levels in the drainages are due to channel stability giving better habitat for algal growth than in Muddy Creek. The algae in the drainages can utilize nitrate, but poor conditions due to stream channel instability in Muddy Creek inhibit nitrate use by aquatic plants or algae. Nitrate concentrations also increase in the drains during cold weather periods when diluting effects of surface waste from irrigation do not occur and algae growth is inhibited by low temperature and light conditions. During 1980, mean nitrate concentrations in three Greenfields Bench drainages exceeded Muddy Creek’s targets for total nitrogen (Walther, 1982).

The majority of Muddy Creek’s base flow is derived from irrigation groundwater return flow draining from the Greenfields Bench aquifer. When discharge is lowest, typically in March, the median nitrate concentration in Muddy Creek is 5.1 mg/l. At this same time, the median nitrate concentration is 5.7 mg/l in groundwater under the Greenfields Bench (Walther, 1982).

Walther (1982) and USGS data at Vaughn is used to identify loading from sources in Muddy Creek (Table 8-4) during 1980. Three of the larger Greenfields Bench drains (E, J, M) contributed approximately 9 percent of the nitrate loading to the Muddy Creek at Vaughn site in 1980 (Table 8-4). Even though loading from dry land areas was not reported because of low sampling frequency (n=9) due to intermittent flows, Walther (1982) indicates that the majority of nitrate load is derived from the Greenfields Bench by extrapolation of data. Because of the intermittent nature of most dry land drainages in Muddy Creeks watershed, accurate gauging and discharge data is not available in dry land areas, thus loading from dry land areas is either grossly estimated or unknown.

During 2000, nitrate loads from six major Greenfields Bench drainages contributed approximately 61 percent of nitrate loading during low flow and 87 percent during high flow conditions when compared to loads at Vaughn (Miller, 2002; USGS, 2002) (Figure 8-11). Other potentially significant sources of nitrates include smaller Greenfields Bench drains, runoff from dry land areas, groundwater discharge directly entering the stream, and stream channel erosion along the Muddy Creek corridor. There is insufficient information about these other sources to provide load estimates.

Figure 8-10. Mean Nitrate Concentrations in Greenfields Bench Groundwater, Drainages from the Bench, Dry Land Drainages, and Muddy Creek.



(Walther, 1982)

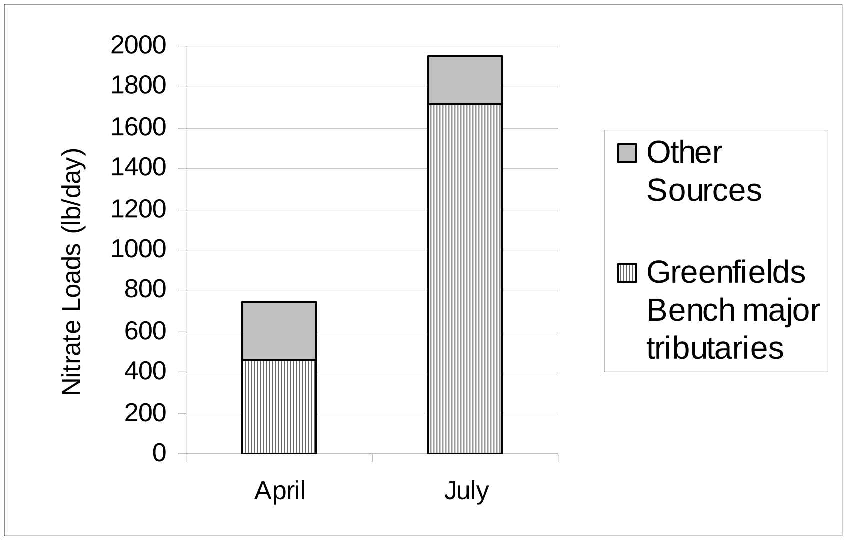
Table 8-4. Muddy Creek Nitrate Loading.

Station	Number of Samples (April –Oct. 1980)	Mean Load (lbs/day)
MC at Cordova (M-1)	14	240
MC upstream of drain E (M-3)	14	460
Drain E (D-1)	14	40
MC upstream of Drain J (M-4)	14	580
Drain J (D-2)	14	120
MC upstream of Drain M (M-5)	14	700
Drain M (D-3)	14	100
MC nr Vaughn - USGS data	20*	2858
MC at Vaughn - USGS data	20*	2929

MC = Muddy Creek
- Drainage data collected and analyzed in 1980 by Walther, 1982.

* USGS data collected April –Oct, 1979-81 and analyzed by MDEQ, 2002.Multi year data (April-Oct data from 1980-1984) used at USGS station to better represent mean conditions.

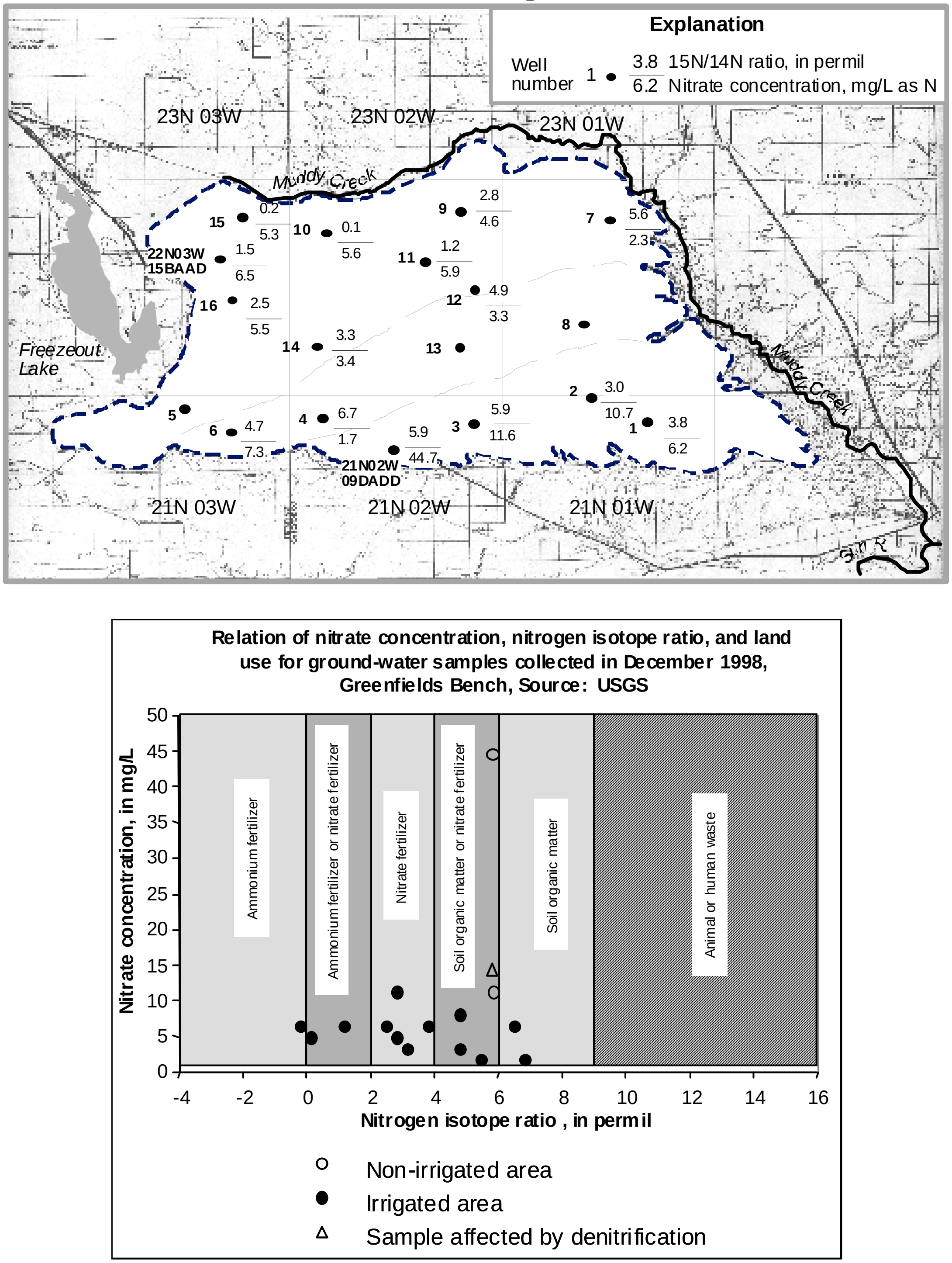
Figure 8-11. Nitrate Loading Contribution to the Muddy Creek at Vaughn USGS Site from Six Major Tributaries Originating on Greenfields Bench.



Greenfields Bench tributary data collected in 2000 by Miller, (2002). USGS data used in this comparison is the monthly (April or July) mean from 1996-2000 at the Muddy Creek at Vaughn station. A USGS mean from a 4-year period is used to offset variability in discharge levels because the two studies were not synoptic.

There are a number of possible nitrate sources on the Greenfields Bench, including fertilizers, domestic septic systems, soil organic nitrogen, stock animals and geologic sources. Nitrogen atoms from each of these sources have different isotopic signatures (Exner and Spalding, 1994). USGS collected water samples from 16 wells for nitrogen isotope analysis. Results indicate that nitrate in groundwater underlying irrigation on the bench is attributable to nitrogen fertilizer, ammonium fertilizer, soil organic nitrogen or a combination of these sources (Figure 8-12) (Miller, 2002). Sixty to seventy percent of the irrigated area groundwater samples indicate that fertilizers could be a major source of nitrate to the groundwater. The two samples collected from wells in non-irrigated areas indicate that soil nitrogen and nitrogen fertilizers are potential sources. Although the relative contribution of each source is not obtainable through this analysis, it is apparent that the majority of nitrate in groundwater under the Greenfields Bench is probably derived from fertilizers or leaching from geologic sources and not from animal or human waste (Miller, 2002).

Figure 8-12. Map Showing Locations of $^{15}N_{NO_3}$ Sampling from Wells Completed in Gravel Underlying the Greenfields Bench and Relation of Nitrate Concentration, Nitrogen Isotope Ratio, and Land-Use Based on Groundwater Samples Collected in December, 1998.



(graphics from Miller, 2002)

Loading from bank erosion on Muddy Creek is also a significant source of nutrients, particularly total phosphorus, which adsorbs to suspended solids (Froelich, 1988). The most severe bank erosion in Muddy Creek's Watershed occurs between Muddy Creek near Vaughn (at Gordon Rd.) and Muddy Creek at Vaughn USGS stations. Total phosphorus loads increase by about 53 percent between these two sites. Nitrate loads decreased by 3 percent between these sites. This indicates that erosion is a source of phosphorus.

There are no MPDES permitted CAFOs or POTWs located in the Muddy Creek Watershed. Power has a non-discharging evaporative wastewater lagoon system that was upgraded in 1990 (MDEQa). Limited areas of septic use may be a small source of nutrients in the lower portion of Muddy Creek, but given the magnitude of the agricultural nutrient sources, septic is not likely a significant contributor of nutrients (Map 8-2).

8.4.3 TMDL and Allocations

Nutrient TMDLs

The nutrient TMDLs for Muddy Creek are the amount of total nitrogen (TN) or total phosphorus (TP) that the stream can receive from sources and support all of its beneficial uses. TMDLs are the sum of the waste load allocation, or point sources, plus the sum of the load allocations, or nonpoint sources, plus a margin of safety. Allocations and the margin of safety are provided in subsequent sections. The nutrient TMDLs are set for the summer (May-September) when biological in-stream beneficial uses are impacted by the availability of excess nutrients. The TMDLs are expressed as discharge dependant equations in Figures 8-13 and 8-14 and are compared to actual load measurements at Vaughn. Muddy Creek summer TN and TP TMDLs are based upon maximum target concentrations of 650 μg/L and 50 μg/L respectively. When targets are exceeded, the TMDL is exceeded. Measured loads above and to the left of the TMDL lines in the graphs are historic exceedances of the TMDLs.

Load measurements at Vaughn are used to compare existing total phosphorus loads to the TMDL because it is just upstream of the confluence with the Sun River. Seventy two percent of the TP samples exceed the TMDL. The conversion factor of 0.269 for the TMDL equation presented in Figure 8-13 is a combination of the TP target, time, water volume conversion, and mass conversion factors.

Load measurements at Vaughn are also used to compare existing total nitrogen loads to the total nitrogen TMDL. Figure 8-14 includes nitrate loads because they indicate that nitrogen loading in the dissolved form is high and because there is not a robust TN data set at Vaughn. Nitrate is only a portion of TN. Actual associated TN loads would be higher than the measured nitrate loads. All of the TN samples exceed the TMDL. The conversion factor of 3.497 for the TMDL equation presented in Figure 8-14 is a combination of the TN target, time, water volume conversion, and mass conversion factors.

Estimated background concentrations ranges are derived from a study by Smith et al. (2003). Information from studies identified in Section 8.1 guided the selection of a background concentration from the range provided in Smith et al. (2003). The background concentration was then converted into a load equation in the same fashion as TMDL targets were converted to TMDL equations and is provided on the TMDL graphs below. Smith et al. (2003) modeled background TN and TP concentrations at a broad scale using reference watersheds in each EPA nutrient ecoregion. The background loads are modeled estimates and are provided as guidance on potentially achievable nutrient levels. Background levels are not necessarily the objective of a TMDL. The TMDLs are based on targets that protect in-stream beneficial uses. Using background loads as an indicator coincides well with the State of Montana’s water quality law because the modeling uses a reference watershed approach and extrapolates to impacted watersheds. See Smith et al (2003) for methods and modeling assumptions.

Figure 8-13. Muddy Creek Total Phosphorus TMDL and Background Loads Compared to Measured Loads at Vaughn.

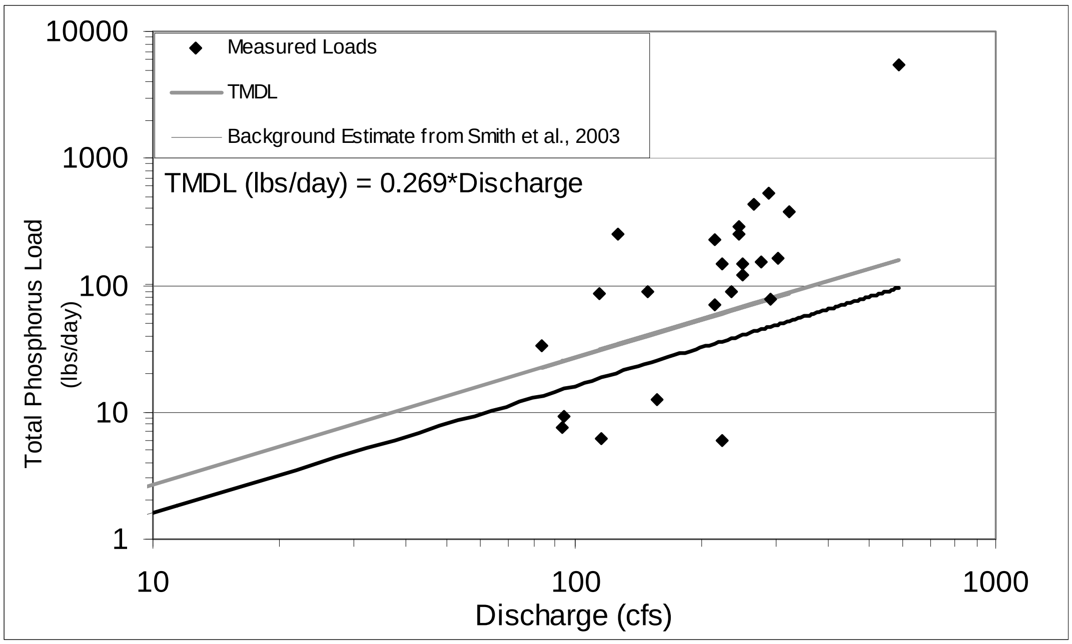
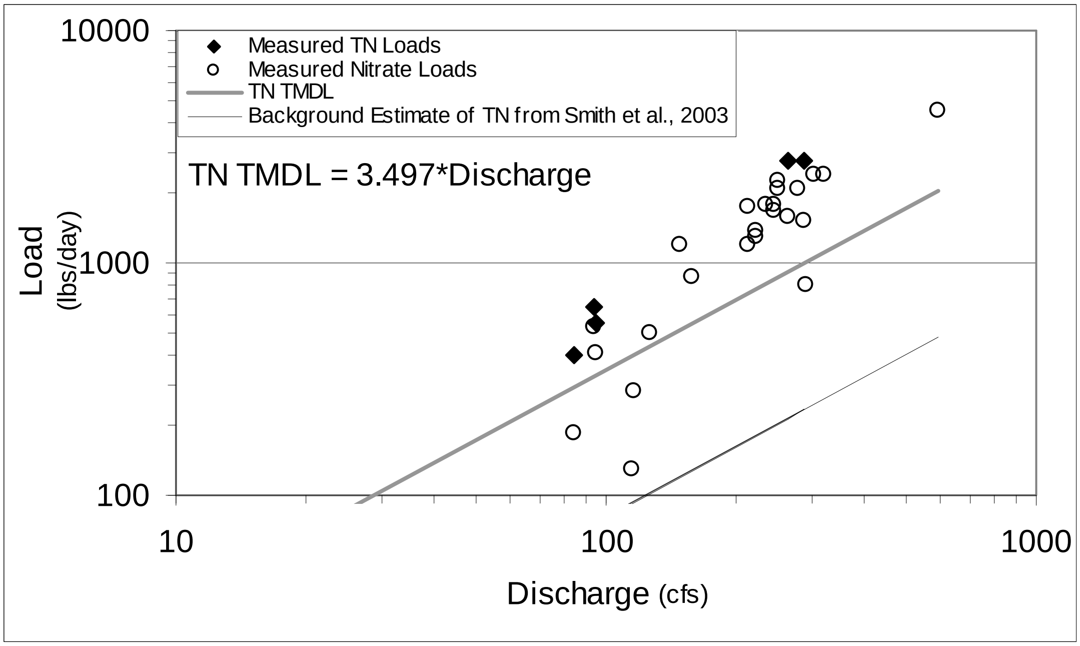


Figure 8-14. Muddy Creek Total Nitrogen TMDL and Background Loads Compared to Measured Total Nitrogen and Nitrate Loads at Vaughn.



Allocations

The current source assessment for nutrients in Muddy Creek provides sufficient detail for a compelling allocation strategy. The source assessment identifies agricultural activities on Greenfields Bench as the major contributor of high nitrate concentration and load. The source assessment also indicates that increased irrigation return flow from Greenfields Bench and poor riparian management on Muddy Creek causes significant bank erosion. The bank erosion produces high phosphorus loads. Fallow cropping in other portions of the watershed is likely a contributor of nitrates, although current data about this source is less compelling. Nutrient reductions of both TN and TP needed to meet nutrient targets and TMDLs for Muddy Creek will come from addressing agricultural activities with reasonable land, soil and water conservation practices, specifically those agricultural activities mentioned above. The actual load reduction of total nitrogen and total phosphorus from agricultural sources depends upon stream discharge conditions. The total nitrogen allocation for agricultural sources is 105.1 lbs/day TN and 10.9 lbs/day TP if Muddy Creek were flowing at 45 cfs at Vaughn. Forty-five cfs is the July through October, 10 year, 7 day duration (summer 7Q10), low flow in Muddy Creek at Vaughn. The nitrogen reductions needed to meet the discharge based TMDL will come from nonpoint source agricultural activities, specifically fertilizer application and activities that cause stream bank erosion. Allocation to specific agricultural sources during future TMDL reviews will contribute to a stronger nutrient allocation for Muddy Creek. There is not a waste load allocation because there are no NPDES POTW point sources in the watershed.

8.4.4 Margin of Safety, Seasonal Consideration, and Adaptive Management

The margin of safety for this TMDL is provided in the allocation process and an adaptive management approach. Ten percent of the TMDL is reserved as a MOS in the allocation of loads to sources. The TMDL is set for an extended summer season, from May-September, because algal growth can be influenced during this timeframe if spring runoff is below average. Total nitrogen and TP TMDLs are presented because as restoration occurs, nutrient conditions may change the limiting nutrient. A monitoring plan to provide data for further refinement of source assessment and allocation is presented in the next section. If followed, the monitoring strategy will provide data for refining the impairment status, source assessment and allocation during future TMDL review. The uncertainty of the Muddy Creek nutrient TMDL analysis is addressed by future TMDL review, which is identified in Montana law.

Identified conservation practices in Section 8.4.5 should be tracked over time to see if implementation occurs. If implementation occurs and does not achieve targets or load allocations in the watershed, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place, the document may need revision.

Figure 8-15 is an example of Muddy Creek's nutrient TMDL, allocation, and margin of safety strategies in use at a specific discharge scenario. The daily average discharge for the scenario is 100 cfs because this is a moderate flow condition. Existing loads at 100 cfs are estimated from an average of three samples similar to this discharge for TN and six samples for TP. Natural load estimates are derived from the background loads identified in Figures 8-13 and 8-14. Subtracting natural loads from existing total loads derives existing agricultural load estimates at 100 cfs. The TMDLs are derived from the TMDL equations. The natural components of the TMDLs were derived by using background loads from Figures 8-13 and 8-14. The margin of safety is 10% of the TMDL allocation. The load allocations are then calculated using the TMDL equation.

Figure 8-15. Muddy Creek Estimated Existing Loads, TMDL, Allocation, and Margin of Safety Scenario at 100cfs.

Daily average Muddy Creek discharge scenario: 100 cfs

Estimated existing loads at 100 cfs:

Total: 65 lbs/day TP 532 lbs/day TN	**Natural**: 16.4 lbs/day TP 80.7 lbs/day TN	**Agricultural Load:** 46.2 lbs/day TP 451 lbs/day TN

Total Maximum Daily Load at 100 CFS

An estimated 66%TN and 83% TP average load reduction is needed from fertilizers, irrigation, riparian grazing, and fallow cropping with flows at 100 cfs

There are no POTWs in the Watershed

10% of TMDL

TMDL = Load Allocation + Natural +Waste Load Allocation + Margin of Safety

26.9 lbs/day TP = 7.81 lbs/day + 16.4 lbs/day + 2.69 lbs/day

349.7 lbs/day TN = 234.0 lbs/day + 80.7 lbs/day + 35.0 lbs/day

8.4.5 Restoration Strategy

Restoration approaches in the Muddy Creek watershed should focus on agricultural activities identified in the allocation Section 8.4.3. The following activities should be addressed with reasonable land, soil, and water conservation practices:

- Fertilizer use on all agricultural lands should be addressed by on-farm nutrient management plans, especially on Greenfields Bench. Use of slow release fertilizers would benefit water quality. Excessive use of ammonia fertilizer contributes to nitrate loading in Muddy Creek and increases crop production costs. In conjunction with nutrient application management, irrigation management will decrease the leaching fraction of water on inefficiently irrigated fields. Decreasing the amount of water that percolates through the soils will reduce nitrate loading to groundwater and will also save irrigators money by reducing the amount of fertilizer needed to grow crops. More fertilizer will be left in the soil for plants to use.
- Irrigation water management should continue to be addressed on the Greenfields Bench to reduce erosion in lower Muddy Creek due to increased stream energy that produces near stream erosion. The bank erosion contributes significant phosphorus loads.
- Areas of fallow cropping that predominate in the northern and eastern portions of the watershed contribute nitrate to Muddy Creek during low flow timeframes. Fallow cropping BMPs could include reduction in summer fallow acreage, flex cropping,

conversion to alfalfa, or temporary inclusion into the Conservation Reserve Program (CRP).

- Intense riparian livestock grazing increases near stream erosion on Muddy Creek and tributaries. The near stream erosion contributes phosphorus loads during high flow. Riparian area livestock grazing can be managed with off stream water, cross fencing, pasture rotation management techniques and potentially with riparian fencing.
- Livestock waste management systems on any AFOs within 300 feet of any stream in the Sun River watershed should be examined. If runoff from these areas reaches the stream network, BMPs will be installed.
- All restoration activities should be tracked in a watershed restoration database. Pre and post BMP effectiveness nutrient monitoring should be conducted on a subset of restoration activities to further define nutrient loading from these categories and to determine BMP effectiveness.

8.4.6 Monitoring Plan

Continuing a nutrient monitoring program is essential because of uncertainties in the source assessment and allocation process. TP and TN monitoring should continue at the USGS station at Vaughn along with discharge measurements. Nutrient monitoring should be conducted monthly at this site. Vaughn data should be used for further refining the TMDL during future TMDL reviews and to determine nutrient trends over time. If the USGS is collecting water samples, they should analyze water chemistry for NO2+NO3 as N, TKN, PO4 as P, and total phosphorus.

Chlorophyll *a* monitoring should occur once per summer during August for at least three of the next five years at Muddy Creek at Vaughn and Power, as well as in 2 of the major Greenfields Bench drainages. The chlorophyll *a* results will be used to refine our understanding of impairment conditions resulting from nutrients in Muddy Creek.

Tracking water quality changes due to restoration activities is an important component of a long term monitoring plan. Spatial and functional attributes of restoration activities should be documented in a spatial database on a 5-year review period in Muddy Creek’s watershed. The restoration tracking system would be used for all pollutant/waterbody TMDL reviews in the future and is not specific to this nutrient TMDL.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Monitoring resources are not defined at this time nor are stakeholder and agency monitoring responsibilities. Future monitoring activities should include developing a detailed monitoring plan, or quality assurance project plan (QAPP), prior to fieldwork.

8.5 Lower Sun River

8.5.1 Nutrient Targets and Current Water Quality Status

Targets

Nutrient targets for Lower Sun River are based on EPA nutrient ecoregion VI/43 and V/42 nutrient criteria and on recently collected MDEQ data from Ecoregion V/42 (see Section 8.1.1). Portions of the lower section of the Sun River fall within EPA nutrient ecoregions VI/43 and V/42. The targets are set for the summer months, May through September when aquatic plant production affects in-stream beneficial uses. The targets for the lower Sun River are set at 50 µg/L total phosphorus and 650 µg/L total nitrogen, 100 mg/m^2 chlorophyll *a* mean and 150 mg/m^2 chlorophyll *a* maximum.

Impairment Status

The lower Sun River has elevated levels of total phosphorus and nitrogen. Fifty eight percent of the 38 total phosphorus water samples collected in this stream segment during the summer months from 1996-2000 were above targets. The highest total phosphorus concentration detected in the lower Sun River, 283 µg/L, was detected near Vaughn (Figure 8-16). This exceedance is 466% of the target concentration. Eighty six percent of the 28 total nitrogen samples from the lower Sun River segment were above targets. The highest total nitrogen concentration sampled in the lower Sun River exceeds targets by 265% (Figure 8-17). Nitrate data from the lower Sun River also indicates nitrogen enrichment.

Benthic algal chlorophyll *a* is a key indicator for determining if high nutrient concentrations are affecting beneficial uses. Benthic chlorophyll *a* has not been assessed in the lower Sun River. Currently, low benthic chlorophyll *a* concentrations would likely be found in portions of the lower Sun River. Elevated streambed and suspended sediment levels derived from Muddy Creek suppress the growth of benthic algae or macrophytes. Even though high nutrient concentrations exist, aquatic plants cannot grow very efficiently because of poor habitat conditions due to high sediment yields and extreme flow fluctuations. Suspended sediment in the water column blocks light. Thus, plants cannot use much of the available dissolved nutrients that are delivered to the stream. Much of the nutrient load delivered to the lower Sun River is transported downstream even during the typical season that algae usually proliferate in nutrient rich conditions. Pictures of the stream bottom could not be taken because the water was too turbid.

Figure 8-16. Lower Sun River Total Phosphorus Summer Concentrations (1996-2003).

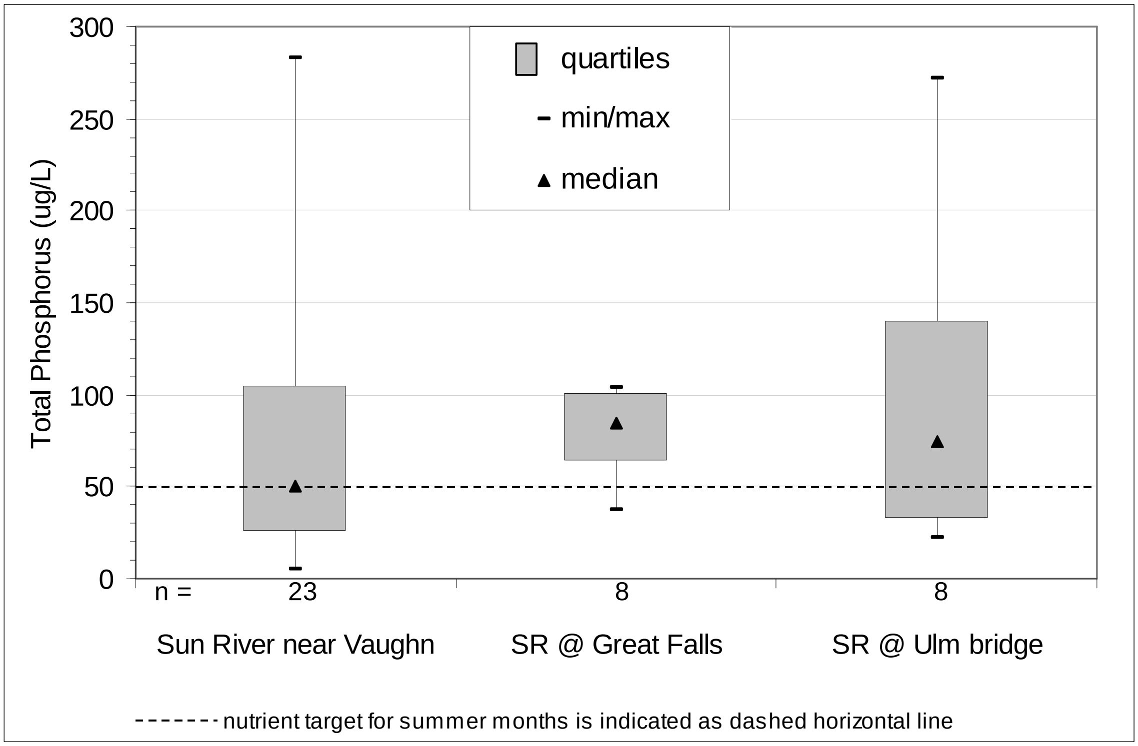
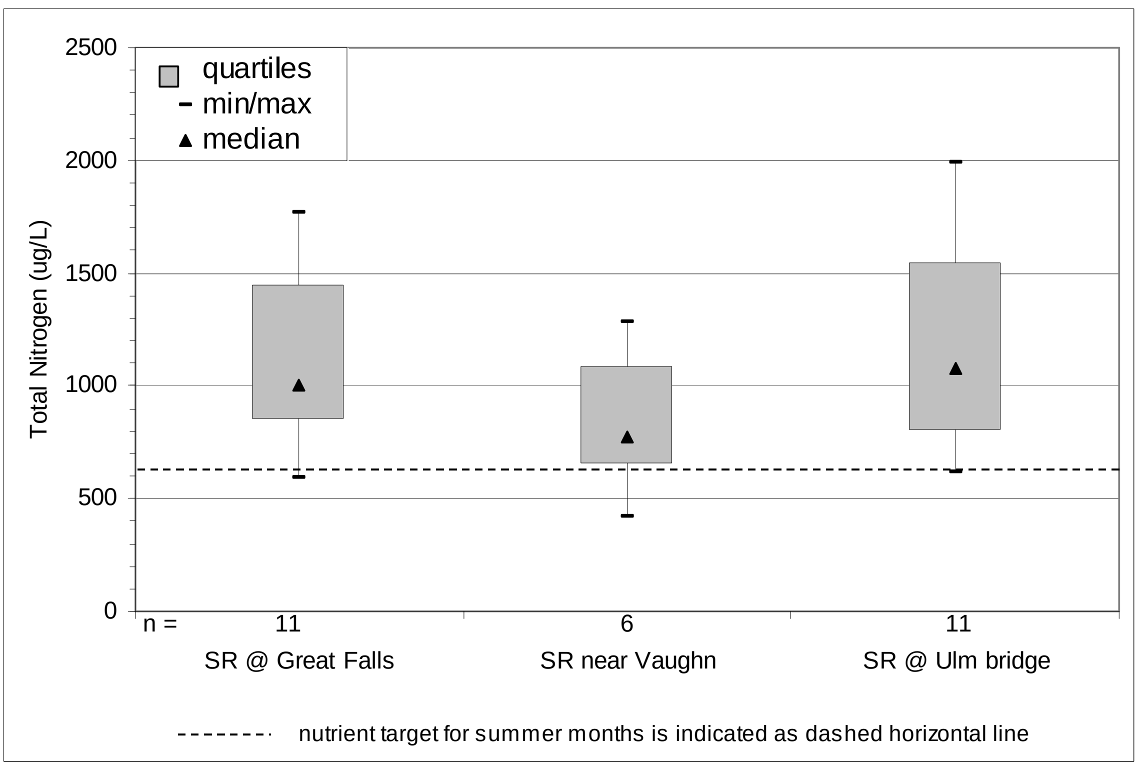


Figure 8-17. Lower Sun River Total Nitrogen Summer Concentrations (1996- 2003).



8.5.2 Source Assessment

SPARROW Model

The source assessment for the lower Sun River uses a modeling approach called "spatially referenced regressions of contaminant transport on watershed attributes" (SPARROW). The SPARROW model was completed at the Sun River watershed scale by the USGS and is used for general watershed scale source assessment (Smith et al., 1997). See Smith et al. (1997), and http://water.usgs.gov/nawqa/sparrow/wrr97/results.html for discussion of SPARROW model methods, justification, assumptions, and uncertainties. The standard error for some of the nutrient source loads indicated by the SPARROW model is quite high. Therefore, it is used as a coarse level source assessment to be used along with existing water quality data.

Agricultural Sources

SPARROW model output indicates that fertilizer and livestock production is the largest human caused contributors of nutrients to the Sun River. SPARROW modeling estimated these two sources combined, contribute about 45% of the total nitrogen and 52% of the total phosphorus loads in the Sun River Watershed (Smith et al., 1997) (Figures 8-18 and 8-19).

Nitrogen from fertilizers can easily be transported as nitrate in groundwater, and are usually associated with augmented groundwater flow and fertilizers from irrigated and Fallow cropped fields (Walther, 1982). Nitrogen from fertilizers is usually transported with groundwater in the form of nitrate. Groundwater derived from irrigation and fallow cropping also increases the amount nitrogen that dissolves from the soil and underlying geology. Groundwater flows are increased from irrigated agricultural areas in Muddy Creek, Duck Creek/Big Coulee, Mill Coulee, Adobe Creek, Elk Creek, and the upper Sun River Valley (Map 2-5). Most of these tributaries have high total nitrogen concentrations when compared to criteria (Figure 8-2).

In the Sun River Watershed, phosphorus tends to cling on soils particles and is usually transported and associated with suspended sediment in water (Walther, 1982). Irrigation return flow causes increases in stream energy, and subsequently, bank erosion in Muddy Creek, Duck Creek/Big Coulee, Mill Coulee, and Adobe Creek. These tributaries also have high total phosphorus concentrations (Figure 8-1). The SPARROW model does not address erosional processes due to increased stream energy.

Highly regulated stream discharge combined with riparian livestock grazing on the upper Sun River decreases the resiliency of riparian vegetation to flood events (Section 9.0). Unstable and eroding banks comprise 25 miles or 19.4 percent of the upper Sun River main stem channel between Gibson Reservoir and the town of Sun River as assessed by Chrest et al. (1987). Historic floods have caused some of the erosion along the Sun River, but a portion of the erosion comes from agricultural practices that reduce riparian vegetative cover and rooting strength of near stream areas. See Section 9.0 for sediment source assessments. The eroding banks are likely a significant source of phosphorus.

Other Sources

The SPARROW model combines rangeland, forestland, and urban sources into one category called non-agriculture. The model estimates that these sources contribute about 42% of the total nitrogen and 45% of the total phosphorus loads to the watershed. Grazing on rangeland is an agricultural activity, even though it is combined into a nonagricultural grouping for the model output. Forestland and upland range are generally not sources of human induced nutrient loading in the Sun River watershed. Better management of riparian area grazing land is expected to foster better riparian vegetation growth and reduce bank erosion and likely total phosphorus loading. Riparian grazing is the only activity found in the Sun River watershed in this general modeling category that is likely a significant source of nutrients, but the model does not consider this detailed linkage of riparian grazing and bank erosion.

Aerial deposition of nitrogen on land surfaces contributes a significant portion of total nitrogen loading in the Sun River watershed. The model (SPARROW) estimated that 12% of the total nitrogen load in the Sun River watershed comes from atmospheric deposition. Aerial deposition is derived from both natural and anthropogenic sources. Natural sources may include wind-blown dust, wildfires, volcanoes, natural gas seeps, non-domestic animals, vegetation emission, and decomposition process. Human influenced sources include agricultural and wild-land burning, wood burning, oil, coal and gas combustion, and other activities. Total phosphorus loads are not significantly influenced by atmospheric deposition according to the model (Smith et al., 1997).

Figure 8-18. SPARROW Model Results: Estimated Total Phosphorus Source Loading in the Sun River Watershed.

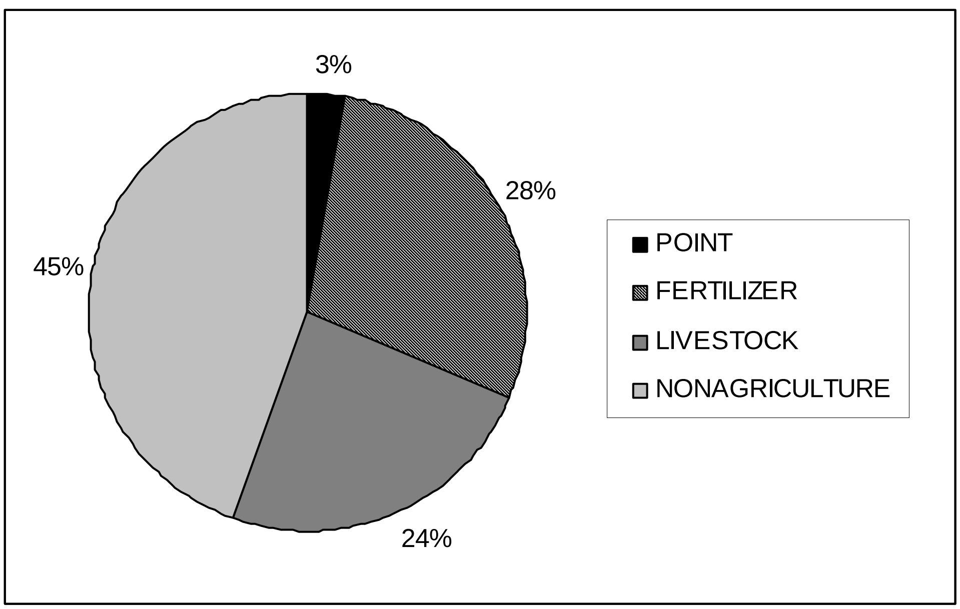
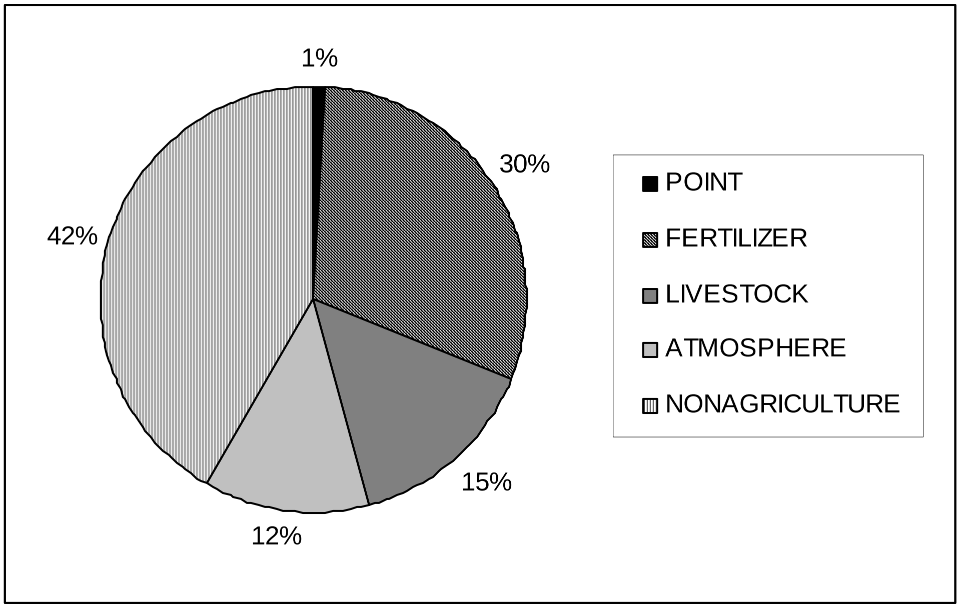


Figure 8-19. SPARROW Model Results: Estimated Total Nitrogen Source Loading in the Sun River Watershed.

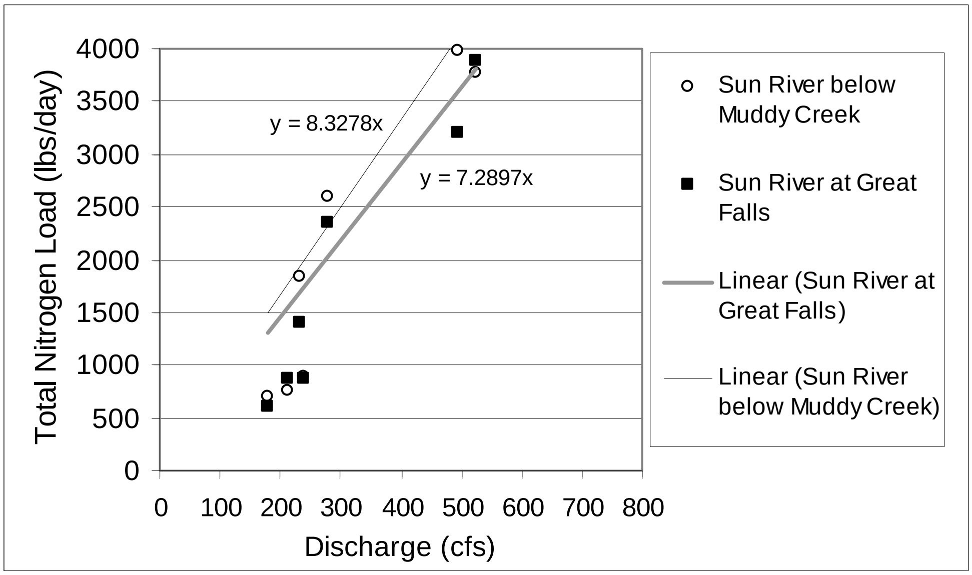


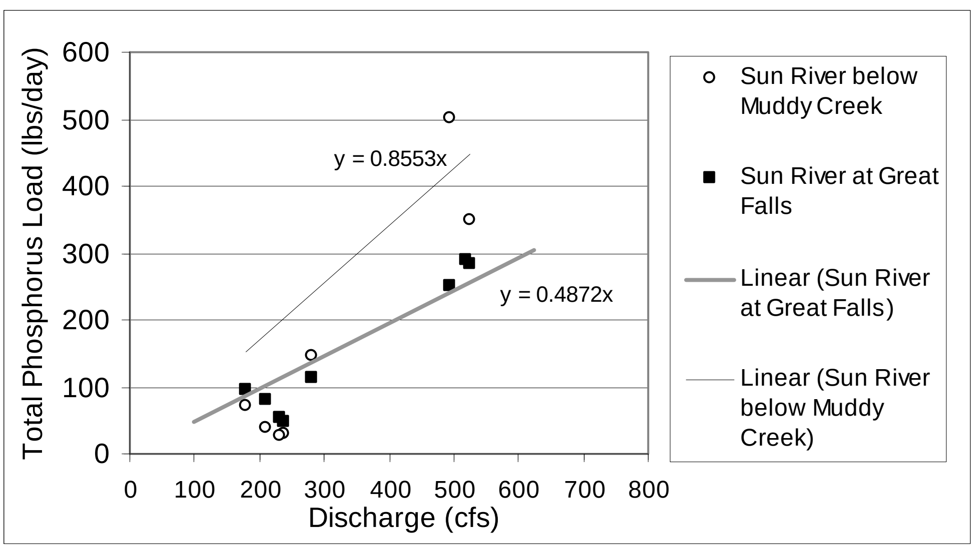
The nutrient source assessment for the lower Sun River also depends heavily upon an approach that considers the upper Sun River watershed and Muddy Creek watershed as source areas. Muddy Creek contributes 63 percent of the total phosphorus loading to the Sun River when comparing the Muddy Creek at Vaughn site to the Sun River near Vaughn site. The contributing land area of Muddy Creek is only 16 percent of the whole Sun River watershed. Total nitrogen loading calculations could not be compared between these sites because of insufficient available data; nitrate loads were analyzed as a surrogate. Muddy Creek contributes 85 percent of the nitrate loading to the Sun River when comparing the Muddy Creek at Vaughn site to the Sun River near Vaughn site (MDEQ, 2002). The upper Sun River contributes 37 percent of total phosphorus loads and 15 percent of nitrate loads to the lower Sun River but encompasses a large land area.

Most of the nutrient load found in this section of river is derived from upstream sources that are identified in the Muddy Creek lower Sun River source assessment sections (Section 8.3.2 and 8.5.2). Other potential sources of nutrients in the immediate lower Sun River corridor and its immediate small, intermittent tributaries are unstable, eroding banks, fallow cropping, hay production, AFOs, a CAFO, urban activities and a POTW. Agricultural lands comprise a significant portion of the near-stream areas along the lower Sun River and small intermittent tributaries. These lands are generally hay pasture, irrigated crops and dry land crops (Maps 2-5 and 2-6). Unstable and eroding banks comprise 11.3 miles or 21 percent of the lower Sun River channel between the town of Sun River and the confluence with the Missouri River as assessed by Chrest et al. (1987). Urban sources in the Great Falls area compose a small portion of the watershed, but may contribute nutrient loads to the lower Sun River.

Although there are a number of potential nutrient sources in the immediate area, these sources do not appear to cause increased nutrient loading. Figure 8-20 shows Sun River nutrient loads in relation to discharge volume near Vaughn and Great Falls. These two sites are at the upper and lower ends of the lower Sun River segment respectively. Total nitrogen and TP loads actually decrease at Great Falls when compared to Vaughn loads upstream. The loading decrease is likely due to Muddy Creek delivering most of the nutrient load to the Sun River at Vaughn and nutrient storage and assimilation occurring in the lower Sun River stream channel due to settling sediment or by limited aquatic plant uptake.

Figure 8-20. Comparison of Nutrient Loads in the Lower Sun River Near Vaughn and Great Falls.





Point Sources and Waste Load Assessment (MPDES)

Sun Prairie Village and the Vaughn sewer districts are the only MPDES permitted wastewater discharges contributing to the Sun River nutrient loads. The town of Fairfield discharges to Freezeout Lake and eventually the load may enter the Teton River. Sun Prairie Village is designed to service 1,835 people. Vaughn is designed to service 542 people. Vaughn is currently discharging slightly below non-degradation guidelines although Sun Prairie Village is well below non-degradation guidelines (Table 8-5). Because nonpoint source nutrient loads are elevated in the Sun River, current wastewater loads to the Sun River are not a significant portion of the overall load. Wastewater sources currently contribute 0.6 % of total nitrogen loads and 0.8 % of measured average summer time total phosphorus loads (Table 8-6). Existing wastewater loading would contribute 1.6 % of total nitrogen loads and 19.3 % of total phosphorus loads to the TMDL at the summer 7Q10 discharge. Wastewater loading levels could increase in the Sun River with an increase in population. If municipalities were to discharge at constant non-degradation thresholds identified in their MPDES permits, wastewater sources in the Sun River watershed would contribute 2.8 % of total nitrogen and 39 % of total phosphorus load to the TMDL at the July-October 7Q10 discharge.

The evaporative lagoon system at Simms may need an upgrade to meet current design standards for seepage loss (MDEQ, 1999b). Simms should remedy excessive groundwater leakage that is occurring from their evaporative lagoon system.

Table 8-5. Wastewater Treatment Plant Nutrient Loading.

Permit	Type of load indicated	Total Phosphorus load (lbs/day)	Total Nitrogen load (lbs/day)
Sun Prairie Village Water and Sewer District MT-0028665*	Current[2]	5.6	17.8
	Non-degradation limit[3] (waste load allocation)	12.8	51
Vaughn Sewer District MT-0021440*	Current[2]	1.7	8.2
	Non-degradation limit [3] (waste load allocation)	2.1	8.4
Total Sun River waste load	Current[2]	7.3	26
	Non-degradation limit [3] (waste load allocation)	14.9	59.4

1. MNI=Monitoring Not Included in Permit
2. Current loads calculated are the mean of the following data: Sun Prairie Village – January 1997-March 2002; Vaughn – October 1999-March 2002
3. Non-degradation limits are based upon non-degradation calculations. MTWQS, ARM 17.30.637 (1)(e); MT Non-degradation Rules, ARM 17.30.700 *et seq.*

* Permits currently without load based limits

[#] Personal comm. Bennatt, 2003.

Table 8-6. Comparison of NPDES Point Source Nutrient Loads to Total Nutrient Loads in the Sun River Watershed.

Description	Total Nitrogen	Total Phosphorus
Percent of current point source load compared to the average measured summer time in-stream load at Vaughn 1996-2000	0.6%	0.8%
Percent of current point source loads contributing to the TMDL at July – October 7Q10 discharge	1.6%	19.3%
Percent of non-degradation load threshold contributing to the average measured summer time in-stream load at Vaughn 1996-2000	0.4%	1.7%
Percent of non-degradation load threshold contributing to the TMDL at July – October 7Q10 discharge	2.8%	39.0%

The USGS Sun River near Vaughn site is used to calculate the total Sun River Watershed load.

8.5.3 TMDL and Allocations

Nutrient TMDLs

The nutrient TMDLs for the lower Sun River are the amount of total nitrogen (TN) or total phosphorus (TP) that the stream can receive from sources and support all of its beneficial uses. TMDLs are the sum of the waste load allocation, or point sources, plus the sum of the load allocations, or nonpoint sources, plus a margin of safety. In this case, the TMDL is computed from the water quality targets and allocations and MOS are built form the TMDL calculation. Allocations and the margin of safety are provided in subsequent sections. The nutrient TMDLs are set for the summer (May-September) when biological in-stream beneficial uses are impacted by the availability of excess nutrients. The TMDLs are expressed as discharge dependant equations in Figures 8-21 and 8-22 and are compared to actual load measurements near Vaughn. Lower Sun River summer TN and TP TMDLs are based upon maximum target concentrations of 650 μg/L and 50 μg/L respectively. When targets are exceeded, the TMDL is exceeded. Measured loads above and to the left of the TMDL lines in the graphs are historic exceedances of the TMDLs.

Sun River near Vaughn data is used to compare existing total phosphorus loads to the TMDL because this site has the most data of all sites on the lower Sun River. Forty six percent of the TP samples exceed the TMDL. The conversion factor of 0.269 for the TMDL equation presented in Figure 8-21 is a combination of the TP target, time, water volume conversion, and mass conversion factors.

Sun River near Vaughn data is also used to compare existing total nitrogen loads to the total nitrogen TMDL. Figure 8-22 includes nitrate loads because they indicate that nitrogen loading in the dissolved form is high and because there is not a robust TN data set for this segment of river. Nitrate is only a portion of TN. Actual associated TN loads would be higher than the measured nitrate loads. Seventy five percent of the TN samples exceed the TMDL. The conversion factor of 2.959 for the TMDL equation presented in Figure 8-22 is a combination of the TN target, time, water volume conversion, and mass conversion factors.

Estimated background concentration ranges are derived from a study by Smith et al. (2003). Information from studies identified in Section 8.1 guided the selection of a background concentration from the range provided in Smith et al. (2003). The background concentration was then converted into a load equation in the same fashion as TMDL targets were converted to TMDL equations and is provided on the TMDL graphs below. Smith et al. (2003) modeled background TN and TP concentrations at a broad scale using reference watersheds in each EPA nutrient ecoregion. The background loads are modeled estimates and are provided as guidance on potentially achievable nutrient levels. Background levels are not necessarily the objective of a TMDL. The TMDLs are based on protecting in-stream beneficial uses. The background loads do coincide well with the State of Montana’s water quality law because the modeling uses a reference watershed approach and extrapolates to impacted watersheds. See Smith et al (2003) for methods and modeling assumptions.

Figure 8-21. Lower Sun River Total Phosphorus TMDL and Background Loads Compared to Measured Loads Near Vaughn.

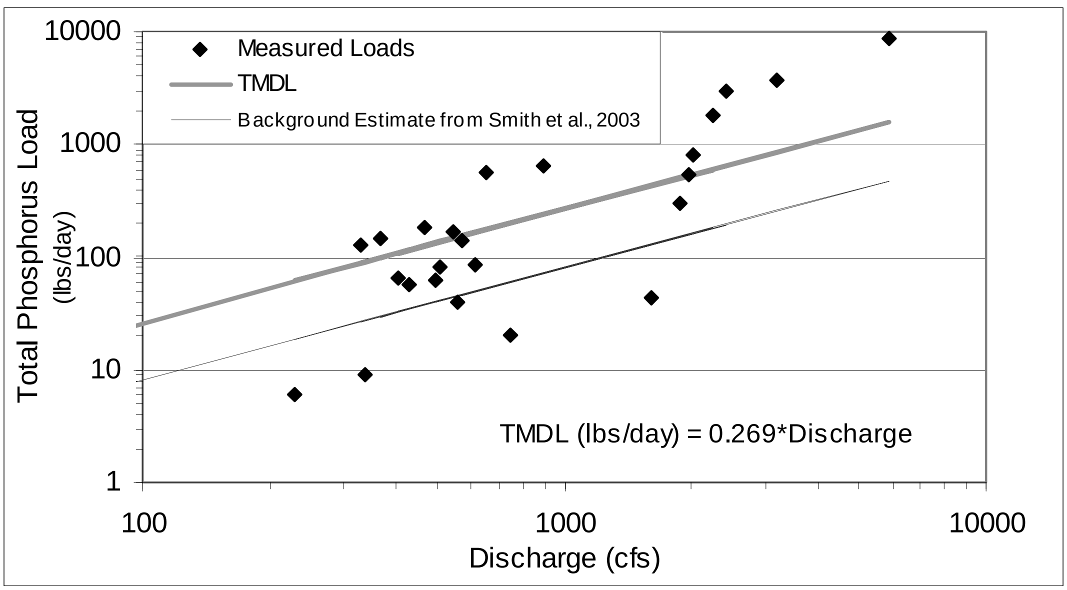
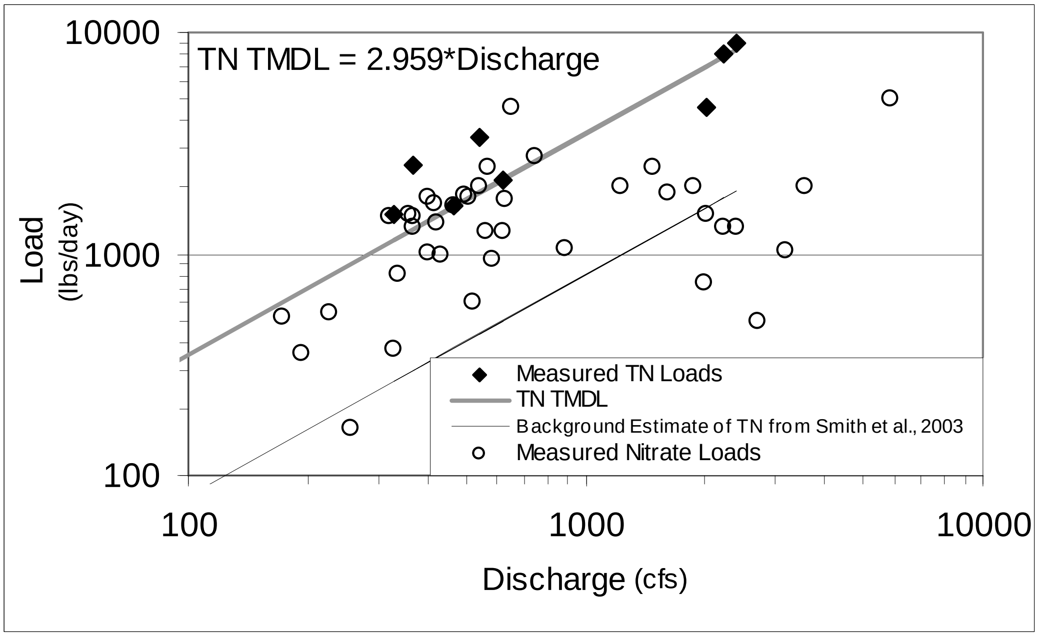


Figure 8-22. Lower Sun River Total Nitrogen TMDL and Background Loads Compared to Measured Total Nitrogen and Nitrate Loads Near Vaughn.



Allocations

The source assessment identifies Muddy Creek as the most significant nonpoint nutrient source in the watershed. A comparison of nutrient loads entering the lower Sun River indicates that they are higher than those exiting the segment during summer months. Immediate sources on the lower Sun River are not significant. Therefore, the full reduction needed to achieve the lower Sun River TMDL is given to Muddy Creek. The upper Sun River nutrient concentrations generally meet the lower Sun River nutrient targets and thus contribute a dilution factor for the lower Sun River. The upper Sun River not increase its nutrient loads to the lower Sun River during the summer months. Muddy Creek's source assessment (Section 8.4.2) identifies agricultural activities on Greenfields Bench as the major contributor of high nitrate concentrations and loading to Muddy Creek. Muddy Creek's source assessment also indicates that increased irrigation return flow from Greenfields Bench and poor riparian management on Muddy Creek causes significant bank erosion in lower Muddy Creek. The bank erosion produces high phosphorus loads. Thus, the full nutrient reduction needed to meet targets and TMDLs for the lower Sun River is given to agricultural activities in the Muddy Creek watershed.

The source assessment identifies that point sources are currently not a significant nutrient contributor because nonpoint sources are so large. When comparing the nutrient TMDL based on 7Q10 low flows to the current wasteload, POTWs become a significant phosphorus source. When comparing the non-degradation limits of the POTWs to the TMDL they become an even larger contribution to the TMDL (Table 8-6).

A waste load nutrient reduction strategy will be implemented by the State of Montana in the Sun River Watershed. Nutrient permit limits will be set according to non-degradation rules for total nitrogen and total phosphorus during the next revision to the Sun Prairie Village and Vaughn's permits. Their next permit revision will also call for to investigate approaches to reduce phosphorus loading during May-September. The second permit revision will reduce phosphorus load limits to help achieve the phosphorus TMDL. The next TMDL review will use results of the phosphorus load reduction studies by Vaughn and Sun Prairie Village to produce revised TP allocations in the watershed. The phosphorus waste load reduction studies should investigate approaches to achieve a combined waste load from the two POTWs that contribute less than 10% of the overall TMDL based on 7Q10 low flows.

8.5.4 Margin of Safety, Seasonal Consideration, and Adaptive Management

The margin of safety for this TMDL is provided in conservative assumptions, the allocation process, and an adaptive management approach. Ten percent of the TMDL is reserved as a MOS in the allocation of loads to sources. The TMDL is set for an extended summer season, from May-September, because algal growth can be influenced during this timeframe if spring runoff is below average. Total nitrogen and TP TMDLs are presented because as sources are addressed with BMPs, the limiting nutrient may shift. A monitoring plan to provide data for further refinement of source assessment and allocation is presented in the next section. If followed, the monitoring strategy will provide data for refining the impairment status, source assessment and allocation during future TMDL review. The uncertainty of the Muddy Creek nutrient TMDL analysis is addressed by future TMDL review, which is identified in Montana law.

Identified conservation practices in Section 8.4.4 should be tracked over time to see if implementation occurs. If implementation occurs and does not achieve targets or load allocations in the watershed, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place, the document may need revision.

Figure 8-23 is an example of the lower Sun River nutrient TMDL, allocation, and margin of safety strategies in use at a specific discharge scenario. The average discharge for the scenario is 400 cfs. Existing loads at 400 cfs are estimated from an average of three samples similar to this discharge for TN and four samples for TP. Natural load estimates are derived from the background loads identified in Figures 8-19 and 8-20. Existing agricultural load estimates at 400 cfs are derived by subtracting natural loads and waste loads from existing total loads. The TMDLs are derived from the TMDL equations. The natural components of the TMDLs were derived by using background loads from Figures 8-13 and 8-14. The margin of safety is 10% of the TMDL. The load allocations are then calculated using the TMDL equation.

Figure 8-23. Sun River Estimated Existing Loads, TMDL, Allocation, and Margin of Safety Scenario at 400cfs.

Daily average lower Sun River discharge scenario: 400 cfs

Estimated existing loads at 400 cfs:

Total: 83.9 lbs/day TP	**Natural**: 32.3 lbs/day TP	**Agricultural Load:** 51.6 lbs/day TP
1905 lbs/day TN	322 lbs/day TN	1583 lbs/day TN

Lower Sun River Nutrient TMDL and Allocation at 400 cfs

An estimated 57%TN and 45% TP average load reduction is needed from fertilizers, irrigation, riparian grazing, and fallow cropping with flows at 400 cfs

~10% of TMDL after TP reduction strategy

10% of TMDL

TMDL = Load Allocation + Natural +Waste Load Allocation + Margin of Safety

107.6 lbs/day TP =53.7 lbs/day + 32.3 lbs/day + 10.8 lbs/day + 10.8 lbs/day

1184 lbs/day TN = 626 lbs/day + 322 lbs/day + 118 lbs/day + 118 lbs/day

8.5.5 Restoration Strategy

Because the nonpoint source nutrient loads are mostly derived upstream, see the Muddy Creek and upper Sun River restoration strategy sections for the highest priority nonpoint source restoration activities (Section 8.4.4). See the allocation section (8.5.3 allocation subsection) for a point source TP reduction strategy.

8.5.6 Monitoring Plan

Continuing a nutrient monitoring program is essential because of uncertainties in the source assessment and to track changes in nutrient conditions. Total phosphorus, TN, and discharge monitoring should continue in the Sun River near Vaughn. Nutrient monitoring should be conducted monthly at this site from May to September. Vaughn data should be used for further refining the TMDL during future TMDL reviews and to determine nutrient trends over time. If the USGS is collecting water samples at this site, they should analyze water chemistry for NO_2+NO_3 as N, Total Kjeldahl nitrogen, PO_4 as P, and total phosphorus. Nutrient and discharge monitoring at Great Falls should also continue for future loading comparisons between Vaughn and Great Falls.

Chlorophyll *a* monitoring should occur once per summer during August at Sun River near Vaughn and Sun River at Great Falls. The chlorophyll *a* results will be used to refine our understanding of impairment conditions resulting from nutrients. If low chlorophyll *a* levels are found during the first year and can be attributed to high sediment conditions impairing plant growth, chlorophyll *a* monitoring may not be useful until sediment yields from Muddy Creek are reduced.

At this time, AFOs have not been specifically identified other than a potential source of nutrients in the SPARROW nutrient modeling described in Section 8.3.2. Livestock waste management systems on any AFOs within 300 feet of any stream in the Sun River watershed should be examined and potentially have BMPs applied. Pre and post restoration monitoring for TN and TP should occur to further the understanding of nutrient impacts due to AFOs.

Tracking water quality changes due to restoration activities is an important component of a long term monitoring plan. Spatial and functional attributes of restoration activities should be documented in a spatial database on a 5-year review period in the Sun River watershed. The restoration tracking system would be used for all pollutant/waterbody TMDL reviews in the future and is not specific to this nutrient TMDL.

This section identifies general ideas for further monitoring but does not provide the detail necessary for future monitoring activities. Monitoring resources are not defined at this time nor are stakeholder and agency monitoring responsibilities. Future monitoring activities should include developing a detailed monitoring plan, or quality assurance project plan (QAPP), prior to fieldwork.

8.6 Freezeout Lake

See Section 3.3 for a discussion about possible reclassification of Freezeout Lake. Because Freezeout Lake's potential for nutrient conditions and exiting nutrient conditions are poorly understood, the nutrient TMDL for Freezeout Lake will be completed at a later date. An existing conditions assessment and a basic strategy to initiate TMDL activities are provided in the following sections.

Existing Conditions

Freezeout Lake is a mosaic of emergent wetland, shallow marsh and deep marsh with interspersed areas of open water. Freezeout Lake was originally a closed basin with a small watershed located between the Teton and Sun River watersheds. It is located just north of Fairfield along Highway 89. Before the Greenfields Bench Irrigation Project, Freezeout Lake water levels fluctuated naturally because of climate conditions in the area. Because Freezeout Lake was a closed basin without a surface water outlet, salinity, selenium and nutrient concentrations fluctuated with water levels. The lake now receives increased water yield through irrigation drainage and canal waste from the Greenfields Irrigation District (GID). Currently there are 27 manmade drain ditches entering Freezeout Lake originating from irrigation of surrounding farmland. As irrigation on Greenfields Bench began, surface and groundwater from the irrigation activities began to influence water levels in Freezeout Lake. Eventually the water level rose above the current SR89 roadbed. In 1953, an outlet ditch to Priest Butte Lake and onto the Teton River was installed. MFWP owns and manages this area (MFWP, 1997a). Water levels are regulated for bird production and to moderate salinity levels in the Teton River.

Freezeout Lake consists of shallow ponds that benefit fish, wildlife and bird populations associated with shallow, salty wetlands of the arid west. Freezeout Lake's hydrology has been altered throughout this century. The system now contains several small lake units separated by dikes. Water is moved between basins for wildlife and bird management. Salinity control in the Teton River, which receives water from a constructed effluent, is also a consideration when managing water. The primary inflows originate from irrigation in the Greenfield Irrigation District (MFWP, 1997a).

Freezeout Lake is in a natural eutrophic condition and was in this same general eutrophic condition prior to surrounding irrigation (The Fairfield Times, 1954). The maximum lake size is 3,120 acres, but most of its area is actually a shallow, open water wetland. Maximum depth at full pool is 12 feet with an average depth of 4 feet. Less than 10 percent of the lake is greater than 5 feet deep. The MFWP lake database indicates that there is both summer and winterkill that impact fish populations in the lake. Winterkill is probably occurring because of the shallow nature of the lake. In relation to biological processes that affect a fishery, this waterbody is more like a large, shallow, open water, wetland that would fall under a warm water classification. The most prominent use of Freezeout Lake is from resident and migrating waterfowl. The highest recreational use of this area is during waterfowl hunting season.

The most abundant fish species in Freezeout Lake are carp (Cyprinus carpio) and stickleback (Culaea inconstans). Although trout enter the lake incidentally through irrigation canals, they are not expected to sustain a viable population in the shallow waters of Freezeout Lake. The most substantial historical and current use of Freezeout Lake is for waterfowl habitat, although fish wildlife and other bird species are important components of the ecosystem. Water quality in the lake currently and prior to irrigation activities was most likely marginal or not supportive of human drinking water, agriculture, and industrial uses.

Lands adjacent to Freezeout Lake consist primarily of native and converted short grass rangelands as well as continuous and fallow-cropped lands. The basin drains bench lands and erosion formed hills. Dry land cropping of wheat and irrigated cropland have been developed in the Freezeout watershed (MFWP, 1997a). The Greenfield Irrigation District lies to the south and west of Freezeout Lake.

MFWP estimates that 80-90 percent of water entering Freezout Wildlife Management Area (WMA) is derived from 3 drainage ditches originating in the Greenfield Irrigation District (MFWP, 1997a). Storm events and snowmelt contribute to most flows from watershed areas used for dry land farming and grazing, although, a couple of spring fed and intermittent drainages contribute minor flows from non-irrigated areas. Discharge from Freezeout Lake is managed depending on water levels in Priest Butte Lake and flow conditions of the Teton River. Most of the outflow to the Teton River occurs from May to July. Water releases out of Freezeout Lake are intended to maintain water quality in the Teton River and adjust water levels relative to bird habitat in Freezout WMA (MFWP, 1997a). Prior to irrigation of the Greenfields Bench and subsequent drainage control, water levels fluctuated greatly from flooding of US89 to a dry alkali flat in the 1930s (The Fairfield Times, 1954).

Although nutrient sources in the watershed may increase plant production in Freezeout Lake, linkage of increased nutrient levels to impairment of uses is not clearly defined at this time. The town of Fairfield POTW discharges to Freezeout Lake and agricultural activities contribute to nutrient loading. There is little useful nutrient chemistry or vegetation condition information available at this time. One of five summer time dissolved oxygen samples were below 5mg/L. Algal blooms occur in Freezeout Lake during warm weather conditions in July and August. Algae and macrophyte decay can cause odorous conditions in the WMA after this warm weather period, but no complaints have occurred (Verbal Com. Mark Schlepp, 2002). Periphyton analysis indicates a healthy community structure for a wetland setting (Apfelbeck, 1996). Nutrients in Freezeout Lake do not affect shorebird or waterfowl uses and may be beneficial to some species of waterfowl (Verbal Com. Mark Schlepp, 2002).

Sources of nutrients are present in the watershed that have potential to affect uses, thus Freezeout Lake nutrient concentration and aquatic vegetation should not increase above current conditions. This nondegradation strategy is outlined to protect beneficial uses in Freezeout Lake in relation to nutrient loading for the interim. Meanwhile, a phased strategy that depends upon outcome from assessment, potential reclassification and subsequent 303(d) listing process will be initiated. If the reclassification assessment and subsequent 303(d) listing assessment indicate a nutrient TMDL is needed, a nutrient TMDL will be completed.

SECTION 9.0
SEDIMENT

This section of the Sun River Water Quality Restoration Plan focuses on sediment related pollutants: siltation, suspended solids, and sources of sediment. Table 9-1 provides a list of those waterbodies within the Sun River TPA that appear on either the 1996 or 2002 303(d) list for sediment related pollutants. Pollution 303(d) listings related to sediment are also provided in Table 9-1. Both pollution and the resulting pollutant listings are addressed by TMDLs in this section.

Table 9-1. Waterbodies Listed for Sediment Related Pollutants in the Sun River Watershed.

Water Quality Limited Segment	1996 303(d) List	2002 303(d) List
Upper Sun River (from Gibson Dam to Muddy Creek Confluence)	Siltation Suspended solids	Habitat alteration Bank erosion Riparian degradation
Lower Sun River (Muddy Creek Confluence to mouth)	Suspended solids Habitat alteration	Siltation Suspended Solids
Muddy Creek	Suspended solids	No causes listed because of use classification
Ford Creek	Not listed for sediment related impairments	Siltation Bank erosion Channel entrenchment Riparian degradation Fish habitat alteration Habitat alteration
Gibson Reservoir	Siltation Suspended solids	

Sediment, suspended or deposited, can impact a number of water uses in Montana. Suspended sediment may cause irrigation equipment to wear quickly. It may affect in-stream biological uses by causing gill abrasion, inhibiting visual predation, or causing avoidance behavior that consumes energy. Deposited sediment can clog irrigation canals, fill reservoirs, smother fish spawning beds, fill pools that fish depend upon for security, and fill interstitial spaces in riffles that aquatic insects depend upon for security and habitat. The most sensitive beneficial uses are usually in-stream, biological uses. Therefore, this section addresses in-stream uses and also protects other, less sensitive uses.

The remainder of this section presents all of the required TMDL elements for each of the above listed waterbodies, one waterbody at a time. In the case of Gibson Reservoir, the impairment status section indicates that a TMDL is not needed.

9.1 Gibson Reservoir

9.1.1 Gibson Reservoir Impairment Status

The basic characteristics of Gibson Reservoir are described in Section 2.8.1. As will be described in the following paragraphs, Gibson Reservoir is not impaired for sediment. Therefore, no TMDL is necessary.

Gibson Reservoir began to store water in December of 1929. Since the initiation of water storage there has been a loss of 7.99 percent of storage capacity (Ferrari, 1997). This equates to 125.7-acre foot loss of storage per year. Assuming that sediments displace water storage, all sediment introduced into the reservoir is from the watershed, and little to no sediment passes through the reservoir there has been a mean annual erosion rate of less than 1/10th of a millimeter per year across the watershed. This equates to an annual sediment load of approximately 2,419 tons entering the Reservoir. Given the landscape, sizeable discharge, steep slopes, and natural erosion potential of this area (Maps 1-1, 2-1, and 2-3), this erosion rate appears to be reasonable for the watershed. When comparing the overall erosion rate for the reservoir to an erosion rate from 1973-1996, the more recent period experienced 10 percent less erosion (Ferrari, 1997). Furthermore, accelerated shoreline erosion does not appear to be occurring. Most of the banks are composed of rock and boulder.

Land use activities in the watershed are mostly recreational, although livestock grazing occurs in some of the lower drainages. Most of the recreation is composed of boating and fishing on the reservoir, hiking and horseback riding on trails, and other outdoor activities. There are only a few developed building sites in the watershed. Most of the watershed is a roadless wilderness area. Historic land use included small-localized logging. In recent decades, there has been no commercial logging. Although five fires have been allowed to burn in the wilderness from 1991-2000, 38 natural and human caused fires have been fully suppressed by the Forest Service within that same period.

Trail maintenance and reconstruction has been completed along 11.5 miles of foot and stock trails on National Forest System lands from 2000-2003. This work involves clearing brush from trails, hardening trail surfaces with aggregate, installing/maintaining cross drain structures, improving stream ford approaches and installing/maintaining bridges and boardwalks. All of these actions will help to reduce erosion and sediment delivery to streams from the recreational trails. A prescribed burn is planned in the Scapegoat Wilderness within the South Fork Sun River drainage. This burn is expected to cover roughly 10,000 acres within a 16,500 perimeter. Implementation of the burn is expected to be over a 5-year period beginning in 2003. The goals of the burn are to 1) allow wild land fire to play a more natural role in the wilderness and 2) reduce the fuels to prevent more intensive burns in the future. Implementation of this burn is expected to reduce the risk of a larger catastrophic fire in the future and therefore, reduce the magnitude of larger sediment loads that are possible with highly fueled, large fires.

Because of the information presented above, a TMDL for siltation and suspended sediment is not warranted for Gibson Reservoir. The Montana DEQ will gather and analyze sufficient and credible data for the Gibson Reservoir according to 303(d) listing data quality objectives by 2006.

9.2 Ford Creek

General characteristics of Ford Creek are presented in Section 2.8.3. Ford Creek's water quality standards and use classification are provided in Section 3.0.

9.2.1 Current Sediment Water Quality Status

It is important that the condition and contributing factors that caused existing conditions in lower Ford Creek are discussed collectively. Lower Ford Creek is incised, or down cut, and cannot effectively access its floodplain. The cause of the incision is not absolutely certain and is due to a combination of historic factors such as riparian grazing, floods, and beaver removal either in this section of stream or as a head cut from areas downstream that had these same influences. The stream will need to slowly erode a small, new floodplain to achieve a functioning stream channel geometry comparable with an upstream reference area. The causes of this incision are key to determining if any TMDL or restoration approaches are needed. The source assessment is discussed in the following section and links back into this impairment section. Measured indications of impairment as they relate to targets are reviewed in this section.

Targets

Ford Creek sediment targets will center on the attainment of an enhanced riparian vegetation community, stream channel geometry, and aquatic insect use. Sediment targets were developed on the premise that proper riparian management will enhance riparian vegetation growth that will allow the stream channel to heal itself slowly over time and achieve balanced stream channel geometry. A target that relates to in-stream use is also provided.

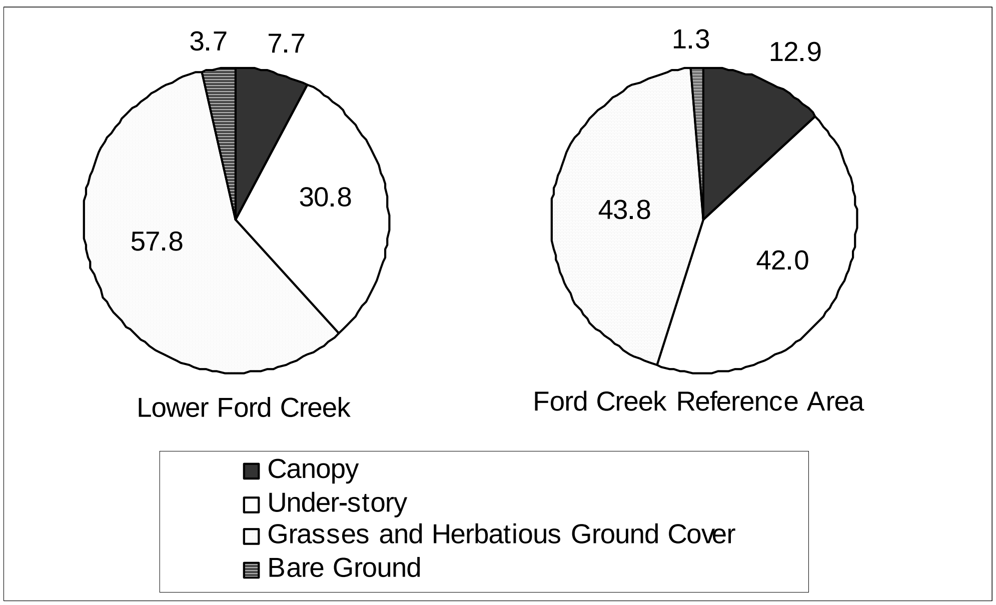
Riparian Vegetation

Natural riparian vegetation, such as willows, grasses and forbs, provide the necessary rooting strength to sufficiently stabilize eroding banks and provide resistance to sheer stress during floods. For example, a study reported in Gordon et al. (1992, pg 338) found that stream banks with a 50 mm-thick root mat of 16-18 percent root volume provided 20,000 times more protection from erosion than comparable banks without vegetation. In addition, properly functioning riparian areas will assist in reducing any tendency toward further channel incision.

An internal reference approach is used to determine the desired riparian condition. Targets are based on reference condition from an upstream area with similar characteristics. The reference area had 16% more combined under-story and canopy cover along the stream banks than the listed segment of Ford Creek (Figure 9-1). Shrub species dominate both the under-story and canopy in the reference area. Shrub species such as willow and dogwood provide a deeper and thicker root mass than most grasses and forbs provide and apparently kept the stream channel stable in the reference section. The riparian vegetation target is essential in providing a resilient riparian community that will resist erosion during floods.

Erosion will continue to occur in the impaired segment as the stream channel builds a new floodplain, but will be decelerated by binding roots from shrub species growing in the stream bank. It will take many years to reach the desired riparian condition on the impaired segment of Ford Creek because of stream channel constraints and because vegetative succession takes time even when riparian areas are managed well. Assessment of the riparian structure indicates that historic circumstances have caused a shift from shrub cover to grasses and forbs.

Figure 9-1. Riparian Community Comparison of Impaired Reach and Reference Reach of Ford Creek.



Stream Channel Geometry

The stream channel geometry targets are derived using appropriate stream channel indicators for the existing valley slope, width, geology and soils, as well as total drainage area. The overall stream slope of lower Ford Creek (T20N R8W section 36) is approximately 0.0035. The valley slope is approximately 0.0063 and valley bottom widths range from 200 to 600 feet with an average of about 400 feet. The stream sinuosity is approximately 1.8. The total watershed area is approximately 16,000 acres or 25.5 mi^2. This stream reach is currently a Rosgen F channel type that is slowly changing to a C channel type. Predictions of Rosgen stream channel type using stream slope, sinuosity, drainage area, valley width and valley slope indicate that a Rosgen C channel type is appropriate for this setting using Rosgen (1996) and Bengeyfield's (1999, 2002) methods.

Stream channel geometry targets are set using a Rosgen C channel type and reference condition from an upstream segment of Ford Creek with similar valley characteristics (Table 9-2). The lower section of Ford Creek is incised and thus has higher bank erosion hazard index rating than the reference section just upstream. Assessment of stream channel geometry indicates impairment because of entrenchment and associated sheer stress on banks that are eroding. To achieve an entrenchment ratio close to a Rosgen C channel, a ratio higher than 2.2 is needed. An entrenchment target of 2.6 is provided. These targets should be met through natural stream channel process and riparian management. The entrenchment ratio target is not set at reference because the reference site had an entrenchment ratio of 5.1. The reference site entrenchment ratio is likely not attainable within a reasonable timeframe without the use of heavy machinery to construct a floodplain. Resources are not available for this type of effort at this time.

Biological Indicators

Macroinvertebrate data helps to provide a better understanding of the cumulative and intermittent impacts that may have occurred over time in a stream, and they are a direct measure of the aquatic life beneficial use. Analytical methods used to interpret macroinvertebrate data are constantly evolving, based on new data and information offered from research. The macroinvertebrate target is intended to provide information regarding which pollutant(s) might be causing the impairment, in this case sediment.

Several biological indicators were considered for Ford Creek. These indicators include: Montana Valley and Foothill Prairies ecoregion Metric (MVFP) (Bollman, 1998) and number of clinger taxa. Of the evaluated metrics, the ***number of clinger taxa*** provides the strongest indication of sediment impairment. Clinger taxa have morphological and behavioral adaptations that allow individuals to maintain position on an object in the substrate even in the face of potentially shearing flows. These taxa are sensitive to fine sediments that fill interstitial spaces, one of their main niches. This metric is calculated as the number of clinger taxa in a sample, and decreases in the presence of stressors. A minimum of 14 clinger taxa are expected in unimpaired Montana streams, and this is proposed as a target (Bollman, 1998).

MDEQ collected macroinvertebrate samples at four locations on Ford Creek on October 3, 1998 as part of a stream assessment. (Bollman, 1999) analyzed the macroinvertebrate samples by comparing them to the Montana Valley and Foothill Plains ecoregion (MVFP) metric and concluded that the macroinvertebrate community indicated water quality impairments at a sampling site located in the lower section of Ford Creek. The MVFP metric at the site near the Smith Creek Confluence scored an average 58.5% of regional potential in the duplicate samples collected. More than half of the aquatic insects sampled here were tolerant to habitat degradation and water quality degradation. The community taxonomic composition and calculated metrics at this site suggested impairment of water quality due to habitat degradation associated with sediment deposition on the stream bottom (Bollman, 1999). In addition, clinger taxa richness was low, with an average of 10.5 taxa at this site in duplicate samples, suggesting fine sediment deposition is affecting the aquatic insect community.

Future Targets

Targets based on stream bottom content, residual pool volume, and potentially other sediment targets may be provided in the future when the stream channel has built a new floodplain at the entrenched level and reverts to a Rosgen C channel type. This will take many years of proper riparian management for the stream to slowly erode a new floodplain, become less entrenched and evolve to a Rosgen C channel that provides more defined riffles and pools. The stream energy and more defined riffle and pool areas will sort sediment more efficiently than the current Rosgen F channel. The C channel structure will provide better fishery and aquatic insect habitat than the current F channel provides. Target refinement may be provided when the stream channel on the lower two miles of Ford Creek has reached the stream channel targets provided in Table 9-2.

The Wolman pebble count method is one method for determining the amount of fine sediment in a waterbody. Wolman pebble counts involve walking a transect in a riffle section from bank full to bank full width. The field person places one foot in front of the other and, without looking down, selects a rock and measures the intermediate diameter of the rock. This information is recorded and the procedure followed until a minimum of 100 rocks per transect are counted (Wolman, 1954). Pebble count data can be interpreted to compare median particle sizes between streams, evaluate the percent fines less than a specific size, and compare particle distributions between streams. Wolman pebble counts were collected in the listed segment of Ford Creek in 2004.

Threshold pebble count values have not been fully developed by MDEQ for Montana. Recent work completed in the Boise National Forest in Idaho showed a strong correlation between the health of macroinvertebrate communities and percent surface fines, where fine sediments are defined as all particles less than 2 millimeters. The most sensitive species were affected at 20 percent surface fines and a definite threshold was observed at 30 percent surface fines (Relyea, personal communication, April 28, 2004). The New Mexico Environmental Department has also established a percent surface fines target of less than 20 percent for TMDL development (NMED, 2002). Although pebble count percent fine measurements are not used as targets for lower Ford Creek at this time, the data is compared to these general reference values. Although this is not used as a current target, Lower Ford Creek pebble count data indicate that 28% of the substrate samples were smaller than 2 millimeters.

Biological and physical indications of impairment are present in the lower end of the watershed. Therefore, a sediment source assessment is pursued in the following section.

Table 9-2. Sediment Targets.

Waterbody	Riparian	Stream Channel	Biology
Ford Creek	**Targets**		
	55% shrub species cover at bank full.	1. Rosgen C channel 2. BEHI ≤ 10 3. Entrenchment ratio ≥ 2.6	14 Clinger Taxa
	Existing Conditions		
	31% shrub species cover at bank full.	1. Rosgen F channel 2. BEHI = 22.5 3. Entrenchment ratio = 1.3	10.5 Clinger Taxa

9.2.2 Sediment Sources

Current human caused sediment sources are agricultural and recreation based. Livestock grazing is the most widespread land use within the watershed. A few irrigated hay fields encroach riparian areas. The road network infringes on riparian areas and is a potential source of sediment delivery. There are no urban areas in the watershed and one Confined Animal Feeding Operation (CAFO).

The conclusions presented in this section have been developed from the best data available at the time this report was prepared. Measured sediment loads from all sediment sources are not available; therefore, estimates were made based on literature values or were developed using various modeling techniques. Further, detailed, on-the-ground assessments have not been conducted in the entire watershed. As a result, interpolation was required and assumptions were made regarding conditions that were not directly observed. However, it is felt that the information contained in the following subsections allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories. Uncertainties are discussed in greater detail in the source summary subsection and other source subsections below.

Individual assessments were conducted to compare the most significant sources. Current agricultural and historic sources were assessed through a stream bank erosion sediment load assessment. Sediment loading from roads was considered using The Water Erosion Prediction Project (WEPP) model. Background upland erosion was estimated using a soil creep erosion estimate. Methodology for each of these is discussed in more detail in the following subsections.

Upland Background Erosion Rate

The background erosion estimate uses an approach based on soil creep rates. This methodology was used along with other background erosion estimates in the Upper Lolo TMDL document. The soil creep equation is:

Annual Erosion Volume (m^3/yr) = L (m)* 2 * D (m) *C (m/yr)

Where: L = Length of stream network in meters
D = Depth of soil in meters
C = Annual creep rate in meters

This approach to estimating background erosion estimates is identified in *Standard Methodology for Conducting Watershed Analysis* (Washington Forest Practice Board, 1997). If no local data exists, methodology recommends a creep rate of 0.001 meters per year if average watershed slopes are less than 30%, as they are in Ford Creek. The most recent national hydrography dataset (NHD) stream layer is used for calculating stream length in a GIS framework. The NHD stream layer and is built from 1:24,000 USGS hydrography mapping. The length of Ford Creek and tributary stream channels is calculated at 87,600 meters. An average soil depth was estimated at one meter for the whole watershed. The average annual erosion rate was calculated at 262.8 m^3/year. The conversion factor of 1.76 tons per m^3 is used to convert the yield to tons per year. The average estimate is 462 tons/year and 18.5 tons/mi2/year.

Bank Erosion

Results reported in the Sun Canyon Range Analysis (USFS, 1997) indicate riparian vegetation is not affected to the degree that would cause bank erosion on USFS lands due to resilient stream channel form and generally low levels of riparian grazing. Ford Creek watershed's USFS lands are generally the same areas encompassed by the Canadian Rockies ecoregion. This ecoregion was therefore not assessed for bank erosion sources.

An aerial photo assessment identified three reaches of Ford Creek in the Montana Valley and Foothill Plains ecoregion that displayed distinct riparian influence characteristics. One segment was identified as a reference area and the other two were identified as segments with potential riparian impacts. Two 1,000-foot sections of Ford Creek were assessed by bank erosion inventories conducted in September, 2004. One inventory section was on the impaired segment of Ford Creek; the other was in the reference reach identified by the aerial photo assessment. The green-line riparian assessment from these two sections is presented in Figure 9-1. The data collected from the bank erosion assessment stream sections were then extrapolated to the whole segment by applying bank erosion rates to the three larger reaches identified in the aerial assessment.

Relative sediment yields from stream bank sources are calculated by multiplying the sediment source erosional area (height x length), by literature values for rate of erosion per year based on severity, and by bulk density of bank soils to derive loads in tons/year.

Yearly sediment load produced by eroding banks was determined using rates based on a range of values from similar stream systems published in scientific literature. These rates are presented in Table 9-3.

Table 9-3. Bank Retreat Rates Used for Banks of Varying Erosion Severity.

	Migration Rate (m/y)		
Condition	**Zaroban and Sharp (2001)**	**Rosgen (2001)**	**Nanson and Hickin (1986)**
Slight	0.032	0.061	0.10
Moderate	0.070	0.189	0.40
Severe	0.183	0.335	0.70

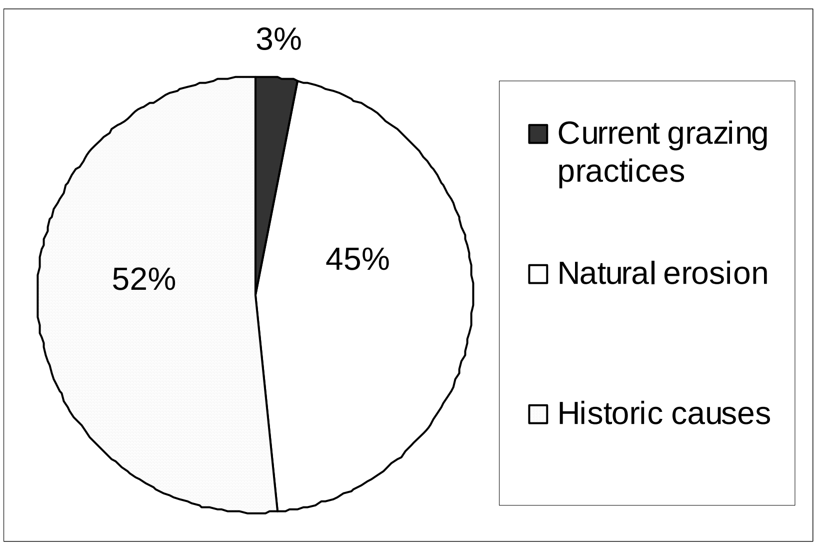
The moderate bank retreat values from Rosgen (2001) will be used for the Ford Creek analysis. These values have been used in stream bank erosion calculations for other TMDLs in Montana (Blackfoot Headwaters TMDL). The sediment TMDL described by Zaroban and Sharp (2001) was conducted in the Palisades Subbasin in Idaho, which has more precipitation and higher stream flow than Ford Creek. Nanson and Hickin (1986) conducted their analysis on 18 meandering river channels in western Canada. These rivers have non-cohesive substrate material, higher discharges, and relatively steep slopes compared to Ford Creek. Rosgen (2001) examined lateral stream bank erosion rates for the Lamar River basin in Yellowstone National Park and a series of streams along the Colorado Front Range. Of the three study areas, these streams most closely resemble the Ford Creek watershed in geomorphic and physiogeographic setting.

The following are steps used to calculate total sediment load from eroding banks:

- Assign retreat rates based on severity of sediment source, based on field observations, fracturing, vegetative cover, and signs of deposition;
- Assign percent of erosion due to separate types and causes of erosion for each eroding bank;
- Calculate tonnage of sediment produced yearly by each eroding bank and each cause (length × height × retreat rate × bulk density);
- Extrapolate from field inventory reaches to the applicable larger reaches determined from aerial photo interpretation to derive yields for entire waterbodies;
- Summarize relative yield of each cause of bank erosion.

The 2004 stream bank sediment source inventory identified the following causes of erosion: 1) current grazing practices 2) combination of past overuse, floods, and beaver removal 3) natural sources. Estimated sediment yields from these three sources are 23, 389, and 340 tons/year respectively. The stream bank erosion source assessment identifies current grazing practices as having little impact on the overall bank erosion sediment yield (Figure 9-2). Natural sources and historic impacts are responsible for 97% of the sediment yield from stream bank erosion.

Figure 9-2. Percent of Stream Bank Erosion Sediment Yield by Source Category.



Road Assessment

The Forest Service WEPP web interface tool was used to determine load estimates from Ford Creek's road network. Aerial photos, USGS DRGs (digital raster graphics), the NHD stream layer, and the 2000 US census road layer was used in a GIS framework to determine road crossings, proximity of roads to the stream network, average road tread width, cut and fill widths, slope of roads and slope of buffer area. Road crossings were modeled using USFS WEPP Web Interface Tool, http://forest.moscowfsl.wsu.edu/fswepp/. The WEPP Road module was used to model sediment derived from roads. All roads in the watershed within a 300-foot buffer of the stream network were assessed. Most roads paralleled the stream and were broken into segments with similar characteristics for analysis. Characteristics that influence sediment production were averaged by the road segment. The longest modeled road segments were 775 feet in length.

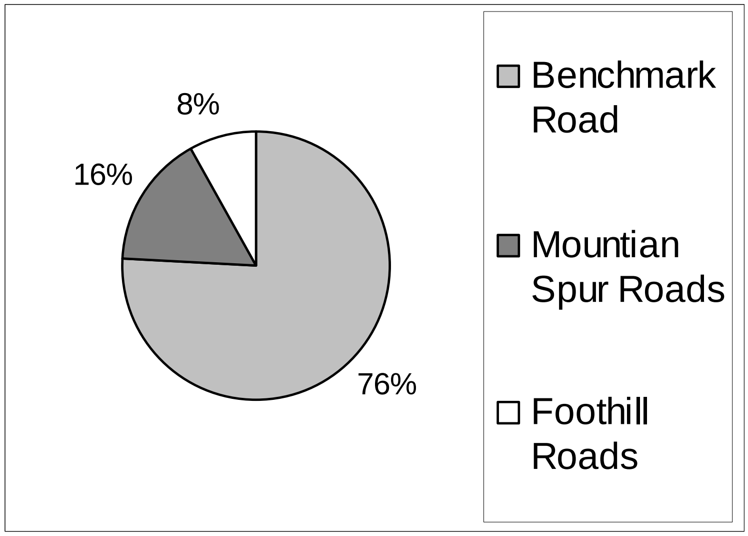
Because aerial photos were used instead of data derived from field monitoring, a number of estimations for model input had to be constructed for the WEPP road sediment analysis. Table 9-4 reviews parameters derived from GIS and aerial photos. When input parameters were difficult to determine from aerial photos and GIS framework, an estimated value was provided that would err on the side of higher sediment production from the road. Thus, the model output likely predicts higher loads than it would if field generated data were used. Weather data from Gibson Dam, MT was used for the model.

Table 9-4. WEPP Road Analysis Input Data.

Ave. Road Width	Ave. Road Slope	Ave. Fill Slope	Ave. Fill Length	Ave. Percent rock (gravel)	Traffic Level	Buffer Gradient	Soil Texture
Benchmark Road							
- 15ft on out-sloped segments (54% of length) - 18ft on in-sloped segments (46% of length)	2.9%	50%	15 ft	30%	High	3%	Sandy Loam
Mountain Spur Roads							
10 ft (all in-sloped)	2.9%	50%	15 ft	30%	Low	3%	Sandy Loam
Foot Hill Roads							
10 ft (all in-sloped)	1%	10%	5 ft	20%	Low	1%	Silty Loam

The WEPP road model predicted an average of 4.1 tons of sediment per year has been derived from roads in the Ford Creek Watershed over the last 30 years. Benchmark Road contributes 76% of this load while the other roads in the watershed produce an estimated 23% of the road derived sediment load (Figure 9-3).

Figure 9-3. Percent of Road Sediment Yield by Road Type.



Other Sources

Other sediment sources in the watershed exist but, based on professional judgment, are considered to be insignificant. Upland forest harvest has occurred on very limited areas of private land in the watershed. A small CAFO has been addressed with mitigation practices (see 8.2.1 for details). Recent forest fires have not burned significant areas of the Ford Creek Watershed. A few irrigation diversions are used to irrigate hay fields in Ford Creek. An irrigation diversion from Smith Creek transects the Ford Creek watershed and runs to Nilan Reservoir but appears to be managed appropriately and does not appear to be a cause of impairment. There are no indications of significant changes to stream energy from irrigation influences. Macroinvertebrate and fishery data do not indicate impairment from dewatering.

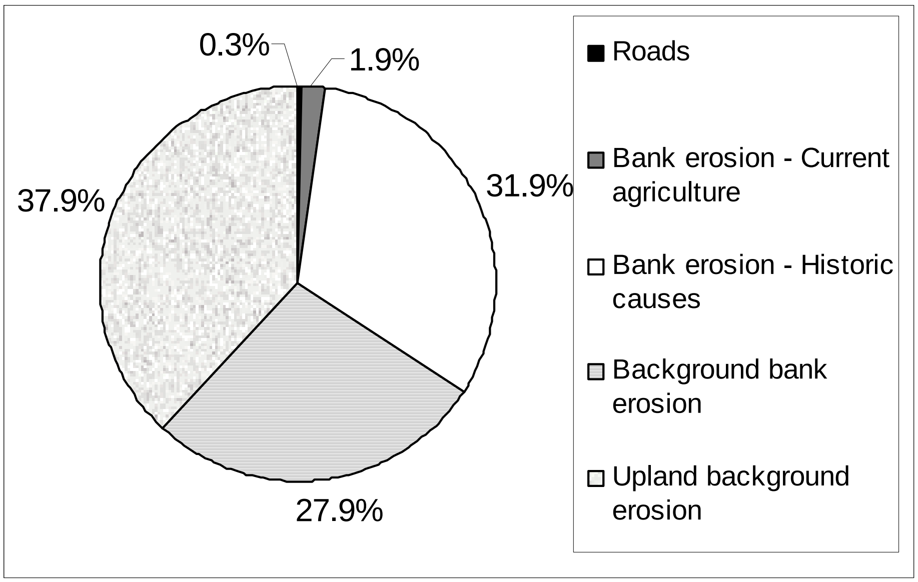
Source Summary

When comparing the individual sediment studies to each other for an overall sediment yield and source assessment, caution should be used. Different models and erosion assessments can provide various estimates of sediment yields for the same source. However, the information contained in the following subsections allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories.

It appears that most, about two-thirds, of the sediment yield in the watershed originates from natural upland and natural bank erosion sources (Figure 9-4). A little less than one third of the sediment yield is derived from historic sources of bank erosion derived from incised conditions. Causes of this historic bank erosion are not easily recognized as stated in the beginning of Section 9.2.1. Human caused sediment yields from roads and current grazing contribute less than 2% of the estimated sediment yield. The source assessment indicates that impairments are caused by historic influences.

The bank erosion caused by historic sources is likely a combination of historic grazing pressure, historic floods, and potentially past beaver removal. Section 2.7 provides historic land use perspective of the Sun River watershed. The extent of each historic source of stream channel incision cannot be determined at this time. Two of the three historic source categories are at least partially influenced by human activity. The segment of Ford Creek directly upstream of the incised segment is in a similar setting and didn't incise in the past. Both stream segments have experienced the same floods and weather conditions. The healthy upstream segment has higher riparian vigor that appears to be a climax community. Historic grazing was likely a cause of the riparian seral stage of the lower Ford Creek segment. Using these lines of evidence, human influence was likely a contributor to the stream channel entrenchment and a TMDL and allocation strategy will be provided.

Figure 9-4. Percent of Total Sediment Yield by Source Category.



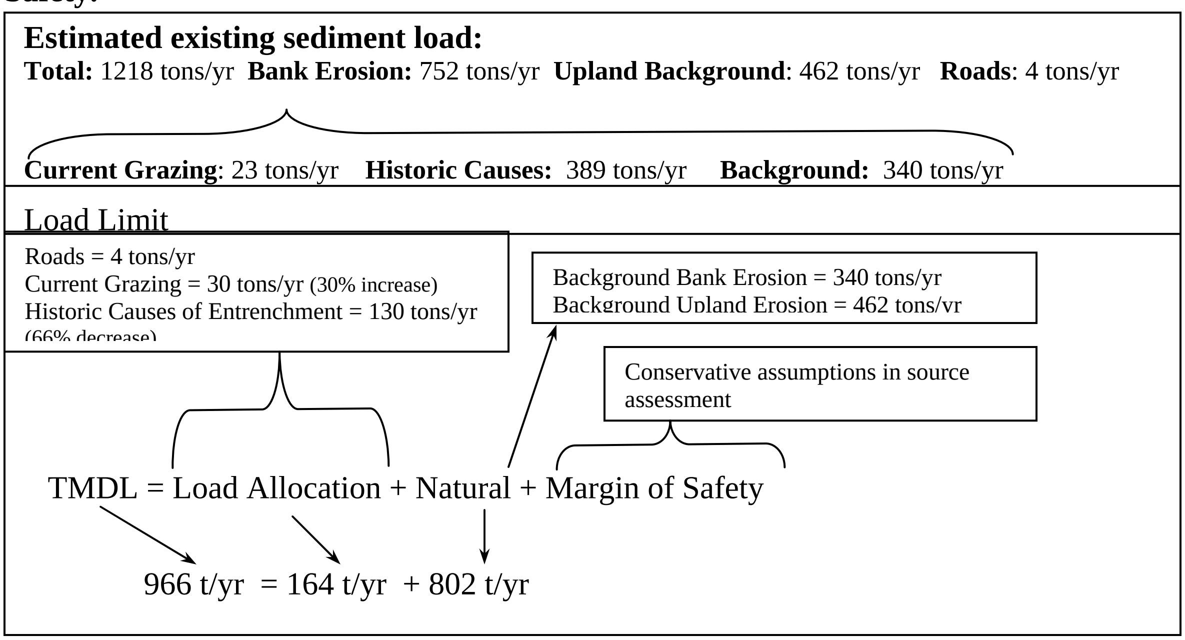
9.2.3. Load Limit and Allocation

There are no NPDES POTW sources in the watershed. Therefore, there is no waste load allocation.

The only significant impact to sediment yield is bank erosion from historic caused channel entrenchment. Reasonable grazing practices are currently in place in the incised section of Ford Creek where historic bank erosion contributes significant sediment loads. Less than 2% of the load is derived from soil exposed from current grazing activities. Further application of grazing management tools can not significantly reduce sediment loads from these sources in the near future, but an allocation to current grazing is provided to ensure reasonable grazing practices continue so that further stream channel incision and bank erosion from the historic causes is not accelerated by potential future grazing activities. Loads from soils eroded due to existing grazing activities should stay below 30 tons per year. This allocation is slightly higher than the estimated load entering Ford Creek from current grazing activities during 2004.

Loads from the historic causes of stream channel entrenchment and subsequent bank erosion should be cut by two thirds in three decades. It is estimated, using professional judgment, that about one third of the bank erosion from the new terrace will be present for a long timeframe and will be considered a natural component of the historic caused bank erosion load. The bank erosion due to historic causes will slowly be reduced as the stream creates a new floodplain and thus reduces sheer stress on the current stream banks. The sediment derived from the new terrace, what are now the stream banks, will slowly decrease as the stream channel evolves from an unstable Rosgen F channel type to a more stable C channel. When the entrenchment ratio reaches about 2.6, the historic terrace will still be eroding on the outside of the channel meander belt. It is estimated that about one-third of the current loads from the terrace will be present with the entrenchment ratio of 2.6 and meander pattern of a Rosgen C channel. The TMDL and allocation strategy are outlined in Figure 9-5. Therefore, the allocation to historic bank erosion loads will be to reduce this source by two-thirds.

Figure 9-5. Ford Creek Estimated Existing Loads, TMDL, Allocation, and Margin of Safety.



9.2.4. Margin of Safety, Adaptive Management, and Seasonal Consideration

The targets, TMDL, and allocation are set to provide a long-term restoration approach that relates to decreasing sheer stress on eroding banks caused by historic sources. While the exact partitioning of the historic causes cannot be determined, lines of reasoning are provided that indicate human affects likely influenced the stream channel to incise and cause subsequent long-term bank erosion. The TMDL and allocation are provided to prevent further stream channel degradation and also to prevent accelerated stream bank erosion while the stream channel naturally adjusts to a new, lower elevation.

Addressing sensitive seasons is less of a concern with sediment production than for many chemical pollutants. The load limit is provided in an average annual load rate. This load limit and allocation timeframe should adequately protect the uses. If loads need to be broken into daily or monthly loads because future knowledge indicates that uses are being impacted seasonally, the load limit timeframe should be addressed in future TMDL reviews.

Based on the source assessment and that sediment load delivered to Ford Creek appears to be largely of natural or historic origin, one could argue that no TMDL is necessary for lower Ford Creek because there is little restoration that can be reasonably implemented to reduce this source in the near term. However, interpretation of the State's narrative water quality criteria is not a "black and white" exercise. The relevant narrative standards prohibit harmful or other undesirable conditions related to pollutant increases above "naturally" occurring levels. To be conservative and err on the side of water quality protection, a TMDL has been prepared that addresses historic causes of current erosion. In the case of lower Ford Creek, this fact alone provides a substantial margin of safety.

A margin of safety for this TMDL is also provided in an adaptive management approach. The uncertainty of the Ford Creek sediment TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 9.2.6 to aid in future TMDL review. Identified conservation practices in Section 9.2.5 should be tracked over time to see if implementation occurs. If implementation occurs and does not achieve targets or load allocations in the watershed, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place; targets, TMDL, allocations, or attainment timeframes may have to be revised.

9.2.5. Restoration Strategy

Current grazing management is allowing lower Ford Creek's channel to slowly erode a new floodplain, does not cause accelerated bank erosion, and is allowing riparian areas to re-vegetate. Currently there is no riparian fencing. Pastures are being managed in a way that is allowing riparian recovery. Grazing management practices that may help to avoid acceleration of stream bank erosion if this area is grazed in the future could include:

- Using riparian browse and grazing indictors to manage riparian grazing pressure.
- Timing grazing to coincide with dry or freezing weather to reduce erosion.
- Timing pasture use to promote grazing, not browse.
- Placing supplemental feed or salt in upland areas to promote even grazing in pastures.
- If needed, fencing riparian areas while providing water gaps.
- Employing weed control.

9.2.6. Monitoring Strategy

If access allows, a permanent cross section on the lower section of Ford Creek should be established to track stream channel elevation, entrenchment of the stream channel, percent fines on the streambed, and parameters necessary for determining Rosgen level 1 stream channel type.

Riparian green line transects should be conducted that can determine the percentage of riparian plant size (bare ground, ground cover, mid-story, canopy) and type (tree, shrub, grass/forb). A bank erosion assessment that measures the same attributes as the bank erosion source assessment should also be conducted along with the green line riparian assessment. This monitoring should occur every decade.

9.3 Muddy Creek

Muddy Creek's general watershed description is provided in Section 2.8.5. Muddy Creek's water quality standards and use classification are provided in Section 3.0.

9.3.1 Targets and Sediment Water Quality Status History

The history of erosion is discussed before the sediment targets are presented because they provide the needed background information for target justification. Muddy Creek has a mean slope of 13 feet per mile, or .0024 (Andrews, 1985a). The slope is indicative of a low gradient, meandering stream. In Muddy Creek's upper valley, the stream bottom is controlled by Colorado shale and overlying gravels. The lower portion of Muddy Creek's valley is composed of 100-foot deep clay and silt sediments that were deposited by ancient Great Falls Lake. Most of the riparian areas in the watershed are grazing land. Fallowed crops encroach the stream channel in limited areas (Andrews, 1985a).

Much of Muddy Creek was intermittent before the initiation of irrigation within the watershed. There was likely only a small amount of base-flow in the lower end of the watershed. Early settlers could not rely on Muddy Creek as a source for summer irrigation (The Fairfield Times, 1978). The Greenfield Irrigation Project was initiated in 1915 and by 1936 the distribution system at Fairfield was mostly complete. Funds were supplied by the Bureau of Reclamation for irrigation drainage until 1958 (Systems Technology Inc, 1979). The initiation of irrigation on the Greenifelds Bench brought increased flows and increased stream energy in Muddy Creek. Controlling the elevated energy derived from high flows is a key component to a sediment restoration strategy.

Greenfields Bench has a thin layer of soil overlying very hydraulically conductive gravel situated on top of less pervious Colorado shale. Irrigation water applied on Greenfields Bench moves quickly through the gravel aquifer. Muddy Creek tributaries draining the bench show significant increase in base-flow about a week after irrigation water application begins. Although Greenfields Bench composes only 25 percent of the watershed, its irrigated lands contribute over 90 percent Muddy Creek's total discharge (Systems Technology Inc, 1979). New irrigation water management improvements have slightly decreased water contribution from Greenfields Bench. Thunderstorms on the bench and subsequent cancellation of irrigation water that is already in route usually occur a few times per year. The surplus storm water and irrigation water flowing in Greenfields Bench main canal and distributary canals surge into Muddy Creek. This situation accelerates stream bank erosion in the deep silts and clays in lower section of Muddy Creek between Gordon Road and the City of Vaughn.

A photo from 1936 indicates that the lower Muddy Creek corridor supported a fairly continuous riparian habitat of willow (Figure 9-6). When floods occurred they were able to spread out across a floodplain. Shortly after this photo was taken, irrigation in the Muddy Creek watershed was further developed on the Greenfields Bench and caused increased stream flow and stream energy. The increased stream energy created a larger stream channel by eroding down into the soft silts and clays of the lower Muddy Creek valley. Riparian grazing exacerbated this vertical and lateral stream instability due to increased runoff from the Greenfield Irrigation Project. The entrenchment eliminated wet riparian areas that can support willow species. The loss of hydrophilic, soil holding, woody riparian species in a silt and clay dominated valley further worsened the erosion and stability conditions (Figure 9-7). The stream could no longer disperse energy exerted by floods to a floodplain. No riparian woody shrub species were present to hold soils together near the stream. After cutting down, or degrading, into the silts and clays, the stream's energy focused on trying to create a larger flood prone area by eroding banks as high as 30 feet. The height of erosion in lower Muddy Creek occurred during the 1950s through the 1970s.

An effort to curb the erosion by the Muddy Creek Task Force and the Sun River Partnership began in the late 1970s. The Task Force/partnership includes landowners, Greenfields Irrigation District, the Cascade County Conservation District and County Commissioners, Teton County Conservation District, City of Great Falls, Audubon Society, Medicine River Canoe Club, Missouri River Flyfishers, Russell Country Sportsman Club, Montana Power Company, Burlington Northern Railroad, and several state and federal agencies. The goals of the Muddy Creek Task Force and Sun River Partnership are to:

1. Reduce sediment delivery to the Sun and Missouri Rivers,
2. Reestablish riparian vegetation along Muddy Creek,
3. Enhance irrigation practices to minimize surface and groundwater degradation,
4. Improve upland range and pasturelands.

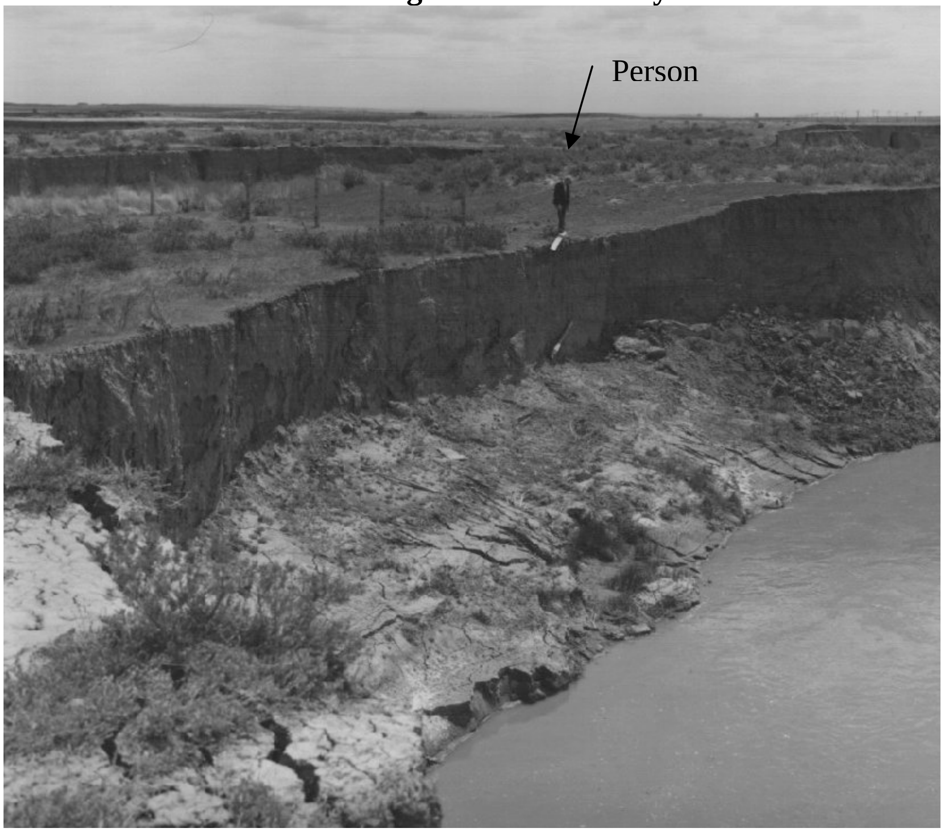
The Muddy Creek Task Force and Sun River Partnership were awarded grant funds to achieve these objectives by:

1. Reducing erosion by installing rock vortex weirs and barbs to stabilize the stream channel (Figure 9-8),
2. Working with land operators to reduce erosion by restoring the Muddy Creek riparian zone through fencing, tree planting, and prescribed grazing systems,
3. Designing better irrigation practices to reduce return flows,
4. Working with Montana Fish, Wildlife, and Parks to produce a productive fishery.

Previous actions from stakeholders and land managers have already shown measurable benefits to Muddy Creek. Yearly average flows have decreased by 2 cfs and yearly maximum discharges have been reduced by roughly 26 cfs (Wittler et al., 1996) (Table 9-5 and Figure 9-9). Base flows have increased and high flows have decreased after initiating irrigation conservation efforts (Figure 9-10). Historic yearly loads have been calculated by the USGS for both Muddy Creek near Vaughn (Gordon) and Muddy Creek at Vaughn sites (Figure 9-11). Suspended sediment loads have been greatly reduced by the restoration efforts in lower Muddy Creek. Changes in the relationship between SSC and discharge are apparent after 300 rock barbs, 11 fish friendly grade control structures and riparian vegetation restoration projects were installed between 1994 and 1996 (Figure 9-12). Since the initiation of the locally lead restoration activities, the mean SSC concentration in Muddy Creek has been reduced by approximately 94 percent (Figure 9-13).

Figure 9-6. Lower Muddy Creek (1936).

Figure 9-7. Mass Bank Erosion Occurring on Lower Muddy Creek.



This picture was taken during the 1975-1983 time period, but the exact year is unknown.

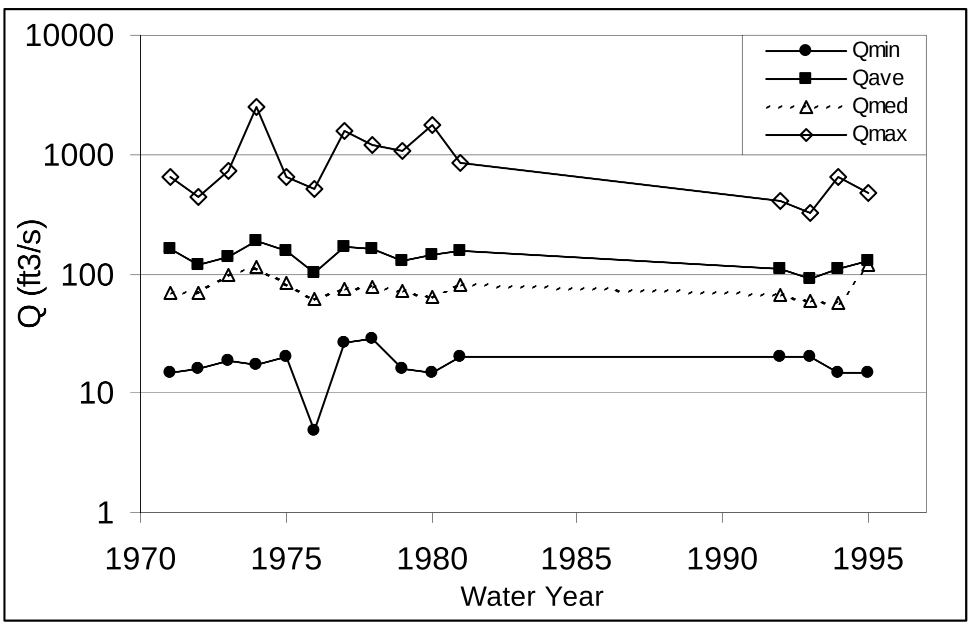
Figure 9-8. Rock Barb Installation on Lower Muddy Creek for Energy Dissipation (1996).

Table 9-5. Minimum, Mean, Median, and Maximum Discharge 1972-82, 1993-96, at Vaughn.

Water Year	Qmin	Qave	Qmed	Qmax
1972	15	162	69.5	654
1973	16	118.1	70	439
1974	19	139.6	99	730
1975	17	189.4	116	2540
1976	20	153.4	84.5	636
1977	4.8	102.4	61	506
1978	26	165.3	75	1600
1979	29	162.2	78	1200
1980	16	128.1	73	1080
1981	15	146.4	65	1740
1982	20	155.4	82	839
1993	20	110.3	67	408
1994	20	92.5	60	328
1995	15	108.7	57	636
1996	15	129.4	117	469

(from Wittler et al., 1996)

Figure 9-9. Water Discharge for Water Years 1972-82, 1993-96 at Vaughn.



(from Wittler et al., 1996)

Figure 9-10. Muddy Creek at Vaughn Flow Duration Relationships for Water Years 1972-82, 1993-2000.

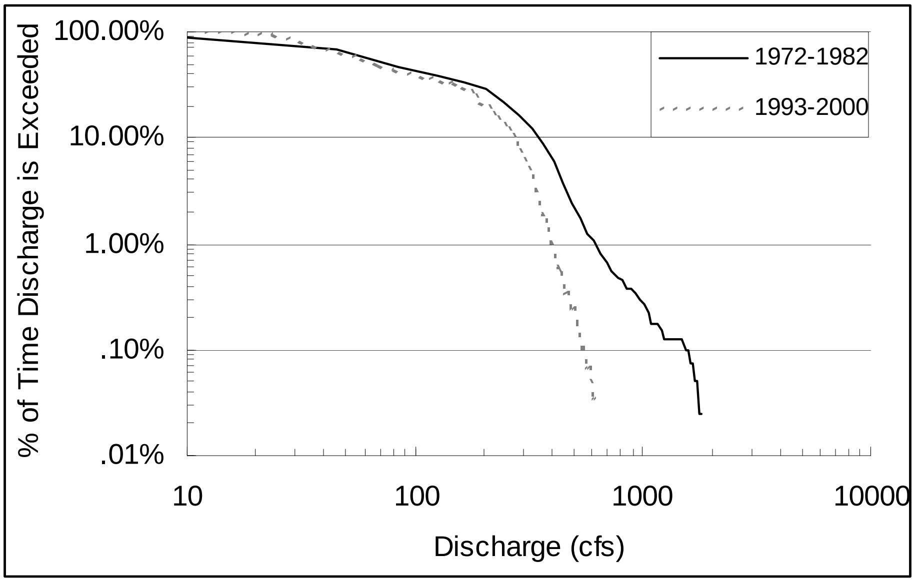


Figure 9-11. USGS Calculated Suspended Sediment Loads and Average Annual Rainfall 1972-2001.

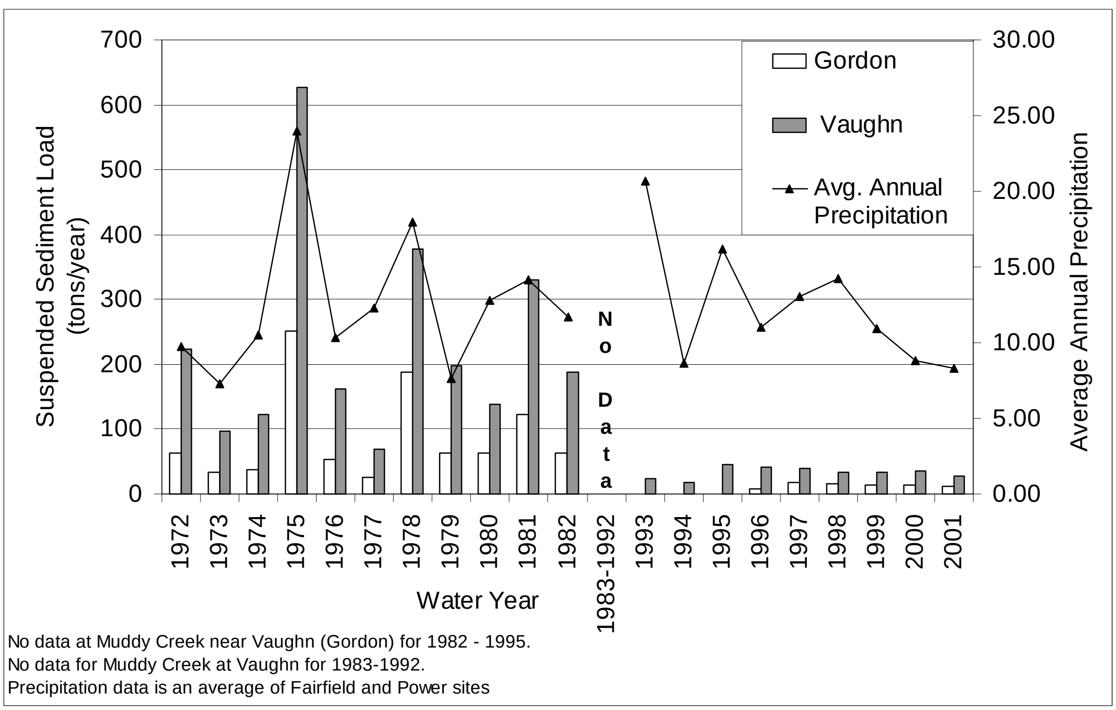


Figure 9-12. Relationship Between SSC and Stream Discharge at Muddy Creek at Vaughn Station 1972-1982 and 1992-2000.

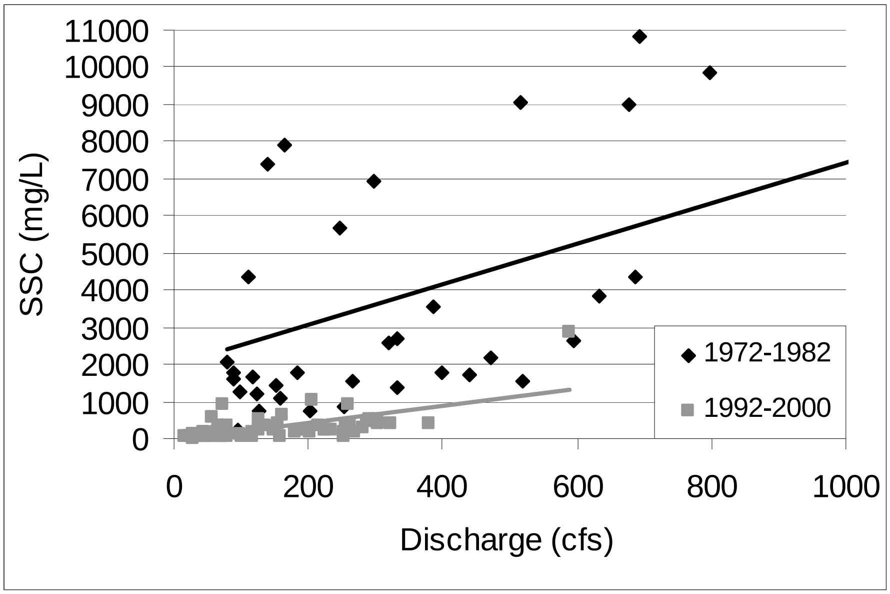
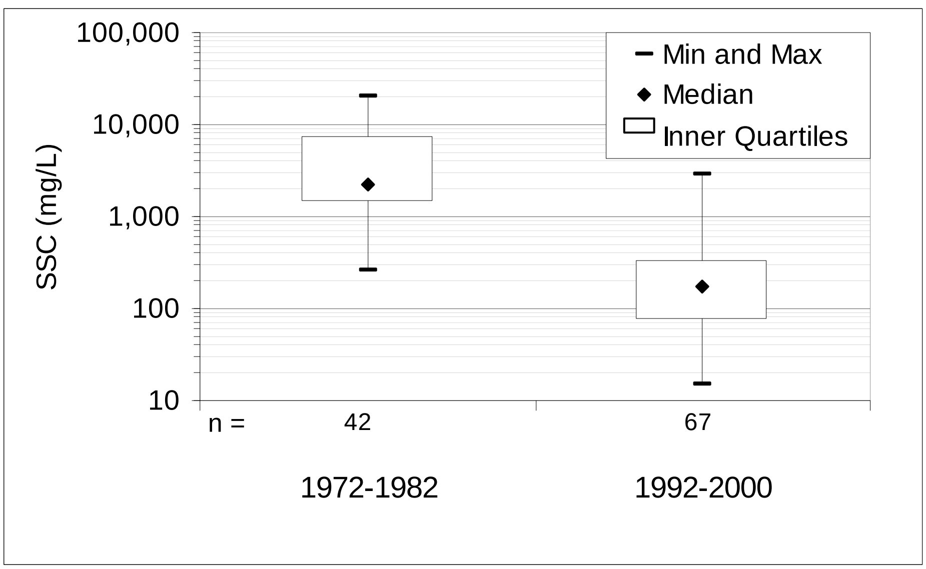


Figure 9-13. Suspended Solids Concentration at Muddy Creek at Vaughn USGS Station 1972-1982 and 1992-2000.



Targets and Impairment Status

Large reductions in SSC concentrations have been achieved through restoration activities that have already been installed (Figure 9-13). The studies that are reviewed in this section indicate that further management activities are likely to reduce sediment loading and erosion in Muddy Creek. Therefore, flow, riparian condition, and sediment loading targets are presented for Muddy Creek based upon conditions that are achievable through management practices (Table 9-6). The targets are based upon principals outlined in the studies described in this section.

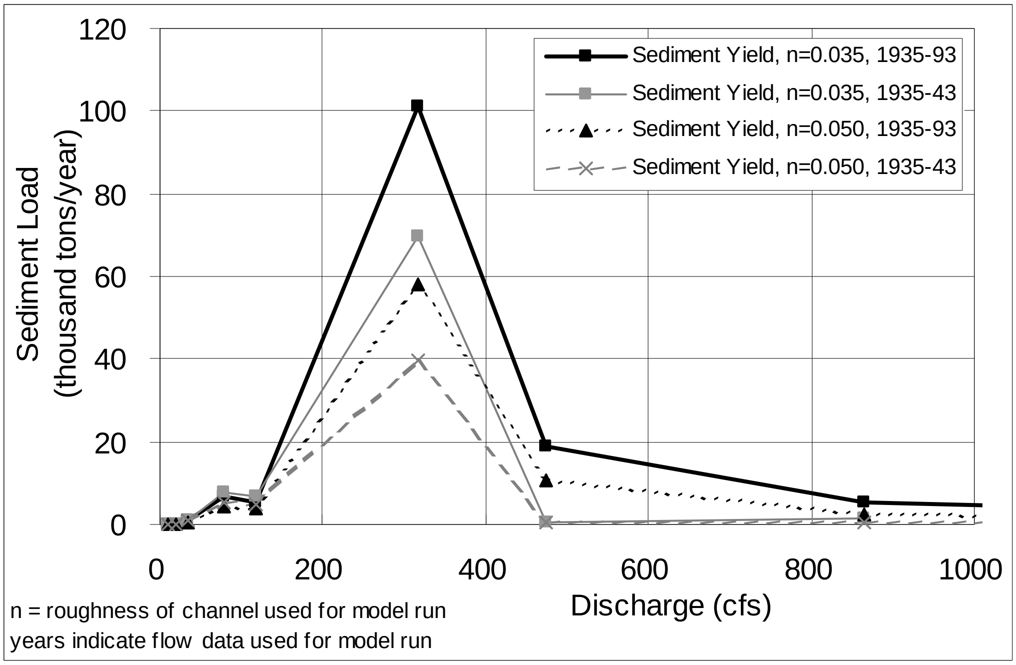
Table 9-6. Muddy Creek Sediment Targets and TMDL.

Targets				
Flow (Discharge)	**Suspended Sediment Load (TMDL)**	**Riparian**[1]	**Channel Indicators**	**Biology**
See Figure 9-15 for target flow duration curve. Reduce surface water irrigation waste from Greenfields Bench by 50% during June, July, and August.	Reduce 3-year average SSC load at Vaughn to 29,959 tons/year. 15% reduction from current USGS estimated load. Based on meeting flow targets.	Achieve PFC for 85% of stream length along Muddy Creek and major tributaries with less than 5% non-functioning riparian areas.	Limit new channel constrictions. Allow the channel adequate space to **slowly** erode a new floodplain. Achieve sheer stress comparable to a Rosgen C or E channel. Little to no channel degradation.	Monitor Muddy Creek fishery, periphyton and aquatic insects for use in future TMDL review.

[1]Using NRCS/BLM/USFS Riparian Area Management Technical Reference 1737-15, 1998.

Wittler et al. (1996) analyzed the relationship between duration of water discharge and the sediment yield at specific discharge rates. This study identifies a stream flow of 320 cfs that is likely to discharge the most sediment load. Because of limited funding, the flow duration to sediment yield relationship was analyzed at relatively few discharge rates. The study identifies a marked increase of sediment loading between the discharge rates of 125 cfs and 320 cfs. Discharges of approximately 200 cfs and higher exert the heightened sheer stress on the stream channel (Figure 9-14). The study indicates that flows from 200 cfs to 400 cfs move the most suspended sediment because their frequency and duration is high and their associated sheer stress is also high. Higher discharges, above 400 cfs, may have higher energy, but occur very infrequently and for short periods. Further analysis of the relationship between duration of discharge and sediment yield at specific discharge rates should be conducted between the discharges rates of 125 cfs and 450 cfs if future funding permits. Further analysis would refine the relationship between these two factors in this critical range of discharge.

Figure 9-14. Sediment Loading from Different Discharges in Muddy Creek.
Note that flow duration is a component of the X-axis.



(from Wittler et al., 1996)

Wittler et al. (1996) estimates that the 300 rock barbs, 11 fish friendly grade control structures and riparian vegetation restoration that occurred from 1994-1996 would increase channel roughness by 30 percent. Stream channel roughness decreases the energy exerted on stream banks. The study builds on this concept by using Mannings equation to estimate that increasing the roughness will likely decrease sediment yields by 42 percent. The modeling results are supported by data collected after the restoration that occurred 1994-1996 (Figure 9-13).

The amount of water that flows through the channel affects stream energy. High discharge has high energy. The longer the duration of high flow the more energy is exerted on the stream channel. Wittler et al. (1996) calculate that flow management practices that would decrease the duration of flows at 100 cfs by 12 percent, 200 cfs by 8 percent and 300 cfs by 4 percent would reduce SSC loads by 38 percent if implemented alone without increasing channel roughness (Figure 9-15). Implementing a flow restoration plan and a physical restoration plan together should decrease loads by 63 percent (Wittler et al., 1996). Most of the physical restoration plan that increases channel roughness is completed. Thus, if the duration of flows stated above can be achieved, at least another 21 percent (63 %-42 %) reduction in SSC loads is expected (Wittler et al., 1996).

Sessoms and Bauder (2002) roughly estimate Muddy Creek base flow, springtime seepage from snowmelt and rain, irrigation seepage, and irrigation spillage for focusing additional investigation efforts of water sources to Muddy Creek (Figure 9-16). If the estimations are accurate, a 200 cfs in-stream average summer target would coincide with roughly a 50 percent reduction in the average annual irrigation spillage to Muddy Creek during June, July and August. The first step to implementing irrigation management projects of this scale is to acquire a comprehensive understanding of Muddy Creek discharge sources. The Bureau of Reclamation, Greenfield Irrigation District, and Montana State University are working together to refine the current understanding about water sources and water flow paths that influence Muddy Creek discharge.

Muddy Creek's flow and SSC loading targets are based upon information that in-stream water discharge and SSC loads can be reduced with initiation of further irrigation management restoration activities. Muddy Creek's SSC target is based upon reducing loads to the lower Sun River by implementing a flow management plan that exceeds 25 cfs 99.9 percent of the time and does not exceed100 cfs more than 25 percent of the time, 200 cfs less than 1.75 percent of the time, 300 cfs less than 0.3 percent of the time and 400 cfs less than 0.15 percent of the time (Wittler et al., 1996) (Figure 9-15 square points). By achieving these discharge rates and durations it is believed that the SSC load can be reduced by 21 percent (Wittler et al., 1996). But, an irrigation management plan that has already taken place in the 1980s is believed to have achieved about a 25 percent of the reduction needed to meet flow targets set forth by Wittler et al. (1996) (Figure 9-15 dashed line). Taking the previous irrigation management activities into account and assuming reduction in discharge and sediment yield is directly proportional, the target becomes a 15 percent reduction of existing average USGS calculated 1997-2001 suspended solids loading at Vaughn, or a reduction from 35,246 to 29,959 tons of suspended solids/year (Table 9-6).

Riparian health targets are provided to guide appropriate riparian management activities. Natural riparian vegetation, such as willows, grasses and forbs, provide the necessary rooting strength to stabilize eroding banks and provide resistance to high stream flows. For example, a study reported in Gordon et al. (1992, pg 338) found that stream banks with a 50 mm-thick root mat of 16-18 percent root volume provided 20,000 times more protection from erosion than comparable banks without vegetation. In addition, properly functioning riparian areas will likely assist in reducing any tendency toward further channel incision. NRCS regularly uses the PFC riparian assessment technique. Currently there are no PFC measurements on the segment for existing condition comparisons.

Muddy Creek's channel geometry targets are performance based because of the magnitude of the sediment erosion problem in the watershed. Lower Muddy Creek's stream channel, between Gordon Road and Vaughn, is highly entrenched. The targets are based upon achievable goals and restoration strategies. Erosion in the Muddy Creek watershed will likely be elevated for many years as the stream enlarges and widens a new, lower altitude valley bottom because of the degradation, or down cutting, that has occurred in the past. One of the goals of Muddy Creek's TMDL/Water Quality Restoration Plan is to reduce downstream impacts to the Sun and Missouri rivers. At this time there are no detailed stream channel morphology targets presented for Muddy Creek, but channel constrictions by new buildings or infrastructure should be limited to allow the stream the needed space to slowly erode a new floodplain. A healthy stream channel morphology comparable to pre degradation is highly unlikely in the short or long term. The goal of the Muddy Creek TMDL is to erode the new, lower elevation, floodplain with reasonable stream channel characteristics at a reasonable erosion rate that does not prevent downstream uses to be met. Meanwhile, the channel should not degrade, or down cut, at an accelerated pace.

Biological targets that relate directly to in-stream beneficial uses should be investigated for use in the future. The fishery, periphyton, and aquatic insect communities should be assessed prior to the TMDL review to indicate if portions or all of Muddy Creek can be reclassified according to the Administrative Rules of Montana. Appropriate biological targets that relate more directly to in-stream beneficial uses will be identified when a reclassification occurs.

Figure 9-15. Muddy Creek at Vaughn Flow Duration Relationships Compared to Targeted Flow Durations.

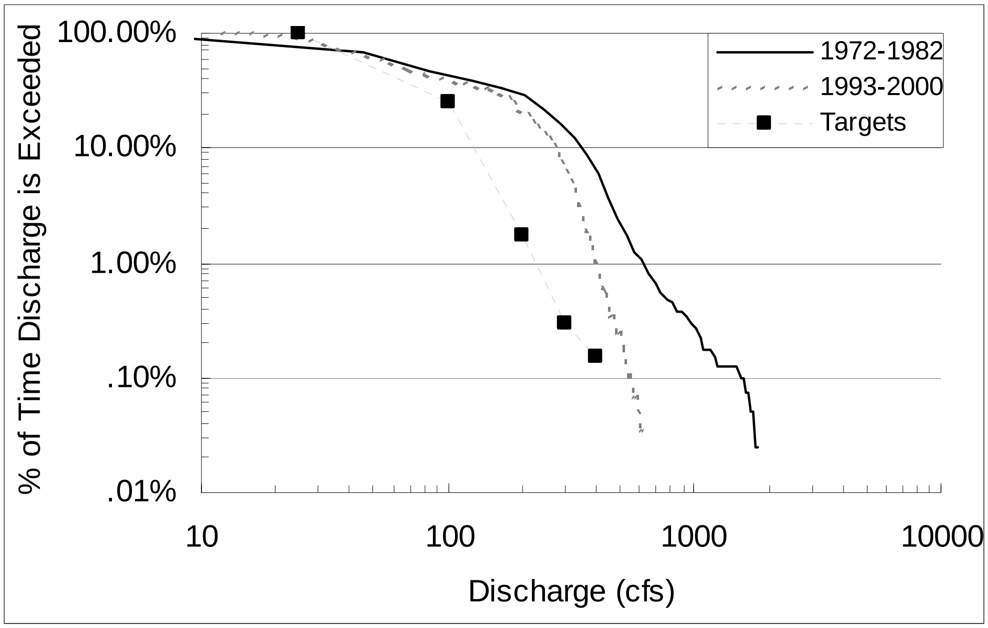
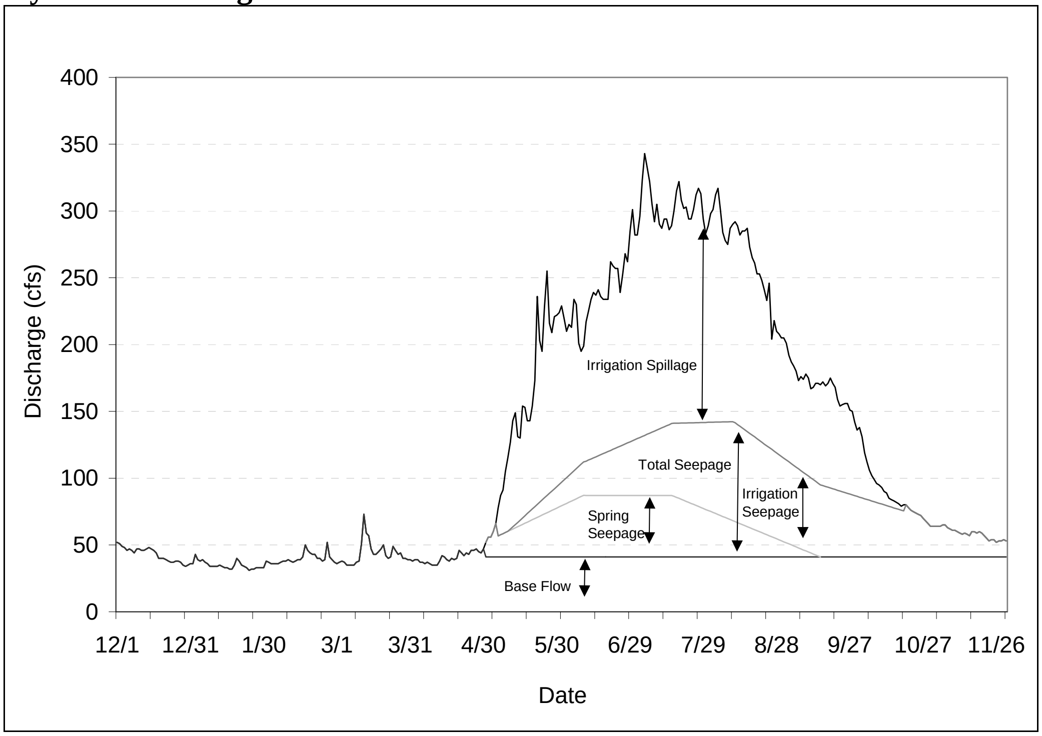


Figure 9-16. Comparison of Estimated Flow Contributions to Twenty-Year Average Flows for Muddy Creek at Vaughn.



(from Sessoms and Bauder, 2002)

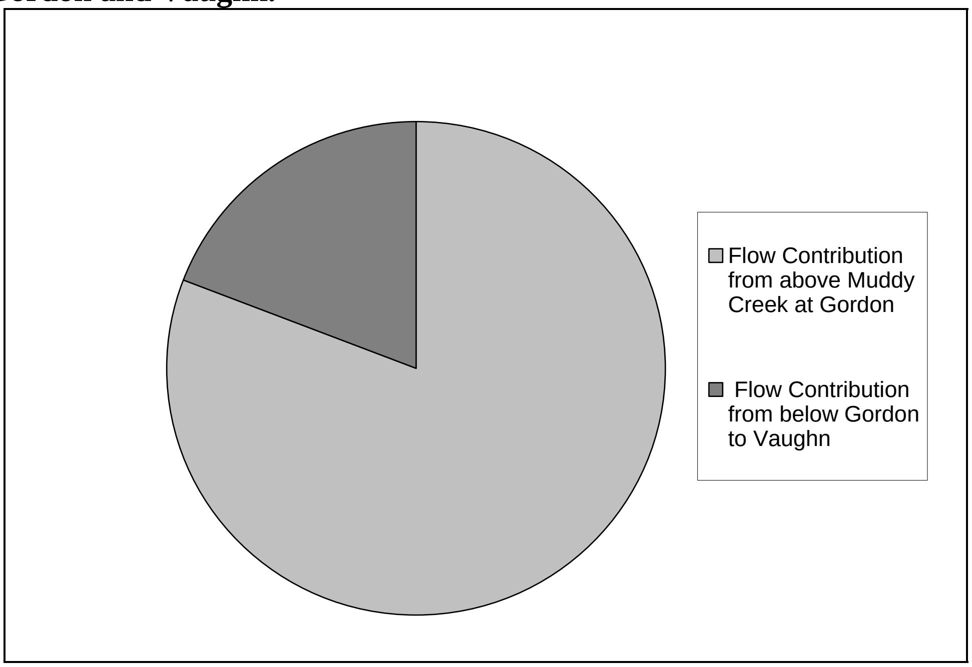
9.3.2 Sediment Sources

Agricultural activities are significant sediment sources that exacerbate the natural erosion process. The primary source is increased stream bank erosion caused by sheer stress of high discharges. Irrigators order irrigation water and then do not use it because rainfall provides water for crops on the Greenfields Bench. The irrigation water is then wasted into Muddy Creek because there is no place to store it. If the irrigators were to use it they would ruin crops and cause field erosion. A secondary source of bank erosion is poor management of riparian livestock grazing. The historic entrenchment that exacerbates sediment loading from bank erosion was derived from these same sources. There are no point source loads and other non-point sources are likely insignificant.

Although Greenfields Bench composes only 25 percent of the watershed, its irrigated lands contribute over 90 percent of Muddy Creek's total discharge (Andrews, 1985a). Sessoms and Bauder (2002) estimate that most of Muddy Creek's discharge is derived above Gordon Road (Figure 9-17). The U.S. Bureau of Reclamation and Montana State University are cooperating to further identify and characterize sediment and water discharge sources to Muddy Creek that are derived from Greenfields Bench but data are not currently available (Verbal Comm. Bauder, 2002). Recent irrigation water management improvements have reduced the discharge contribution to Muddy Creek from Greenfields Bench. Sediment and flow contributions from specific Greenfields Bench tributaries will be available in the near future.

Suspended solids loads are used as an indicator of sediment trends and for source assessment in Muddy Creek. On average, from 1997-2001, suspended sediment loading per square mile of watershed area increase by 191% between Gordon Road and Vaughn USGS sites (Table 9-7). During the same timeframe, average suspended solids loads increase by 264% between Gordon Road and Vaughn USGS sites (Table 9-7). The two USGS sites are about 12.5 river miles apart. The increase in load from this section of stream is due to eroding banks from increased stream energy and historic entrenchment from increased stream energy and riparian grazing.

Figure 9-17. Comparison of Total Flow Contribution (Acre Feet) from Above Gordon to Between Gordon and Vaughn.



(From Sessoms and Bauder, 2002)

Table 9-7. Suspended Solids Loads (1996-2000).

Site	SSC Load (tons/yr)	Watershed Drainage Area (mi^2)	Load per area (tons/mi^2/yr)
Muddy Creek nr Vaughn (Gordon Rd)	13,374	282	47
Muddy Creek at Vaughn	35,246	391	90

9.3.3 Load Limit and Allocations

The TMDL is set to reduce the 3-year average suspended solids load at Vaughn to 29,959 tons/year (Table 9-6). The basis for the 15% reduction of load is presented in the Section 9.3.2 because it is based on meeting flow (discharge) targets that are also presented in that section. The full load allocation is given to natural sources and bank erosion accelerated by agricultural activities in the watershed. There is no waste load allocation. The allocations are based on modeling that identifies loads would be achievable through irrigation water management activities and riparian grazing management.

9.3.4 Margin of Safety, Adaptive Management, and Seasonal Considerations

A margin of safety for this TMDL is provided in an adaptive management approach. The uncertainty of the Muddy Creek sediment TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 9.3.7 to aid in future TMDL review. Identified conservation practices in Section 9.3.6 should be tracked over time to see if implementation occurs. Irretrievable harm has occurred to Muddy Creek through massive degradation, or down cutting of the stream channel. The water quality goals in the Muddy Creek sediment TMDL should be achievable over a period of decades if resources are allocated to restoration work. When the goals in this TMDL are achieved, the stream should be assessed for potential reclassification and sediment targets based upon beneficial uses should be considered.

Addressing sensitive seasons is less of a concern with sediment production than for many chemical pollutants. The load limit is provided in an average annual load rate. This load limit and allocation timeframe is provided for a long term restoration approach. If loads need to be broken into daily or monthly loads because future knowledge indicates that uses are being impacted only seasonally, the load limit timeframe should be changed during future TMDL reviews.

9.3.5. Restoration Strategy

Reducing surface irrigation water waste to alleviate sheer stress on eroding banks in Muddy Creek is a priority. Restoration approaches to irrigation water management delivery need to be further developed on the Greenfields Bench. On-farm irrigation and delivery system efficiency will also be useful to reduce summer groundwater return flow to Muddy Creek. On-farm erosion prevention strategies are also incorporated into the sediment restoration strategy. In order of importance, restoration activities for the Muddy Creek Watershed TMDL include:

- Capturing all or most of the surface irrigation waste water and/or devising a more efficient approach to water delivery on Greenfields Bench that may include draining surface waste water to Freezeout Lake instead of Muddy Creek.
- Preventing on-farm surface irrigation water runoff from exiting fields or ditches.
- Studying water loss in ditches, prioritizing ditch lining using water loss study, and lining ditches in areas that leak the most, especially near the periphery of the Greenfields Bench in Muddy Creek’s watershed. Using evapotranspiration or soil moisture monitoring for irrigation scheduling.
- Installing head gates that can be fully controlled, if not already in use.
- Using efficient irrigation methods on Greenfields Bench.
- Leaving crop residue on fields by using low/no till methods when possible.

Current grazing management, in conjunction with reduced sheer stress from irrigation water management, should allow Muddy Creek to slowly erode a new floodplain, prevent accelerated bank erosion, and allow riparian areas to revegetate. Pastures should be managed in a way that allows riparian recovery. Grazing management practices that may help to avoid acceleration of stream bank erosion in the future could include:

- Using riparian browse and grazing indictors to manage riparian grazing pressure.
- Timing grazing to coincide with dry or freezing weather to reduce erosion.
- Timing pasture use to promote grazing, not browse.
- Placing supplemental feed or salt in upland areas to promote even grazing in pastures.
- If needed, fencing riparian areas and provide water gaps.
- Employing weed control.

9.3.6. Monitoring Strategy

Permanent cross sections on Muddy Creek should be established to track stream channel elevation, entrenchment of the stream channel, and parameters necessary for determining Rosgen level 2 stream channel type. Riparian green line transects should be conducted that can determine the percentage of riparian plant size (bare ground, ground cover, mid-story, canopy) and type (tree, shrub, grass/forb). Data should be collected to estimate sheer stress near cross sections. Proper functioning condition assessment should occur on riparian areas near the cross sections. USGS SSC monitoring should continue at both Gordon Road and at Vaughn. Analysis of suspended solid loads should continue at both sites.

9.4 Upper Sun River

A generalized watershed description for the Sun River can be found in Section 2.8.4. The upper Sun River water quality standards and use classification are provided in Section 3.0. This segment of the Sun River is approximately 80 miles long. Therefore, it is broken into two reaches for the existing condition report. The first reach starts at Gibson Dam and ends at the Highway 287 Bridge near Augusta. The second reach runs from Highway 287 Bridge and ends at Muddy Creek. The source assessment, and TMDL encompasses the whole upper Sun River watershed, both reaches combined.

9.4.1 Existing Conditions and Targets

9.4.1.1 Gibson Dam to Highway 287 Bridge

This reach of the main stem Sun River used to be called the North Fork of the Sun River and Elk Creek was once called the South Fork of the Sun River. Now, the north fork of the Sun River is a named stream segment above Gibson Dam.

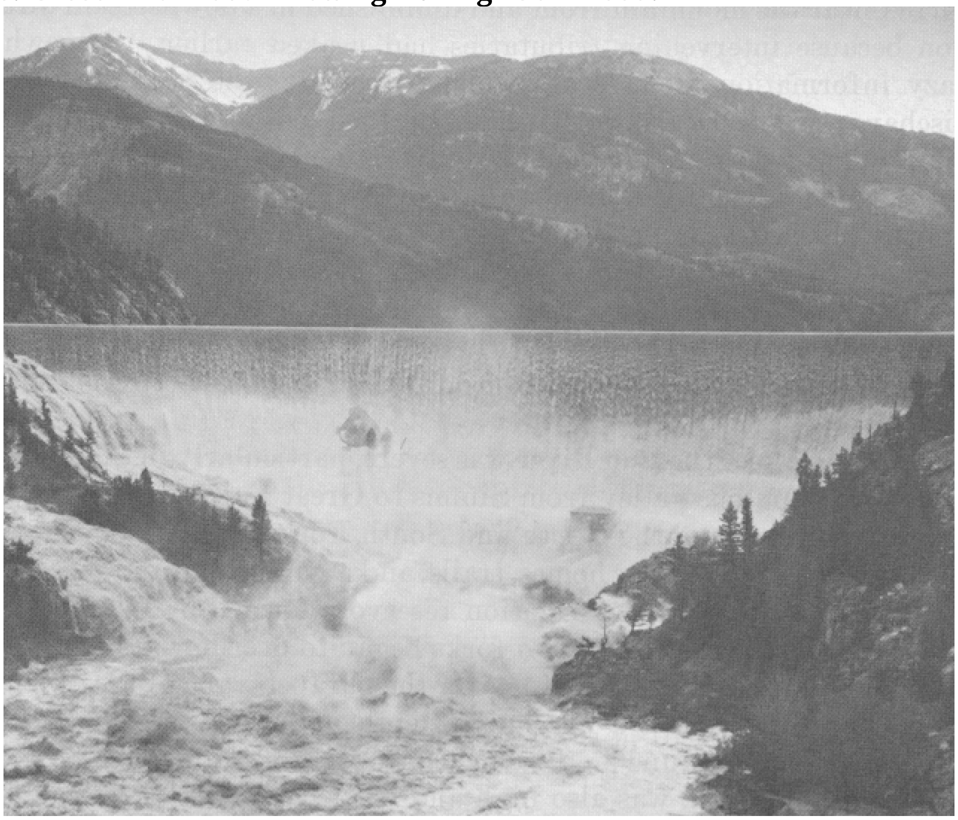
Physical and Riparian Indicators

Stream gradient from Gibson Dam to the Highway 287 Bridge is 0.0039 (Chrest et al., 1987). The Sun River exhibits B and some limited C Rosgen channel type characteristics in this reach (Rosgen, 1996). A considerable amount of the channel substrate in the upper 12 miles of this reach is composed of bedrock and large boulders. Areas of cobbles and gravel are limited and are usually associated with side drainages. Since the construction of Gibson and Diversion Dams in 1929, very little smaller sized bed load has entered this reach, thereby preventing development of a more diverse substrate composition. Channel substrates diversify somewhat farther downstream, and are composed of boulders and cobbles. Percent fines less than 2 millimeters were not found during two pebble count measurements in pool tail-outs in this reach (Table 9-8). The targeted upper threshold for percent fines less than 2 millimeters is a cumulative 20% in riffles. Pool tail out areas are more prone to siltation than are riffles. See Section 9.2.1 *Future Targets* for justification of the percent fines target. Fine bed load sediment does not appear to cause impairment in this reach of the Sun River. Lack of fine sediment may be of a concern, but this section of the Sun River likely had little fine sediment prior to dam installation above.

The combination of natural flooding, higher stream gradient, bedrock control, and an upstream dam that impedes sediment movement has caused scour in this portion of the stream channel. The average of two entrenchment ratio measurements near Willow Creek's confluence is 1.8, which is appropriate for a Rosgen B channel. Bedrock control does not allow the stream to entrench from the scour. The dam and natural scour influence the substrate particle size to larger fractions by intercepting upstream sand, pebble, and small cobble sediment supply and by moving these sediment fractions downstream, out of this reach.

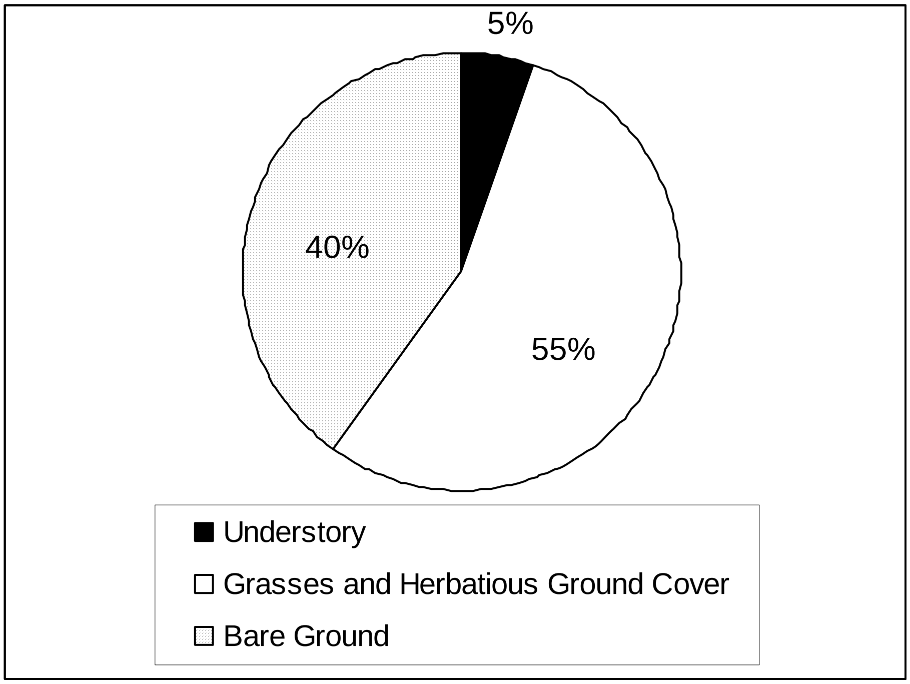
This reach of the Sun River is severely dewatered at times, but the dewatering does not appear to influence in-stream sediment or stream channel conditions. Spring floods and associated stream energy are reduced during many years because of water retention in Gibson Dam, but this is not always the case. Spring floods in 1964 overtopped the dam and provided extreme scour in the Sun River (Figure 9-18). Flooding during 1988 was also quite severe. The effects of lower stream energy during spring floods due to upstream dams does not appear to reduce the ability of this reach to transport sediment. Changes in stream energy do not appear to cause siltation or stream channel instability in this reach.

Figure 9-18. Gibson Dam over Flowing During 1964 Flood.



There are very few unnatural sediment sources on this reach of the Sun River other than very minor impacts from historic grazing. The riparian community in this upper segment is naturally limited. A large area of stream bank is bare ground because of bedrock outcrops. Well drained, boulder and sand dominated, alluvial banks containing little soil for vegetative growth dominate many riparian areas. An arid climate and very permeable bank conditions also contribute to stream banks that do not support much vegetation. Chrest et al. (1987) indicate that only 9.3% of the stream banks in this reach of the Sun River are actively eroding. Grasses and forbs along with bare ground dominate bank full elevations. Willows and cottonwood grow in limited areas of stream banks (Figure 9-19). Bank erosion from this reach is estimated to produce less than one percent of the overall sediment load to the upper Sun River segment (Section 9.4.2).

Figure 9-19. Sun River Bank Full Vegetation Assessment Above Highway 287.



Biological Indicators

Macroinvertebrate and periphyton communities have not been assessed in this reach of the Sun River. Fish shocking occurred during 1987 on the up-stream and down-stream portions of this reach. Fish shocking results are provided in Table 1-4. Low fish counts are due to extreme low flow conditions produced by irrigation water withdrawal for Greenfields and Fort Shaw irrigation districts from the upper end of this reach.

Water Quality Indicators

Limited total suspended solids data is available in this reach. All four samples collected during 2001 were below a detection limit of 10 mg/L. The data is of little use to determine impairment because suspended solids concentration and loading are variable and extremely dependent upon discharge conditions, rainfall events, and other weather conditions that can fluctuate by the moment. These limited samples do not constitute a data set that can adequately reflect these variations over time and are of little use. However, this limited data indicates that during these sampling events, TSS in this reach was below detection limits and below target levels.

9.4.1.2 Highway 287 to Muddy Creek

Physical and Riparian Indicators

The gradient in this section of the Sun River is approximately 0.0022 (Chrest et al., 1987). This reach of the Sun River has a C Rosgen channel type. Substrate consists of cobbles and gravel with moderate amounts of silt. Deposition of sand and silts in the stream bottom increases in a downstream direction. This reach receives recharge water and significant amounts of sediment from irrigation surplus water derived on bench lands north of Sun River, via Big Coulee, Duck Creek, and Mill Coulee. Irrigation on the south side of the river in the Fort Shaw and Adobe Creek areas also contribute discharge and sediment associated with irrigation. Much of the time this portion of the river is severely dewatered. Most of this segment is slowly degrading, or incising.

The average of two entrenchment ratio measurements near Simms is 2.8, which is appropriate for a Rosgen C channel. Simms is near the middle of this reach. A gentle gradient and more sediment sources contribute to higher fine sediment accumulation in a downstream direction on this reach. Nevertheless, at Simms, near the middle of this reach, there was an average of only 14.5 % particles less than 2 millimeters found in pool tail outs using Wolman pebble count methods. All of the particles less than 2 millimeters were silts. The targeted threshold for percent fines less than 2 millimeters is a cumulative 20% in riffles. See Section 9.2.1 *Phased Targets* for justification of the percent fines target. Pool tail out areas are more prone to siltation than are riffles. When comparing recent data near Simms to this target it appears that this reach is not impaired due to siltation.

In this reach, grazing is more concentrated and crop production impacts the river. Numerous irrigation diversions along this segment cause severe de-watering at certain times of the year, to the detriment of aquatic life and the fishery (Chrest et al., 1987). From the Town of Simms to Muddy Creek, human impacts on the river are most pronounced. About 26.5% of the stream banks are actively eroding according to Chrest et al. (1987). Grasses and forbs dominate bank full elevations. Willows and cottonwood produce a more significant under story and canopy here than upstream (Figure 9-20). Though, it is estimated that bank erosion from this reach produces significant amounts of sediment delivery to the upper Sun River segment (Section 9.4.2).

Limited TSS data from 2002 and 2003 indicates that tributaries such Adobe Creek, Mill coulee and especially Big Coulee contribute sediment to this reach of the Sun River (Figure 9-21). Irrigation activities and grazing impact stream energy and riparian resilience in these tributaries. Tributaries of Big Coulee are actively incising and contributing sediment loads because of these sources (Figure 9-22 and 9-23). Big Coulee, Adobe, and Mill creek confluences are below the town of Simms where many of the stream channel indicators were assessed, but above the town of Sun River area where macroinvertebrate samples were collected. An adaptive management and follow up monitoring strategy that addresses these tributaries is provided in Sections 9.5.4 and 9.5.6.

Figure 9-20. Sun River Bank Full Vegetation Assessment Near Simms.

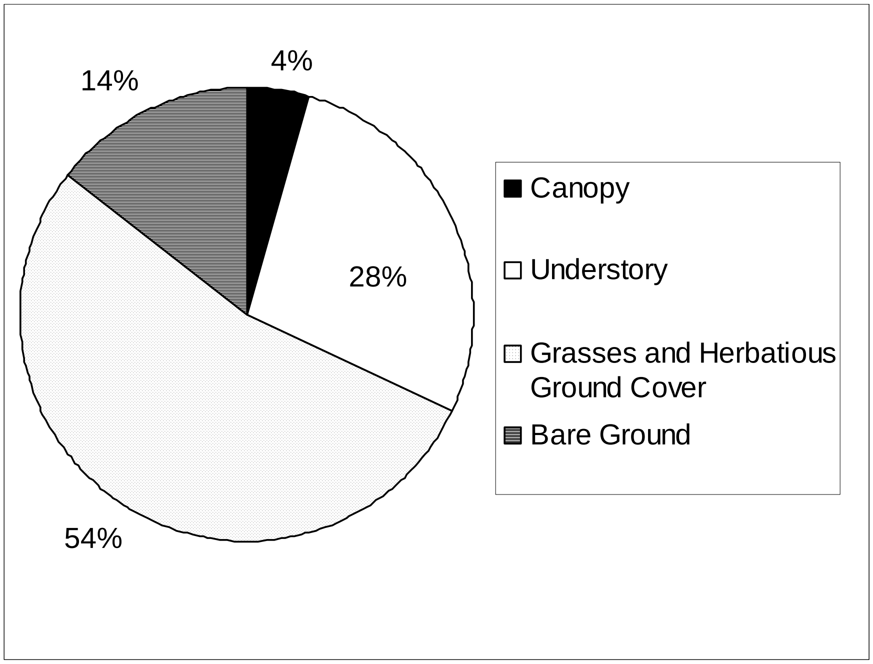


Figure 9-21. Upper Sun River Tributary Total Suspended Solid Concentrations.

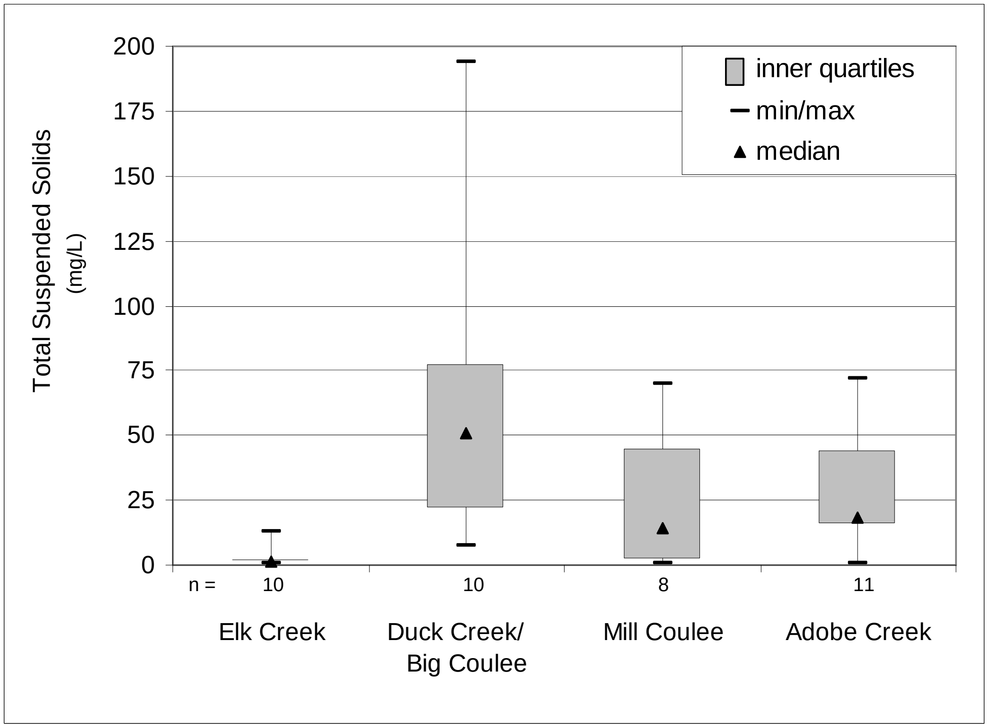
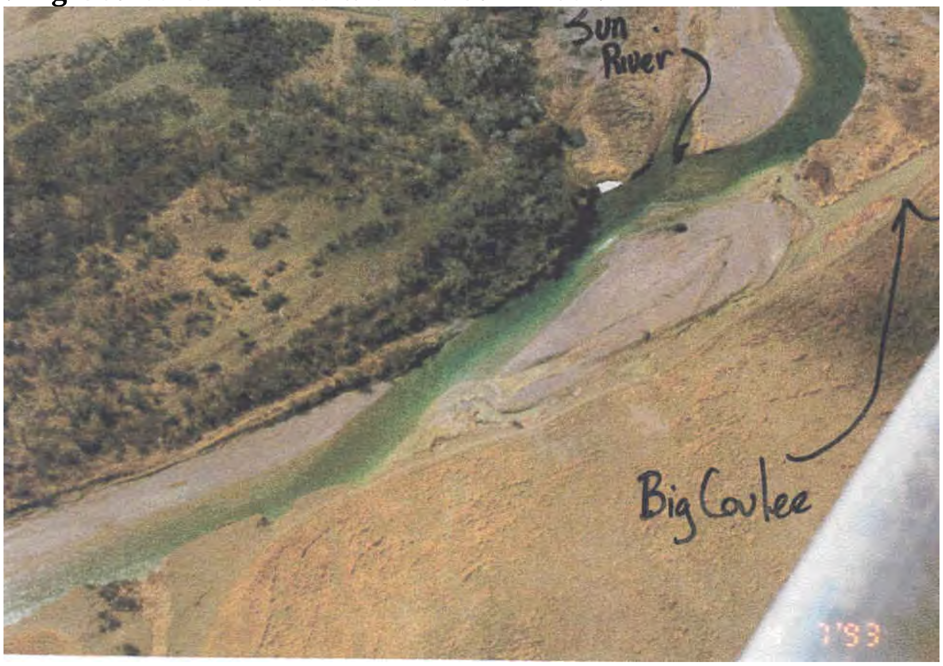
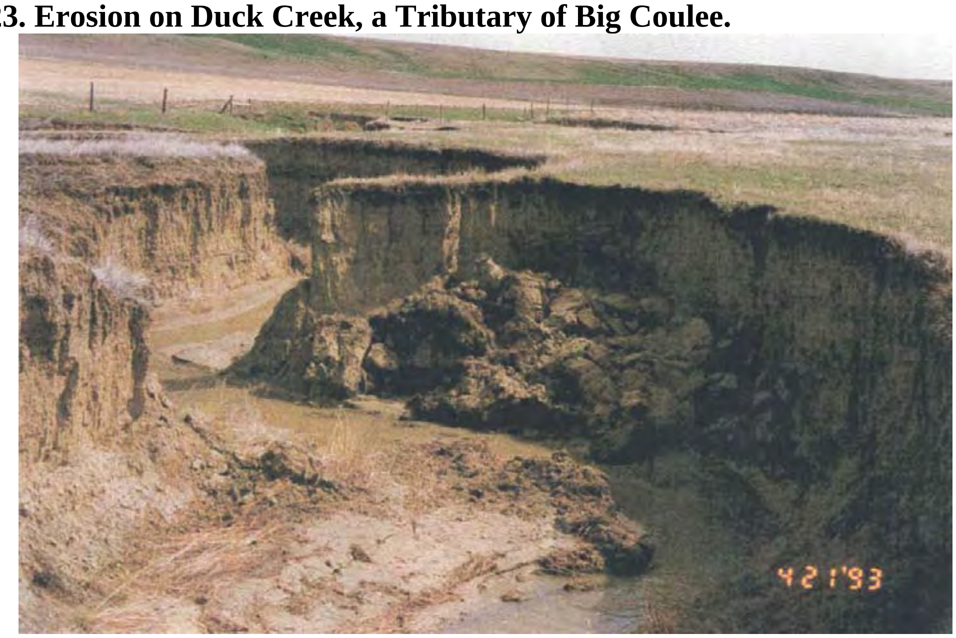


Figure 9-22. Big Coulee Confluence with the Sun River.



Note the difference in turbidity between Big Coulee and Sun River

Figure 9-23. Erosion on Duck Creek, a Tributary of Big Coulee.



Biological Indicators

Macroinvertebrate samples have been collected near the Town of Sun River, on the lower end of this reach, during 2001 and 2002. Of the many macroinvertebrate metrics that are assessed, the number of clinger taxa provides the strongest indication of sediment impairment. These taxa are adapted to live on rocks and other surfaces in swift currents. They are sensitive to fine sediments that fill in their habitat. The average number of clinger taxa found in the two samples was 10.5. At least 14 clinger taxa are expected in unimpaired Montana streams (Bollman, 1998). This is a proposed target for the Sun River. Other indicators relating to the macroinvertebrate community are percent of individuals that are filterers found in a sample. Aquatic insects that filter stream water usually cling to hard surfaces and use antennae, webs, or other means of filtering water as it passes by. High numbers of filtering macorinvertebrates support a conclusion that fine suspended sediment transport is occurring just upstream of Muddy Creek's confluence. Filterers composed 55.5 % of the samples at Sun River. Filterers composed 8.4 % of the samples collected during the same sampling timeframe on the Dearborn River near its confluence with the Missouri River. Siltation and suspended sediment appear to be influencing the aquatic insect community on the lower end of this reach.

Fish shocking occurred during 1987 and 2001 at various locations on this reach. Fish shocking results are provided in Tables 1-3 through 1-5. Low fish counts are due to extreme low flow conditions produced by irrigation water withdrawals for irrigation.

Water Quality Indicators

Limited total suspended solids data is available in this reach. Available TSS data from this reach of the Sun River is provided in Figure 9-24. All available TSS data for this reach is summarized in Figure 9-25. Caution should be advised in using suspended solids concentration and loading for impairment justification because TSS is variable and extremely dependent upon discharge conditions, rainfall events, and other local conditions that may fluctuate by the moment. The data set is not robust enough to adequately reflect environmental variations over time, and therefore, caution should be used when interpreting this data. However, this limited data set is used in conjunction with biological and physical indicators to support that suspended sediment may impact uses in this reach.

TSS is weakly correlated with flow in this reach (Figure 9-25). TSS concentrations are above 10 mg/L during low flow discharges below 200 cfs. This indicates that unnatural sources of sediment likely influence TSS concentrations. TSS data and pictures of mass bank wasting indicate that Big Coulee/Duck Creek tributaries are sources of TSS loading even when the Sun River may be at low discharge.

Figure 9-24. Sun River Total Suspended Solids Concentration.

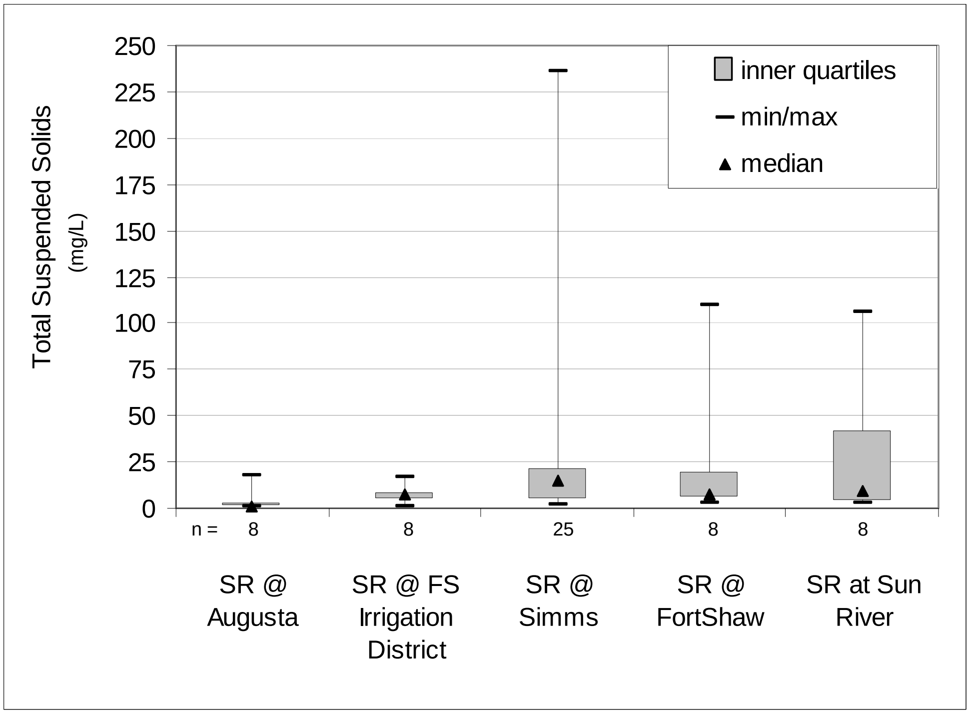


Figure 9-25. Sun River Total Suspended Solids Concentration and Discharge Relationship Near Simms.

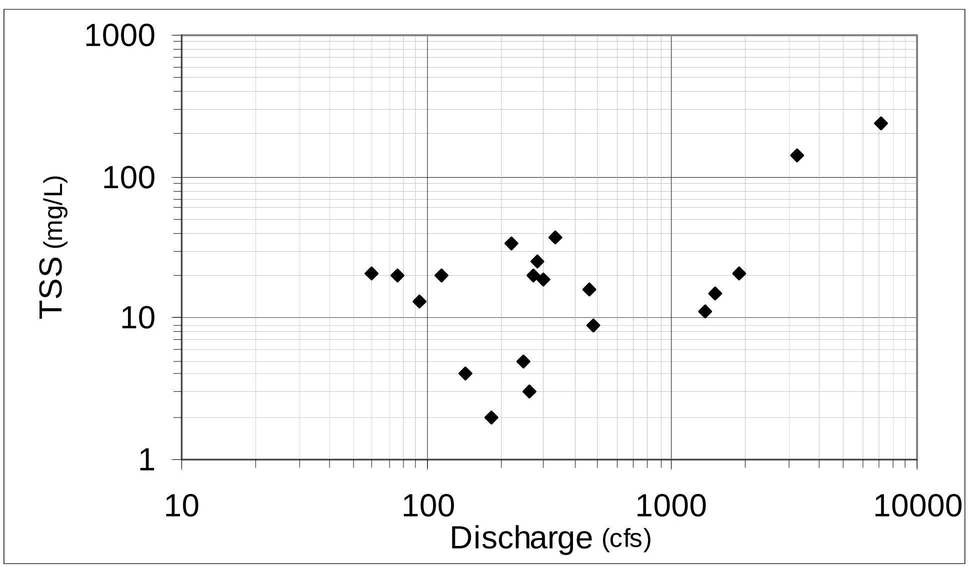


Table 9-8. Upper Sun River Sediment Targets and Existing Conditions.

Reach	Riparian	Stream Channel	Biology	TSS
Gibson Dam to Highway 287 Bridge	**Targets**			
	Eroding banks ≤ 10%	1. Entrenchment ratio 1.4-2.2 2. Percent fines (2mm) < 20%	**Macroinvertebrates** 14 Clinger Taxa % of sample filter feeders ≤ 20%	Less than 10 mg/L at discharges under 200 cfs
	Existing Conditions			
	Eroding Banks = 9.7%	1. Entrenchment ratio = 1.8 2. Percent fines (2mm) = 0%	Unknown	No exceedance in four samples.
287 Bridge to Muddy Creek	**Targets**			
	Eroding Banks ≤ 10%	1. Entrenchment ratio ≥ 2.2 2. Percent fines (2mm) ≤ 20%	**Macroinvertebrates** 14 Clinger Taxa % of sample filter feeders ≤ 20%	Less than 10 mg/L at discharge under 200 cfs
	Existing Conditions			
	Eroding Banks = 26.5%	1. Entrenchment ratio = 2.8 2. Percent fines (2mm) = 14.5%	**Macroinvertebrates** Average of 10.5 Clinger Taxa in two samples 55.5% of samples are filter feeders.	Four of six samples exceed target.

Upper Sun River Impairment Summary

The reach above Highway 287 is not impaired due to sediment, riparian habitat, or stream channel conditions. Siltation, stream channel form, and TSS conditions are meeting targets in this reach. No biological samples have been collected on this reach, but are proposed for collection in the follow up monitoring strategy as a precautionary measure. There are insignificant human caused sources of sediment in this reach (Section 9.4.2). This reach is severely dewatered to the extent that impacts the fishery. However, sediment, stream energy, and stream channel dimensions that influence sediment transport and sorting, do not appear to impact beneficial uses here. To ensure this is the case, the TMDL monitoring plan in Section 9.5.6 identifies macroinvertebrate sampling should be conducted in this reach.

The lower end of the reach from the Highway 287 Bridge to Muddy Creek appears to be impaired by TSS and potentially siltation. Pebble counts indicate there is not a siltation impact at Simms, about midpoint of this reach. All of the fines found at this site were silt sized particles. However, low numbers of clinger taxa and high numbers of filter feeders in the aquatic insect community near the town of Sun River, on the lower end of the reach, indicate impairment due to siltation and TSS. TSS samples collected as Simms also indicate that there are suspended solids concentrations at moderate levels during low discharges. There are significant sediment sources in this reach (Section 9.4.2). Sediment and TSS appear to impact in-stream beneficial uses in the lower end of this reach, from Simms to the Muddy Creek’s confluence.

9.4.2 Sediment Sources

The source assessment does not consider sediment sources above the Gibson Reservoir because the reservoir effectively traps most sediment from above. Sediment sources are agricultural and potentially transportation based. Livestock grazing, irrigated cropping, and fallow cropping are the most widespread land use within the watershed. The road network infringes on riparian areas and is a potential source of sediment delivery. There are very few lightly developed urban areas in the watershed that include Augusta, Simms, Fort Shaw, and Sun River but they do not have POTWs that discharge to the Sun River. Vaughn has a POTW that is permitted and discharges to the lower end of this segment.

The conclusions presented in this section have been developed from the best data available at the time this report was prepared. Measured sediment loads from all sediment sources are not available; therefore estimates were made based on literature values or were developed using various modeling techniques. Further, detailed, on-the-ground assessments have not been conducted in the entire watershed. As a result, interpolation was required and assumptions were made regarding conditions that were not directly observed. However, it is felt that the information contained in the following subsections allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories. Uncertainties are discussed in greater detail in the *source summary* subsection and *other sources* subsection below.

Individual assessments were conducted to compare the most significant sources. Current agricultural, hydromodification, and historic sources that affect bank stability were assessed through a stream bank erosion sediment load assessment. Sediment from roads were considered by extrapolating loads by using the Ford Creek Water Erosion Prediction Project (WEPP) model results estimate loads from roads in the upper Sun River watershed. Background upland erosion was estimated using a soil creep erosion estimate. Methodology for each of these is discussed in more detail in the following subsections.

Upland Background Erosion Rate

The background erosion estimate uses an approach based on soil creep rates. This methodology was used along with other background erosion estimates in the Upper Lolo TMDL document. The soil creep equation is:

Annual Erosion Volume (m^3/yr) = L (m)* 2 * D (m) *C (m/yr)

Where: L = Length of stream network in meters
D = Depth of soil in meters
C = Annual creep rate in meters

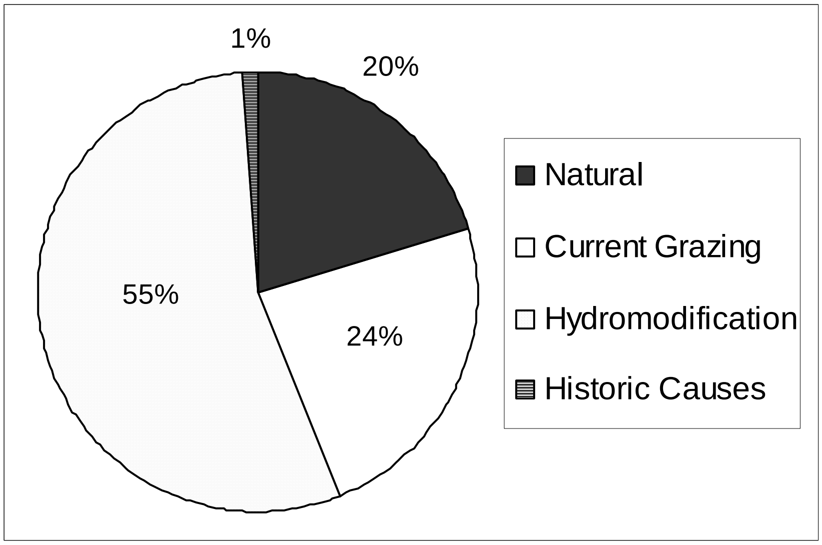
This approach to estimating background erosion estimates is identified in *Standard Methodology for Conducting Watershed Analysis* (Washington Forest Practice Board, 1997). If no local data exists, methodology recommends a creep rate of 0.001 meters per year if average watershed slopes are less than 30%, as they are in the upper Sun River. The most recent national hydrography dataset (NHD) stream layer is used for calculating stream length in a GIS framework. The NHD stream layer is built from 1:24,000 USGS hydrography mapping. The length of the upper Sun River and tributary stream channels from Gibson Dam to Muddy Creek (not including Muddy Creek) is calculated at 4,233,130 meters. An average soil depth was estimated at one meter for the whole watershed. The average annual erosion rate was calculated at 8,466 m^3/year. A conversion factor of 1.76 tons per m^3 is used to convert the yield to tons per year. The average estimate of background upland loading is 14,901 tons/year.

Bank Erosion

Chrest et al. (1987), an aerial photo assessment, and field conformation identified two reaches of the upper Sun River that displayed distinct stream channel characteristics. The reaches coincide with those presented in the impairment status section for the upper Sun River. Representative, one thousand-foot sections of each reach were assessed by bank erosion inventories conducted in September, 2004. The data collected from the two bank erosion assessment stream sections were then extrapolated to each reach by dividing the length of the reach in feet by 1,000 and multiplying the results by the load derived in the representative section. See Section 9.3.2, subsection *bank erosion,* for a detailed description of the bank erosion source load estimate methodology that was conducted on each 1,000-foot section.

The 2004 stream bank sediment source inventory identified the following causes of erosion: 1) current grazing practices 2) combination of past overuse, floods, and beaver removal 3) natural sources 4.) hydromodification from dams and irrigation. Estimated sediment yields from these four sources are 8,943, 376, 7,742 and 20,867 tons/year respectively. Bank erosion from the reach above Highway 287 contributes an estimated 1.7 % while the lower segment contributes 98.3% of sediment load from all bank erosion. The stream bank erosion source assessment identifies current grazing practices produce about 24% of the total bank erosion sediment yield (Figure 9-26). The most significant source of bank erosion on the upper Sun River is hydromodification, which accounts for 55% of the overall calculated bank erosion sediment yield. Very low discharge dewaters stream banks, which in turn, reduce riparian vegetation growth at and below bank full. When floods occur, the vegetative bank protection is not present and banks erode more easily. This, along with historic floods, creates a unprotected banks many areas of this segment. Natural sources are responsible for approximately 20% of the calculated sediment yield from stream bank erosion on the upper Sun River. The stream bank erosion assessment did not assess tributary erosion.

Figure 9-26. Percent of Stream Bank Erosion Sediment Yield by Source Category, Upper Sun River.



Road Assessment

Professional judgment indicates that sediment loading from roads is not a significant impact in the Sun River watershed. A very coarse road sediment loading assessment was conducted to back professional judgment. Road related sediment yields were grossly estimated by comparing the upper Sun River road network to the Ford Creek watershed road network and extrapolating sediment yield. The length of roads within 300 feet of a stream corridor was calculated using US Census road data and the most recent version of the national hydrography dataset (NHD) in a GIS framework. Upper Sun River sediment loads from roads were derived by dividing the length of road in the upper Sun River watershed by the length of road in Ford Creek's watershed and multiplying by the sediment load associated with roads in Ford Creek's watershed.

An assumption is that the road and stream network are comparable in these two areas, which may not be the case. Roads in the upper Sun River watershed are more likely to have a stream buffer with gentler slopes than in Ford Creek. Road approaches to a stream are likely a gentler slope than those in Ford Creek. Road surface types and road sanding were not considered in this comparison. There are no paved roads in Ford Creek's watershed, but there are a number of paved roads in the upper Sun River watershed. Based on professional judgment, road sanding is likely not a significant source in the Sun River watershed. All of these assumptions and those identified in the road assessment for Ford Creek indicate that this assessment produces gross estimates and should be used only for general purposes. However, the results allow a reasonable comparison to be made regarding the relative contribution of sediment from roads to other source categories. The road assessment predicted 193 tons of sediment per year is derived from the road network in the upper Sun River watershed.

Point Sources

The only permanent point source is half a mile from the lower end of this stream segment. Sun Prairie Village POTW discharges 6.6 tons of TSS per year. This equates to about 0.01% of the estimated sediment load in the upper Sun River. The point source is not a significant sediment source. At Sun Prairie Village's non-degradation threshold limit, it would contribute about 0.05% of existing sediment load in the upper Sun River.

Other Sources

Tributary bank erosion was not assessed in the source analysis. This source could be significant given the mass wasting found in Duck Creek (Figures 9-22, 2-23). Tributary sediment sources will be addressed in an adaptive management approach and follow up monitoring plan. The limited TSS concentration data indicates that Duck Creek/Big Coulee, Mill, and Adobe Creeks are potential sources of unnatural sediment production (Figure 9-21). These tributaries will be identified for further bank stability source assessment monitoring in the TMDL monitoring strategy.

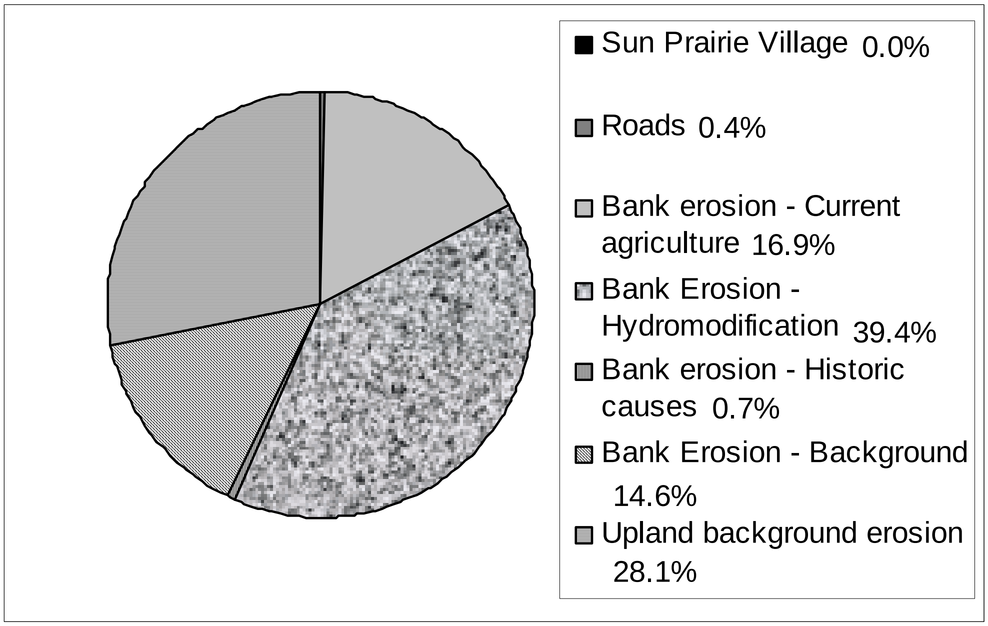
Other sediment sources in the watershed exist but, based on professional judgment, are considered to be insignificant. Although there have been fires above Gibson Dam, recent fires have not burned significant areas in the upper Sun River watershed below the dam. Only a few small towns are located in this watershed, therefore urban sources are not considered except for the Sun Prairie Village POTW.

Source Summary

When comparing the individual sediment studies to each other for an overall sediment yield and source assessment, caution should be used. Different models and erosion assessments can provide various estimates of sediment yields for the same source. However, the information contained in the following subsections allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories.

According to the source assessments, about 43% of the sediment yield in the watershed originates from natural upland and natural bank erosion sources when combined (Figure 9-27). Historic sources of bank erosion, the point source, and roads, when combined, contribute less than 1.5% of the total assessed load. These three human caused sources are not significant contributors to the sediment load. Bank erosion due to current agricultural activities and hydromodifcation contribute an estimated 16.9% and 39.4% of the sediment loads respectively. The allocation process will call for reductions from these two sources.

Figure 9-27. Percent of Total Sediment Yield in the Upper Sun River by Source Category.



9.4.3. Load Limit and Allocation

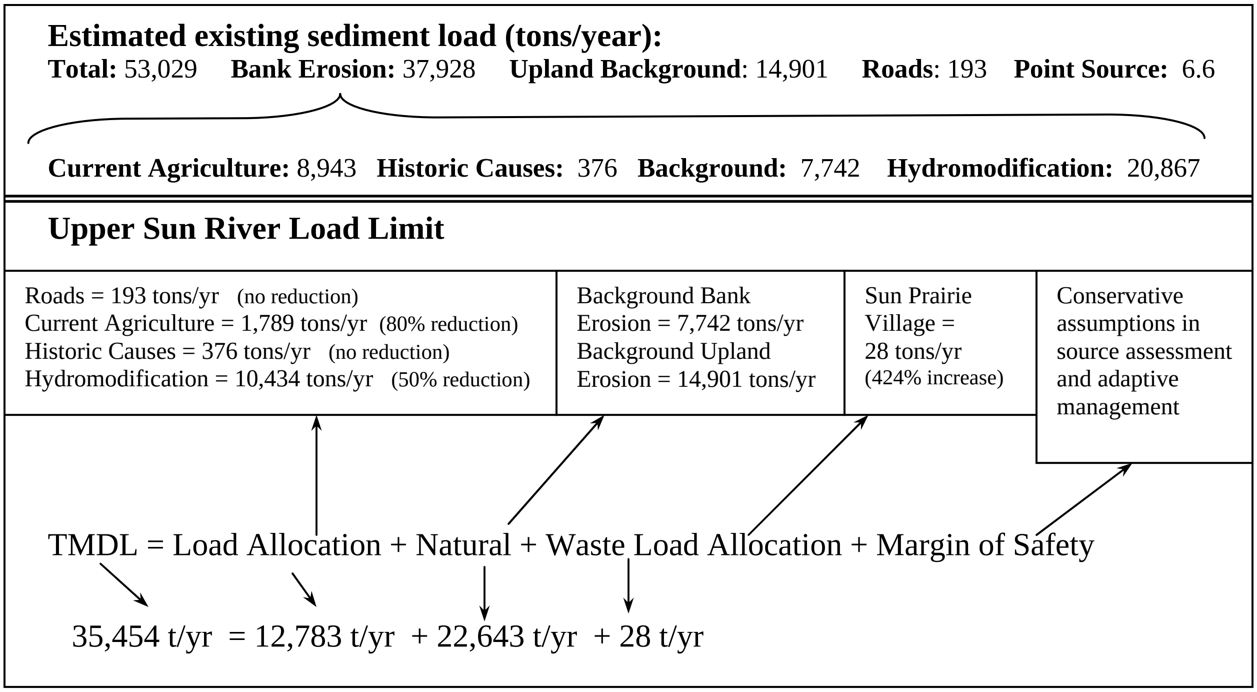
A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

TMDL = WLAs + LAs + Natural + MOS

The source assessment identified riparian agricultural impacts and hydromodification as the two most significant human caused sources of sediment loads in the upper Sun River. It is estimated, based on professional judgment, if grazing and crop practices identified in the restoration strategy are implemented, loads from riparian agricultural impacts can be reduced by 80 percent (Figure 9-28). Loads from eroding banks due to existing grazing activities could be reduced to an estimated 1,789 tons/year. It is also estimated, based on professional judgment, that if irrigation water management practices identified in the restoration strategy are implemented, loads from hydromodification impacts can be reduced by 50 percent. Loads from eroding banks due to hydromodification could be reduced to an estimated 10,434 tons/year (Figure 9-28). Sun Prairie Village POTWs allocation is to stay below the non-degradation threshold limit. This would be an increase of 424% of current TSS discharge. Because this source is insignificant, this increased allocation is estimated at 0.08% of the TMDL. Other sources are allocated their current estimated loads in the source assessment. An overall 33% reduction from currently assessed estimated sediment loads is needed to achieve the TMDL.

A phased allocation approach will be used to assess sediment sources and provide allocations to tributaries of the upper Sun River. For this allocation process, the tributary bank erosion sources are assumed to be the same proportions as those found on the main stem of the upper Sun River. The phased allocation can be accomplished by implementing the monitoring strategy in Section 9.4.6. The tributary sources can then be addressed by future TMDL reviews as provided for in Montana law.

Figure 9-28. Upper Sun River Estimated Existing Loads, TMDL, Allocation, and Margin of Safety.



9.4.4. Margin of Safety, Adaptive Management, and Seasonal Considerations

Although some of the source assessment techniques are based on methods that provide gross estimates, they used assumptions that would tend toward protecting natural resources when uncertainties were encountered. See Section 9.2.5 for specific examples.

A margin of safety for this TMDL is provided in an adaptive management approach. The uncertainty of the upper Sun River sediment TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 9.4.6 to aid in future TMDL review and the phased allocation for tributary bank erosion. Conservation practices identified in Section 9.4.5 should be tracked over time to see if implementation occurs. If implementation occurs and does not achieve targets or load allocations in the watershed, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place, targets, TMDL and allocations may have to be revised.

Addressing sensitive seasons is less of a concern with sediment production than for many chemical pollutants. The load limit is provided in an average annual load rate. This load limit and allocation timeframe should adequately protect the uses. If loads need to be broken into daily or monthly loads because future knowledge indicates that uses are being impacted seasonally, the load limit timeframe should be addressed in future TMDL reviews.

9.4.5. Restoration Strategy

Grazing Management

Application of grazing management tools can reduce sediment loads from bank erosion sources. Grazing management practices that may help to avoid acceleration of stream bank erosion on the upper Sun River and tributaries are:

- Using riparian browse and grazing indictors to manage riparian grazing pressure.
- Timing grazing to coincide with dry or freezing weather to reduce erosion.
- Timing pasture use to promote grazing, not browse.
- Placing supplemental feed or salt in upland areas to promote even grazing in pastures.
- If needed, fencing riparian areas and providing water gaps.
- Employing weed control.

Riparian Buffer Zones

Allowing a riparian buffer between the river and agricultural fields will promote growth of riparian vegetation with better soil binding properties. The riparian species root mass will protect banks better than shallow rooted field grasses.

Irrigation Water Management

Reducing surface irrigation water flowing back into tributaries is a priority. This will alleviate sheer stress on eroding banks in tributaries. The recovered water should be left in the Sun River to promote riparian vegetation growth by stabilizing in-stream water levels. Restoration approaches that address inefficient irrigation water delivery are vital. Increasing on-farm irrigation and delivery system efficiency will be useful to reduce summer irrigation water return flow to tributaries and divert less water from the Sun River. On-farm erosion prevention strategies are also incorporated into the sediment restoration strategy. The following activities should be addressed by BMPs:

- Capturing all or most of the surface irrigation waste water and/or devising a more efficient approach to water delivery on Greenfields Irrigation District.
- Preventing on-farm surface irrigation water runoff from exiting fields or ditches.
- Studying water loss in ditches, prioritize ditch lining using water loss study, and lining ditches in areas that leak the most, especially near the periphery of the Greenfields Bench.
- Using evapotranspiration or soil moisture monitoring for irrigation scheduling.
- Installing head gates that can be fully controlled, if not already in use.
- Using efficient irrigation methods on Greenfields Bench.

- Leaving crop residue on fields by using low/no till methods when possible.

Duck Creek/Big Coulee erosion is severe enough to specifically include in a restoration strategy at this time even though supporting information is pragmatic (Figures 9-22 and 2-23). The state of Montana has received complaints about the erosion in this sub-watershed in the past and pictures of mass erosion are available. The causes of this in-stream erosion are a combination of increased stream energy due to inter-basin irrigation water transfers and riparian management. The exact restoration approaches for this tributary cannot be presented at this time, but should include irrigation water management practices and riparian management. Engineered fixes may be appropriate in entrenched sections of Duck Creek. A more detailed source assessment and project restoration design should be constructed prior to restoration work. Pre and post restoration monitoring should occur to determine the effectiveness of restoration.

9.4.6 Monitoring Strategy

Water Budget Analysis

Discharge monitoring along the Sun River, major diversions, and major tributaries was conducted during the summer and fall of 2004 to determine existing flow conditions in the Sun River watershed. A feasibility analysis of basin-wide irrigation management practices, associated water savings, and the feasibility of applying saved water to in-stream flow should be conducted. The water budget and feasibility analysis could be used in conjunction to solidify how much water can be applied to in-stream uses.

Trend Monitoring

If access allows, permanent cross sections near Simms and Sun River should be established to track stream channel elevation, entrenchment of the stream channel, and percent fines on the streambed. A bank erosion assessment using the same methodologies as those in this document should be conducted along with riparian green line assessments just prior to the next TMDL review.

Biological Monitoring to Determine Use Attainment

Biological monitoring should occur in the upper Sun River above the Highway 287 Bridge, at Simms, and at Sun River prior to the next TMDL review. Biological monitoring should include macroinvertebrate and periphyton sampling and analysis according to MDEQ protocols. Data from this assessment should be available prior to the next TMDL review for the Sun River watershed.

Phased Source Assessment

A phased source assessment should be conducted prior to the next TMDL review. An aerial photo and GIS assessment of Big Coulee/Duck Creek, Adobe Creek, Simms Creek and Mill Coulee should be used to partition these streams into segments with similar attributes. A phased sediment source assessment using the same bank erosion assessment methods as those used on the Sun River main stem should be conducted on these tributaries. A few representative cross sections should be measured on these tributaries to assess Rosgen level 1classification, stream channel stability, width/depth ratios, sheer stress, and entrenchment. This data will then be used to allocate to tributary streams during the next TMDL review as provided for in Montana law.

Restoration Management Tracking

All restoration management projects that fall into categories provided in Section 9.4.5 should be tracked using a Sun River watershed BMP spatial database. Project location, size, type, and restoration results should be attributed.

9.5 Lower Sun River

The lower Sun River's general watershed description is provided in Section 2.8.4. The lower Sun River's water quality standards and use classification are provided in Section 3.0.

9.5.1 Targets and Water Quality Status

Stream gradient from Muddy Creek's confluence to the Missouri River is very low, 0.0003. From the Muddy Creek confluence to the mouth, the Sun River channel alternately exhibits estimated C6 and F6 channel types, denoting excessive silt deposition, slightly to highly entrenched, meandering, gentle gradient channel. The silt deposition in this area is a direct result from excessive sediment loads that have been deposited in the channel originating from Muddy Creek and other upstream tributary sources over the past half century. This reach receives major recharge from surplus water as a result of irrigation practices occurring on the bench lands of Sun River, principally via Muddy Creek. This segment's channel is confined by sedimentary bench land deposits, as well as dikes associated with residential development. The channel characteristics and flow are also influenced increasingly in a downstream direction by backwater effects from Black Eagle Dam, which is located on the Missouri River approximately 1.5 miles below the Sun River confluence. During limited times when the Missouri River stage is high, backwater affects are exerted along most of this stream segment.

Stream Channel and Riparian Indicators

An attempt to collect stream channel cross section and substrate particle size data during the 2004 sampling was unsuccessful using the same methodologies as upstream sites on the Sun River. Deep, muddy substrates were a drowning hazard at a number of locations. Therefore, no channel geometry data exists. The USGS has had to move discharge monitoring stations near Vaughn because of problems associated with shifting and deep fine sediments. The USGS now measures discharge at low flows on a sandstone cross vein near Vaughn on this segment of the Sun River. Estimated cross section data at this bedrock controlled site using stream depth measurements from high flows could be provided, but does not represent all other areas of this stream segment that are not bedrock controlled. This more empirical information of a high volume of fine sediment deposition in itself provides enough support to justify sediment impairment. When sediment prohibits monitoring that could be conducted just a few miles upstream, above Muddy Creek, is there impairment?

Riparian green line vegetation and bank erosion assessments were completed on this segment of the Sun River. At a representative riparian site, half of the bank full area is covered by grasses and herbatious ground cover and the other half is covered by willows or sapling cottonwood that compose an under story. Chrest et al. (1987) measured 11.3% eroding banks in this segment of the Sun River. The 2004 sediment source bank erosion assessment results are described in Section 9.5.2.

Setting stream channel or riparian vegetation condition targets is presently problematic because a specific reference condition for this reach is unknown. A general bank erosion target for less than 10% eroding banks is provided to address eroding bank sources in this segment. More specific targets that relate to stream channel geometry such as W/D ratio, entrenchment, and number and quality of pool habitat should be considered during future TMDL reviews.

Suspended Sediment

Total suspended solids and suspended solids concentration data are available for this segment. Suspended sediment concentrations are variable and extremely dependant upon discharge conditions, human activity, rainfall events, and other weather conditions that can fluctuate by the moment. The available samples constitute a moderate sized data set that can be used to infer about suspended solids variations over time and characterize conditions relatively well. The high magnitude of human caused fine sediment transport in this segment of the Sun River also contributes to an easier interpretation of suspended sediment data.

Ingman et al. (1984) conducted two synoptic TSS sampling events in September of 1980. The limited TSS data from this study suggests that Muddy Creek is the main source of high suspended solid concentrations (Figure 9-29). More recently collected TSS and SSC concentrations from USGS and SRWG monitoring also indicate high concentrations downstream of Muddy Creek's confluence (Figure 9-30). The 75th percentile of suspended sediment data collected on the Sun River above Muddy Creek's confluence near the town of Sun River is 42 mg/L, while at the USGS gauge station near Vaughn, below Muddy Creek, it is about 90 mg/L (Figures 9-26 and 9-30). The 75th percentile of SSC concentrations in Muddy Creek near Vaughn is 327 mg/L during recent monitoring (Figure 9-13). Suspended sediment concentrations in the lower Sun River are not very flow dependant, but are likely more dependant upon discharge rates in Muddy Creek (Figures 9-31 and 9-12).

The suspended sediment problem in the lower Sun River is a matter of loading from bank erosion sources on the Sun River and tributaries. It is thought that the appropriate suspended sediment condition in the lower Sun River should approximate the existing suspended sediment condition just above Muddy Creek, at the town of Sun River. Therefore, suspended solids targets for lower Sun River are based on upstream conditions in the Sun River at the town of Sun River (Table 9-9). The basis for this target is professional judgment, and therefore may need revision during the next TMDL review.

Figure 9-29. Mean TSS Concentrations Below Muddy Creek During Two Sampling Events, September 1980.

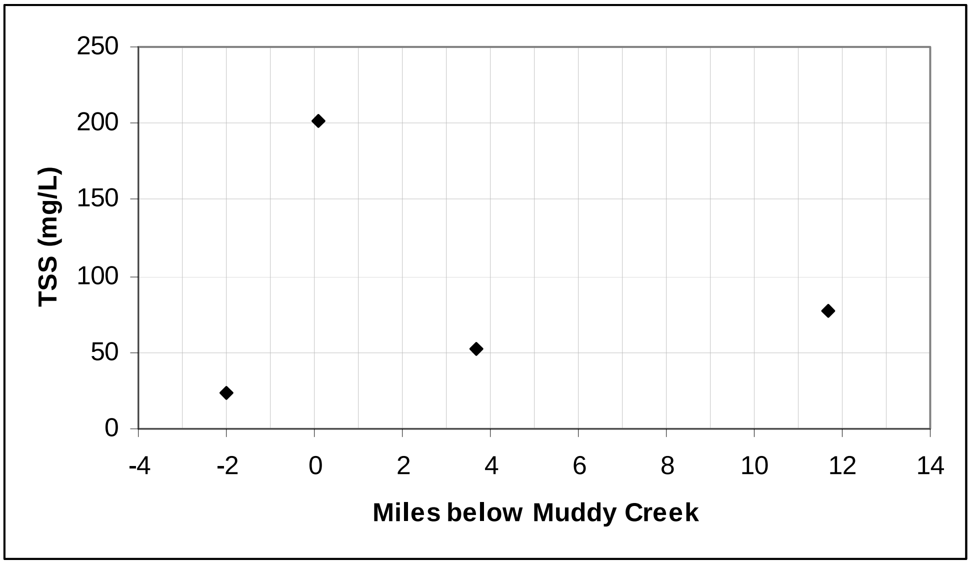


Figure 9-30. Suspended Sediment Concentrations in the Lower Sun River at Ulm Bridge, USGS Gauge, and Great Falls.

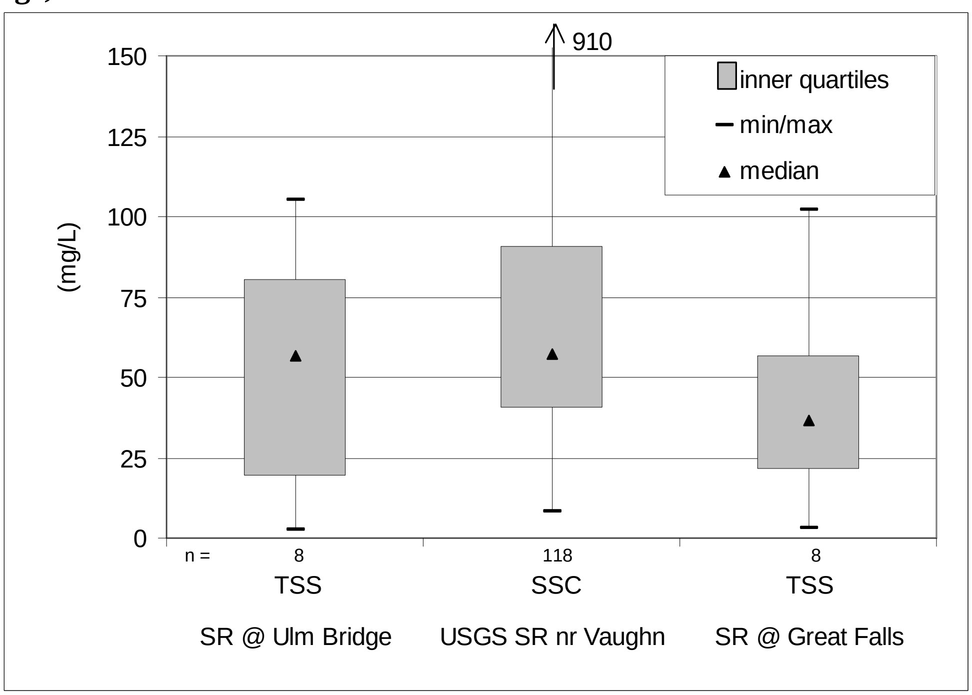
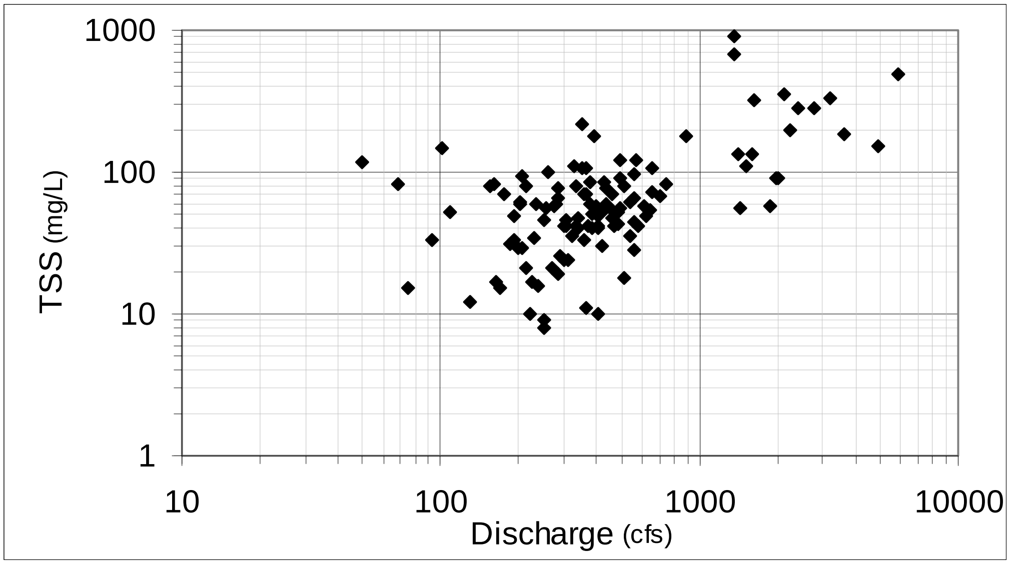


Figure 9-31. Suspended Sediment Concentration and Flow Relationship at Sun River Near Vaughn USGS Gauge.



Biology

The only fisheries data from this reach of the Sun River was collected in 1981 (Table 1-3). Montana FWP has not devoted resources to sampling this section of river since then because of its severely impaired nature and presently low fishery value. The lower Sun River is classified as B-3, which should support a warm water fishery. Depressed fish populations are apparent in this section of the Sun River most likely due to sediment conditions, but cold-water species are present along with warm water species. This section of the Sun River may be misclassified because cold-water fish inhabit this section of river.

Ingman et al. (1984), indicate that sediment production from Muddy Creek reduces benthic algal biomass growth in the Sun River. This study also found that the number of aquatic insects colonizing artificial substrates was lowest just downstream of Muddy Creek. No biological data has been collected in this segment of the Sun River since 1980.

Currently, there is not enough, or the right type of biological information in the lower Sun River to use for target setting. Biological sampling in 1980 did not collect organisms from their habitat, instead it provided habitat for organisms to colonize. These biological results from 1980 indicate impairment but were not monitored in the same way as in other streams in this region and are therefore not comparable to reference data. Also, this stream segment lies within the periphery of a prairie ecoregion but drains mountainous and foothill areas; Because of this, comparable reference areas are not easily identified. Biological monitoring that is comparable to reference stream segment data should be conducted prior to future TMDL review. Biological monitoring is addressed in the lower Sun River’s adaptive management section and TMDL monitoring strategy section (Section 9.4.6).

Table 9-9. Lower Sun River Sediment Targets and Existing Conditions.

Riparian	Stream Channel	Biology	SSC
Targets			
Eroding banks ≤ 10%	Phase channel geometry targets.	Phased biological targets based on reference condition.	75th percentile near Vaughn ≤ 42 mg/L
Existing Conditions			
Eroding Banks = 11.3%	Unable to access representative site for conventional X-section sampling due to deep mud in channel.	Severely impacted due to suspended sediment and siltation in 1980.	75th percentile near Vaughn = 90 mg/L

9.5.2 Sediment Sources

The source assessment does not consider sediment sources above the Gibson Reservoir because the reservoir effectively traps most sediment from above. The conclusions presented in this section have been developed from the best data available at the time this report was prepared. Measured sediment loads from all sediment sources are not available; therefore, estimates were made based on literature values or were developed using various modeling techniques. Further, detailed, on-the-ground assessments have not been conducted in the entire watershed. As a result, interpolation was required and assumptions were made regarding conditions that were not directly observed by using data from representative areas. However, it is felt that the information contained in the following subsections allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories. Uncertainties are discussed in greater detail in the *source summary* subsection and *other sources* subsection below.

Individual assessments were conducted to compare the most significant sources in the Sun River watershed. Current agricultural, hydromodification, natural and historic sources that affect bank stability were assessed through a stream bank erosion sediment load assessment in the upper Sun River, Muddy Creek and immediate lower Sun River watershed watersheds. Sediment from roads were considered by extrapolating loads derived from the Water Erosion Prediction Project (WEPP) model in Ford Creek to the upper Sun River, Muddy Creek and immediate lower Sun River watersheds. Background upland erosion was estimated using a soil creep erosion estimate for each of these watershed areas. See Section 9.2.2 for methodology of each of these assessments.

Bank Erosion

A bank erosion estimate for Muddy Creek was not necessary for Muddy Creek’s sediment TMDL because Muddy Creek’s TMDL is performance based for flow management. A bank erosion estimate for Muddy Creek that is comparable to the upper Sun River bank erosion assessment is necessary for comparing these two source areas. Muddy Creek was broken into two segments for the bank erosion sediment assessment. One stream reach is located between Gordon Road and the confluence with the Sun River where stream bank erosion is extreme. The other reach is above Gordon Road where stream bank erosion is less severe. Muddy Creek’s average eroding bank height, length, severity and causes are estimated using professional judgment based on pictures, cross sectional data, and first hand knowledge of the area, instead of actual measurements such as were conducted on the Sun River and Ford Creek. These estimates were used to model sediment production in Muddy Creek in the same manner as actual measurements were on the Sun River and Ford Creek (Section 9.2.2). Muddy Creek bank erosion assessment results are compared to the upper Sun River for relative sediment contribution for the TMDL but should be refined using actual stream bank measurements in the future (Table 9-10, Column C).

A representative 1,000-foot section of the lower Sun River was assessed by a bank erosion inventory conducted in September, 2004. The data collected from the bank erosion assessment was then extrapolated to the whole segment by dividing the length of the segment in feet by 1,000 and multiplying the results by the load derived in the representative section. See Section 9.2.2, subsection *bank erosion,* for a detailed description of the bank erosion source load estimate methodology.

Background Erosion

The background erosion estimates for the lower Sun River and Muddy Creek (for comparison to the upper Sun River) uses an approach based on soil creep rates. This methodology was used along with other background erosion estimates in the Upper Lolo TMDL document. The soil creep equation is:

Annual Erosion Volume (m^3/yr) = L (m)* 2 * D (m) *C (m/yr)

Where: L = Length of stream network in meters
D = Depth of soil in meters
C = Annual creep rate in meters

This approach to estimating background erosion estimates is identified in *Standard Methodology for Conducting Watershed Analysis* (Washington Forest Practice Board, 1997). If no local data exists, methodology recommends a creep rate of 0.001 meters per year if average watershed slopes are less than 30%, as they are in Muddy Creek and the lower Sun River. The most recent national hydrography dataset (NHD) stream layer is used for calculating stream length in a GIS framework. The NHD stream layer and is built from 1:24,000 USGS hydrography mapping. The length of the lower Sun River and tributary stream channels from Muddy Creek to the confluence with the Missouri River is calculated at 261,647 meters. The length of Muddy Creek and tributaries is calculated at 1,370,000 meters. An average soil depth was estimated at one meter for both watersheds. The average annual upland erosion estimates for Muddy Creek and the lower Sun River are 4,822 and 921 tons/year respectively.

Roads

Professional judgment indicates that sediment loading from roads is not a significant impact in the Sun River watershed. A very coarse road sediment loading assessment was conducted to back professional judgment. Road related sediment yields were grossly estimated by comparing the Muddy Creek and lower Sun River watershed's road networks to Ford Creek watershed road network and extrapolating sediment yield. The upper Sun River's road assessment was presented in Section 9.4.2. The length of roads within 300 feet were calculated using US Census data and the most recent version of the national hydrography dataset (NHD) in a GIS framework. Muddy Creek's and lower Sun River's sediment loads from roads were derived by dividing the length of road in the each watershed by the length of road in Ford Creek's watershed and multiplying by the sediment load associated with roads in Ford Creek's watershed. The same assumptions are made for Muddy Creek's and the lower Sun River's road assessments as are made for the upper Sun River road sediment source assessment in Section 9.4.2. Results are reported in Column F of Table 9-10.

Suspended Sediments

MDEQ suspended sediment concentration load estimates are used for SSC load comparison of the upper Sun River at Simms to Muddy Creek at Vaughn. MDEQ used a regression of discharge to SSC concentration and then calculated the average discharge for each month of the year during 1996-2000 timeframe (Table 9-10, Column B). The average monthly discharges from this timeframe were then applied to the regression equation to derive an average sediment yield for each month of the year. USGS estimates of SSC load were available at Vaughn in an unpublished format. MDEQ and USGS load assessments used different methodology. There was a 33% difference between USGS and MDEQ estimates at the Muddy Creek at Vaughn site. The MDEQ estimate was higher than the USGS estimate.

Point Sources

Vaughn and Sun Prairie Village, the only POTW point sources in the Sun River watershed, contribute 0.013% of the MDEQ estimated sediment load combined from Muddy Creek and the upper Sun River in Column B of Table 9-10. The sediment load from Muddy Creek and upper Sun River combined is used as a surrogate comparison to a watershed outlet load. The point sources are not significant.

A review of SSC loading, bank erosion, upland background, point source, and roads sediment source assessment results for the upper Sun River, Muddy Creek, and the immediate lower Sun River areas are provided in Table 9-10. The results are reviewed in the sediment source summary section below.

Table 9-10. Lower Sun River Sediment Source Assessment (Tons Per Year).

A Source Area (size)	B SSC Load Estimated From In-stream Monitoring	C Main Stem Bank Erosion	D Upland Back-ground	E Point Sources (TSS)	F Roads	G Total of columns d, e, f, g
Upper Sun River	15,335^	Hydromodification – 20,867 Riparian Agricultural – 8,943 Natural – 7,742 Historic – 367 **Total**: 37,919	14,901	6.6	193	53,020 (52%)
Muddy Creek	35,326* 47,091^	Hydromodification – 28,977 Riparian Agricultural – 3,585 Natural – 3,585 **Total**: 36,147	4,822	none	177	41,146 (41%)
Lower Sun River	ID	Riparian Agricultural – 3,107 Natural – 3,107 **Total**: 6,214	921	2.0	34	7,171 (7%)

*USGS unpublished estimated load 1997-2001
^MDEQ estimated load 1996-2000
ID = Insufficient Data

Other Sources

Bank erosion in tributaries to the upper Sun River, Muddy Creek, and the lower Sun River were not assessed in the source analysis. This source could be significant given the mass wasting found in Duck Creek (Figures 9-22 and 2-23). Significant tributaries will be identified for further bank stability source assessment monitoring in the sediment TMDL monitoring strategy. For the current source assessment, it is assumed that the same sources of sediment are influencing sediment production in the tributaries by the same portions as the main stem of the upper Sun River.

Other sediment sources in the watershed exist but, based on professional judgment, are considered to be insignificant. Although there have been fires above the Gibson Dam, recent fires have not burned significant areas in the Sun River watershed below the dam. Only a few small towns are located in the upper Sun River and Muddy Creek watersheds therefore urban sources are not considered except as point sources in these areas. The Great Falls urban area encompasses the extreme lower end of the Sun River watershed and should be considered in future TMDL reviews but is not thought to be a significant source at this time. Industrial storm water and agricultural CAFO MPDES permitted facilities are not thought to be a significant source of sediment based on infrequency of runoff from these sources and very limited data from a number of the permits.

Source Summary

When comparing the individual sediment source modeling studies to each other for an overall sediment yield and source assessment, caution should be used. Different models and erosion assessments can provide various estimates of sediment yields for the same source. However, the information contained in Table 9-10 allows reasonable comparisons to be made regarding the relative contributions of sediment from each of the various source categories.

According to the modeled source assessments, about 43% of the sediment yield in the watershed originates from natural upland and natural bank erosion sources when combined. When combined, historic sources of bank erosion, POTWs, and roads, contribute less than 1.5% of the total assessed load. These sources are not significant contributors to the sediment load. When combined, bank erosion on the Sun River and Muddy Creek due to current agricultural activities and hydromodifcation contribute an estimated 16.9% and 39.4% of the sediment loads respectively. The allocation process in Section 9.5.3 will call for reductions from these two source categories.

Actual water quality monitoring of SSC loads support that the modeling source studies are reliable. SSC loads do not consider all sediment loads, only the portion of sediment load that is small enough to be moved in the water column. The portion of sediment that moves along the stream bottom is not considered by the SSC load assessment. SSC loads can be used as an indicator of sediment trends or used for source assessment. Existing in-stream loads were calculated because data was already available and the analysis is used to identify sediment source areas. Based upon MDEQ SSC load estimates at Sun River near Simms and Muddy Creek at Vaughn, the upper Sun River contributes about 25% of the sediment yield to the lower Sun River, and Muddy Creek contributes about 75% of the yield. A problem in this source assessment scenario exists; tributaries between Simms and Muddy Creek's confluence are not assessed. These tributaries are Big Coulee, Adobe Creek, and Mill Coulee. When combined, these tributaries are likely significant contributors of suspended sediments in the Sun River watershed. Big Coulee is likely a significant sediment source in itself (Figures 9-22 and 9-23). Further monitoring should quantify sediment loads from these tributaries (Section 9.4.6).

Empirical evidence, an aerial photo of Muddy Creek's confluence with the Sun River, supports the SSC load assessment data reported in Table 9-10 which indicates Muddy Creek is the most influential source of suspended sediment to the lower Sun River (Figure 9-32).

Figure 9-32. Muddy Creek Confluence with the Sun River, Flight Date 8/9/95.

Note the difference in turbidity between Muddy Creek and Sun River

Evaluation of sediment production estimates from the bank erosion, upland sediment, point sources, and roads reveals that the upper Sun River, Muddy Creek, and the lower Sun River contribute 52%, 41% and 4% of the estimated loads respectively (Table 9-10). The estimate methods are very coarse, use different methodologies, and are meant to be used for general comparisons. The modeling of these sources in the upper Sun River, Muddy Creek, and the lower Sun River areas indicates that 60%, 80% and 43% of the respective loads in each area are likely human caused.

9.5.3. Load Limit and Allocation

A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

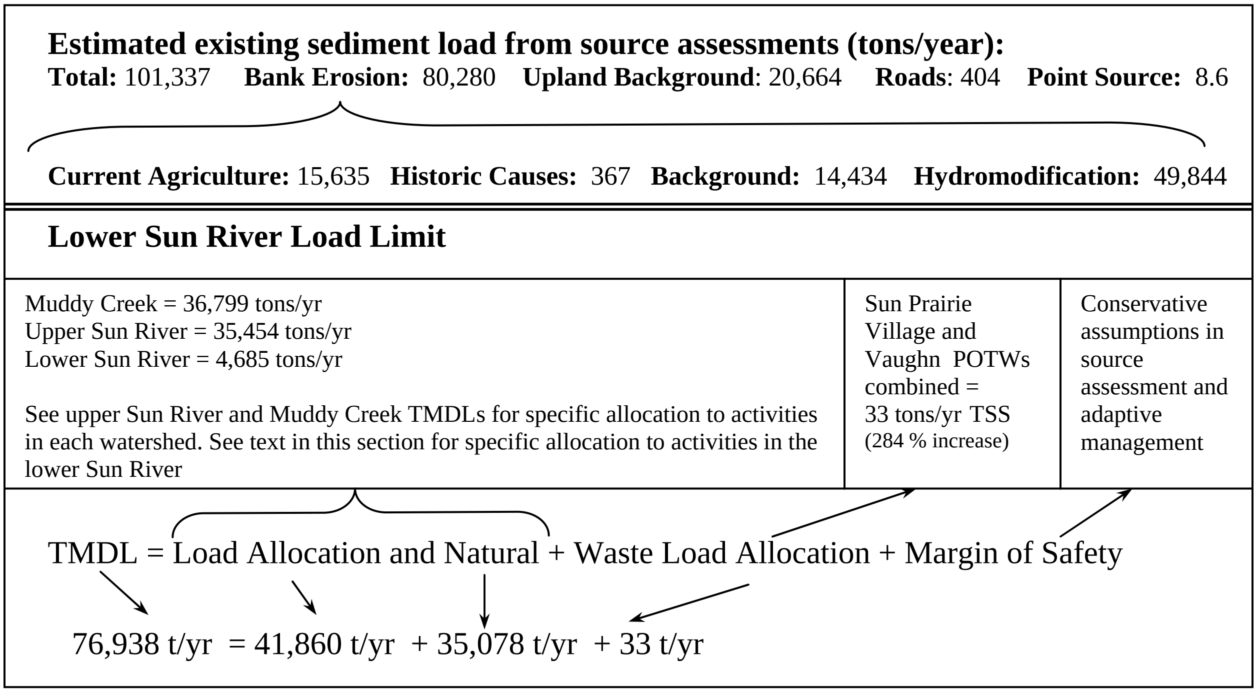
TMDL = WLAs + LAs + Natural + MOS

Total sediment loads based on the different source assessments (road, upland erosion, bank erosion, and point source TSS loading) will be used to represent an allocation for the whole Sun River watershed. Based on modeling the use of reasonable irrigation water management practices, estimated loads from Muddy Creek can be reduced by 15% (Section 9.3.4). If the 15% reduction is applied only to the estimated total sediment load from the bank erosion on Muddy Creek due to hydromodification, it equates to a total allocation of 36,799 tons of sediment per year to all of Muddy Creek's sediment sources. Implementing irrigation and grazing management BMPs along with setting a permit limit for the POTWs at the non-degradation criteria is estimated to reduce 33% of total sediment loading from the upper Sun River (Figure 9-28). This equates to an allocation of 35,454 tons/year to the upper Sun River sediment sources (Figures 9-28, 9-33).

The source assessment for the immediate lower Sun River identified riparian agricultural impacts as the most significant human caused source of sediment load. It is estimated, based on professional judgment, that if grazing and crop practices identified in the restoration strategy are implemented, loads from riparian agricultural impacts can be reduced by 80 percent. Loads from eroding banks due to existing grazing activities could be reduced to an estimated 621 tons/year. Other sources that were assessed in this segment are either natural or insignificant. The total allocation to all natural and human caused immediate sediment sources on the lower Sun River will be 4,685 tons/year. The overall allocation assesses a 35% reduction in loading from immediate sources in the lower Sun River (Figure 9-33).

A phased allocation approach will be used to assess sediment sources in significant tributaries throughout the Sun River watershed and provide allocations to these areas. This can be accomplished by implementing the monitoring strategy in Section 9.4.6. The tributary sources can then be addressed by future TMDL reviews as provided for in Montana law. The TMDL and allocation strategy in Figure 9-33 does not consider bank erosion sources on tributaries to the Sun River or Muddy Creek.

Figure 9-33. Sun River Estimated Existing Loads, TMDL, Allocation, and Margin of Safety.



9.5.4. Margin of Safety, Adaptive Management, and Seasonal Variation

Although some of the source assessment techniques are based on methods that provide gross estimates, they used assumptions that would tend toward protecting natural resources when uncertainties were encountered. See Section 9.2.5 for specific examples.

A margin of safety for this TMDL is provided in an adaptive management approach. The uncertainty of the Sun River sediment TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 9.5.6 to aid in future TMDL review and the phased allocation for tributary bank erosion. Identified conservation practices in Section 9.5.5 should be tracked over time to see if implementation occurs. If implementation occurs and does not achieve targets or load allocations in the Watershed, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil and water conservation practices are in place, targets, TMDL and allocations may have to be revised.

9.5.5. Restoration Strategy

Loading from upstream is the most major source of sediment on this segment of the Sun River. See Muddy Creek and upper Sun River restoration sections for specific restoration approaches that relate to each source area (Sections 9.3.5 and 9.4.5). Upstream restoration activities in Muddy Creek and the upper Sun River are crucial to restoring uses in the lower Sun River. The source assessment indicates that most of the sediment sources are upstream. Channel geometry may not be in a stable form in sections of the lower Sun River, but it is likely that this is caused by upstream sediment loads and low stream energy caused by both naturally low gradient and backwater effects from damming the Missouri River near Great Falls. Grazing management and buffer enhancement are the only restoration goals presented for the lower Sun River segment at this time.

Grazing Management

Application of grazing management tools can reduce sediment loads from bank erosion sources. Grazing management practices that may help to avoid acceleration of stream bank erosion on the upper Sun River and tributaries are:

- Using riparian browse and grazing indictors to manage riparian grazing pressure.
- Timing grazing to coincide with dry or freezing weather to reduce erosion.
- Timing pasture use to promote grazing, not browse.
- Placing supplemental feed or salt in upland areas to promote even grazing in pastures.
- If needed, fencing riparian areas and providing water gaps.
- Employing weed control.

Riparian Buffer Zones

Allowing a riparian buffer between the river and agricultural fields will allow riparian vegetation with better soil binding properties to grow. The riparian species root mass will protect banks better than shallow rooted field grasses.

9.5.6. Monitoring Strategy

Trend Monitoring

SSC and associated discharge monitoring should continue at the Sun River near Vaughn site. Sites closer to the confluence with the Missouri River are problematic because discharge monitoring is costly or dangerous on this section of the Sun River because of deposited sediments. Also, backwater effects that would obscure discharge monitoring results occur in the lower portions of this segment due to Rainbow Dam on the Missouri River. This data will be used during future TMDL review for determining watershed loads and assessing trends in SSC loading over time.

Biological and Physical Monitoring to Determine Use Attainment

Biological monitoring should occur near the USGS gauge station at Vaughn prior to the next TMDL review. Biological monitoring should include macroinvertebrate and periphyton sampling and analysis according to MDEQ protocols. Data from this assessment should be available prior to the next TMDL review for the Sun River Watershed. These data will then be used to determine use attainment during the next TMDL review as provided for in Montana law.

A stream channel cross section should be measured at a representative site on this section of the Sun River prior to the next TMDL review. Data will be used to solidify Rosgen level 1 classification and assess stream channel stability, width/depth ratios, sheer stress, channel gradient, and entrenchment. This data will then be used to identify stream channel restoration potential during TMDL review and may provide data useful for target revisions. This monitoring may prove to be difficult because of sediment conditions.

Phased Source Assessment of Tributaries

A phased source assessment should be conducted prior to the next lower Sun River TMDL review. An aerial photo and GIS assessment of Big Coulee/Duck Creek, Adobe Creek, and Mill Coulee should be used to partition these streams into segments with similar attributes. A phased sediment source assessment using the same bank erosion assessment methods as those used on the Sun River main stem should be conducted on these tributaries. A few representative cross sections should be measured on these tributaries to assess Rosgen level 1classification, stream channel stability, width/depth ratios, sheer stress, and entrenchment. This data will then be used to allocate to tributary streams during the next TMDL review as provided for in Montana law.

TSS data is being collected by a combined effort of MDEQ and SRWG near the mouth of these tributaries (Figure 9-21). This monitoring should continue. Associated discharge measurements are essential when collecting the TSS samples to determine TSS loads derived from these tributaries.

Restoration Management Tracking

All restoration management projects that fall into categories provided in Sections 9.3.5, 9.4.5 and 9.5.5 should be tracked using a Sun River Watershed BMP spatial database. Project location, size, type, and restoration results should be attributed.

9.6 Sediment Water Quality Restoration Strategy and Monitoring Summary for the Sun River TPA

This section of the sediment section compiles a restoration strategy for the entire Sun River watershed and should be used for prioritizing restoration work when possible. Restoration opportunities may be driven by landowners’ willingness to work with local watershed groups and government agencies that provide environmental funding incentives or cost share. Groups or agencies that work with landowners should use this section as guidance for where restoration funds will provide the most benefit to restoring water quality. This section also provides a prioritized list of restoration practices and associated areas that should be implemented to help restore water quality impairment related to sediments and stream channel geometry.

9.6.1 Sun River Sediment Restoration Plan

The following is a prioritized list of restoration actions and locations that should be followed if landowner and agency participation permits.

1. Identify where surface water irrigation waste originates on the Greenfields Bench. Reduce surface irrigation water waste from Greenfields Irrigation District that enters Muddy Creek.
2. Complete a feasibility study to reduce surface irrigation water waste entering Big Creek/Duck Coulee, reduce sheer stress in incised sections, and prevent further degradation. Follow remedies identified in the feasibility study.
3. Stabilize flows in the upper Sun River to promote hydrophilic riparian vegetation growth on eroding banks in the section of the Sun River between Augusta and the town of Sun River. This is a relatively simple statement with a very complex and potentially confrontational solution. A feasibility study should be completed before embracing this task. In general, this would include irrigation water management (IWM) in all irrigation delivery systems that take water from the segment of river between Gibson Dam and Muddy Creek. Water savings could also come from on farm IWM BMPs that will save water. The only way to achieve this goal is to use the saved water to manage in-stream flows that would provide higher water levels during the critical summer growing season. The 2004 field crew identified that water level fluctuations are causing bare banks in many areas because low summer flows do not allow for water loving plants that have binding roots to grow at an appropriate level on the bank that protects against bank erosion during average spring discharge.
4. Apply riparian grazing management practices and cropping practices that will promote more hydrophilic plant growth in riparian areas along Muddy Creek, upper Sun River, upper Sun River tributaries, and the lower Sun River.

See the sediment restoration sections of each waterbody for restoration approaches to irrigation water management, riparian grazing, and stream buffer management (Sections 9.3.5, 9.4.5, and 9.5.5).

9.6.2 Sun River Watershed Sediment Monitoring Plan

9.6.2.1 Monitoring for Phased Approaches

This monitoring is strongly encouraged for comparing existing conditions to targets and providing a stronger source assessment.

1. *Ford Creek phased targets for residual pool volume and percent fines* – Residual pool volume and percent fine data should be collected for the impaired segment and a reference area for the Ford Creek TMDL review.
2. *Upper Sun River phased tributary source assessment* - A phased source assessment should be conducted prior to the next TMDL review. An aerial photo and GIS assessment of Big Coulee/Duck Creek, Adobe Creek, and Mill Coulee should be used to partition these streams into segments with similar attributes. A phased sediment source assessment using the same bank erosion assessment methods as those used on the Sun River main stem should be conducted on these tributaries. A few representative cross sections should be measured on these tributaries to assess Rosgen level 1classification, stream channel stability, width/depth ratios, sheer stress, and entrenchment. This data will then be used to allocate to tributary streams during the next TMDL review as provided for in Montana

law. TSS data is being collected by a combined effort of MDEQ and SRWG near the mouth of these tributaries (Figure 9-21). This monitoring should continue. Associated discharge measurements are essential when collecting the TSS samples to determine TSS loads derived from these tributaries.

3. *Lower Sun River Source Assessment and Target Revision* – Data for stream channel and biological target setting should be collected for the TMDL review. Biological monitoring should occur near the USGS gauge station at Vaughn prior to the next TMDL review. Biological monitoring should include macroinvertebrate and periphyton sampling and analysis according to MDEQ protocols. Data from this assessment should be available prior to the next TMDL review for the Sun River watershed. These data will then be used to determine use attainment during the next TMDL review as provided for in Montana law. A stream channel cross section should be measured at a representative site on this section of the Sun River prior to the next TMDL review. Data will be used to solidify Rosgen level 1classification and assess stream channel stability, width/depth ratios, sheer stress, channel gradient, and entrenchment. This data will then be used to identify stream channel restoration potential during TMDL review and may provide data useful for target revisions. This monitoring may prove to be difficult because of sediment conditions. The phased tributary assessment for the upper Sun River also applies to defining loading to the lower Sun River.

9.6.2.2 Monitoring for Future TMDL Reviews

This monitoring should occur in conjunction with the next TMDL review for the Sun River watershed. This monitoring will provide minimal trend information and restoration implementation tracking.

1. *Ford Creek* – Two permanent cross sections on the impaired segment would provide entrenchment ratio and streambed elevation trends. Riparian green line transects and bank erosion inventory that are comparable to the assessments conducted for the TMDL source assessment will provide a comparison to 2004 data. This monitoring should occur every other TMDL review because target conditions will change very slowly over time. It is not envisioned that targets will be attained in a short timeframe, less than 30 years, even with good riparian stewardship.
2. *Muddy Creek* – Permanent cross sections on Muddy Creek should be established to track stream channel elevation, entrenchment of the stream channel, and parameters necessary for determining Rosgen level 2 stream channel type. Riparian green line transects should be conducted that can determine the percentage of riparian plant size (bare ground, ground cover, mid-story, canopy) and type (tree, shrub, grass/forb). Data should be collected to estimate sheer stress near cross sections. Riparian green line transects and bank erosion inventory that are comparable to the assessments conducted for the TMDL source assessment on the Sun River will refine sediment source loads. USGS SSC monitoring should continue at both Gordon Road and at Vaughn. Suspended solid load estimates analysis for both sites should continue.
3. *Upper Sun River* – Permanent cross sections near Simms and Sun River should be established to track stream channel elevation, entrenchment of the stream channel, and percent fines on the streambed. A bank erosion assessment using the same methodologies

as those in this document should be conducted along with riparian green line assessments just prior to the next TMDL review. Biological monitoring should occur in the upper Sun River above the Highway 287 Bridge, at Simms, and at Sun River prior to the next TMDL review. Biological monitoring should include macroinvertebrate and periphyton sampling and analysis according to DEQ protocols. Data from this assessment should be available prior to the next TMDL review for the Sun River watershed.

4. *Lower Sun River* – Urban sources should be assessed further for future TMDL reviews. All riparian restoration and irrigation water management projects should be tracked using a Sun River watershed BMP spatial database. Project location, size, type, and restoration results should be attributed.

SECTION 10.0 TEMPERATURE

This section of the Sun River Water Quality Restoration Plan focuses on thermal related pollutant listings and sources of heat. Table 10-1 provides a list of those waterbodies within the Sun River TPA that appear on either the 1996 or 2002 303(d) list for temperature related pollutants. Both pollution and the resulting thermal pollutant listings are addressed by TMDLs in this section. Temperature related water quality standards are reviewed in Section 3.2.2.

Table 10-1. Waterbodies Listed for Thermal Related Pollutants in the Sun River Watershed.

Water Quality Limited Segment	1996 303(d) List	2002 303(d) List
Upper Sun River (from Gibson Dam to Muddy Creek Confluence)	Thermal Modification	Thermal Modification
Lower Sun River (Muddy Creek Confluence to mouth)	Thermal Modification	No thermal related pollutant listing during 2002
Muddy Creek	Thermal Modification	No causes listed because of use classification

High water temperatures can impact fisheries and associated aquatic life uses in Montana. Although all energy comes from the sun, there are two major source categories of thermal energy that affect stream temperature. The first is direct solar radiation and the second is latent energy dissipating from warmed soils, air or other heat sources. Climate, elevation, flow volume, stream channel geometry, stream shading, riparian function, and ground water affect water temperature. Therefore, critical factors that can be influenced by human activity relate to the amount of area exposed to latent thermal sources and solar energy and also relate the volume of water present to adsorb the energy.

The remainder of this section presents all of the required temperature TMDL elements for each of the above listed waterbodies, one waterbody at a time. In the case of the lower Sun River, the impairment status review indicates that a TMDL is not needed at this time.

10.1 Upper Sun River

A generalized watershed description for the Sun River can be found in Section 2.8.4. The upper Sun River's water quality standards and use classification are provided in Section 3.0.

10.1.1 Targets and Thermal Water Quality Status

This section reviews water temperature, stream channel, riparian condition, biological, and flow conditions that relate to thermal conditions on the upper Sun River.

10.1.1.1 Targets

An EPA and several independent studies show that salmonids need cool water to survive and compete with other fish (USEPA, 1976; Coutant, 1977; Cherry et al., 1977; Bell, 1986; Lee and Rinne, 1980). These laboratory studies indicate some approximate conditions that salmonids are influenced by increased water temperatures. Increased water temperature can affect fish reproduction, susceptibility to disease, metabolism, and feeding habits. Warmer water temperatures can lead to a shift in fish species from cold-water to warm-water fish. Increases in water temperature are not normally lethal to fish because they can usually avoid areas of warmer water by migrating to areas of thermal refuge. However, prolonged periods of extremely warm water temperatures without any cold-water refuge can be fatal.

USDI, 1998 equated specific in-stream threshold temperature values to the success of various life stages of cold-water fish. These primary life stages are spawning, incubation, rearing, and migration. In the Sun River TPA, it is believed that spawning and incubation temperatures are not limiting cold-water fish. Instead, warm mid-summer temperatures may be influencing migration, adult survival, or rearing. Existing in-stream data in the Sun River TPA has shown that spring and fall temperatures routinely drop due to day length and natural weather conditions. Therefore the focus of this WQRP and the in-stream temperature targets is on mid-summer maximum temperatures.

Montana Administrative Rules state that “the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67º Fahrenheit) is 1° (F) and the rate of change cannot exceed 2° F per hour. If the natural occurring temperature is greater than 67º F, the maximum allowable increase is 0.5º F” (ARM 17.30.623(e)) for a B-1 classification. Use of this narrative standard is the preferred route to use as the primary temperature targets for the Sun River. The only way to interpret this standard is to compare the impaired streams to appropriate reference streams.

An attempt was made to identify a suitable reference stream with which to assess “naturally occurring temperatures” in the Sun River Watershed so that the temperature standards could be more directly applied. Ambient data from the Sun River could be compared with those from other streams of similar size near the Sun River, including the Dearborn River, Teton River, Marias River, Smith River, and Little Prickly Pear Creek. However, all of these regional, similar sized streams have been listed on a 303(d) list (the 1996 or 2002 303(d) list or both) for thermal modifications, and are therefore not considered appropriate as reference streams for the Sun River. No other appropriate reference streams were identified.

Reference temperature conditions were modeled. The modeling methods and results are provided in the source assessment Section 10.1.2.2. The modeling indicates that the state water quality temperature standards are exceeded on at least a portion of the upper Sun River.

In addition to a modeled reference condition to use for comparing to the temperature standards, four other supplemental targets are used that are based upon literature values of thermal criteria that protect a cold-water fishery. One of these surrogate targets is based on protecting riparian vegetation to promote shading. The targets provided for indication of temperature impairment are: riparian shade, absolute maximum temperature, maximum daily temperatures, and weekly average temperature.

Reference condition for riparian shade target was investigated during 2004 monitoring. The only area on the impaired segments where increased shading potential was found was on the Sun River from Highway 287 Bridge to Muddy Creek's confluence. The target for riparian shade only applies to this reach of the Sun River, is based on a reference site in this area, and is set at 22% shade.

Thermal requirements specific to westslope cutthroat trout were investigated because they inhabit the Sun River headwaters above Gibson Dam and are temperature sensitive and a species of concern. As reported by McMahon et al. (2004), the thermal requirements of westslope cutthroat trout are largely unknown. In addition, increased water temperature is thought to favor non-natives in many cases, yet the affect of temperature on competition between westslope cutthroat trout and non-natives in unknown. Also, hybridization between westslope cutthroat trout and non-native rainbow trout has resulted in a decline in populations of genetically pure westsopes. McMahon et al. (2004) conducted laboratory tests to assess the thermal requirements of hybrids, as well as how competitive interaction between hybrids, genetically pure westslope cutthroat trout, and non-natives is influenced by water temperature. The tests were conducted over 60 days and used the acclimated chronic exposure method to assess upper thermal limits and growth optima during 60-day trials. Preliminary results suggest upper limit for survival of westslope cutthroat trout is near 69.8 F, whereas peak growth occurred around 53.6 F.

A number of reasons contribute to not using targets that relate to the McMahon et al. (2004) research for the Sun River TPA at this time. The results of the study are preliminary. Cutthroat trout are not found in this segment of the Sun River. Also, MFWP is not managing the Sun River below Gibson Reservoir for cutthroat trout populations. The McMahon et al. (2004) optimal growth criterion was compared to temperature data in the upper Sun River (Column K, Table 10-2). The differences between the criterion and existing conditions are quite large. Professional judgment indicates that targets relating to optimal growth of this species may not be achievable in the upper Sun River even when all reasonable land, soil, and water conservation practices are in place. This criterion may be appropriate if temperature conditions greatly improve due to restoration activities identified in this document, and will be considered as an added target during future TMDL reviews that are mandated by State law.

The following temperature targets are based on MFWPs' Drought Fishing Closure Policy, Bell (1986), Cherry et al. (1977), and Lee and Rinne (1980):

- Daily maximum water temperature should not exceed 73 ºF for at least some period of time during 3 consecutive days. (MFWP)
- Average temperatures over any 7-day period should not exceed 66 ºF. (Bell, 1986; Cherry et al., 1977)
- Temperatures should not exceed 75 ºF. (Lee and Rinne, 1980)

These targets are justified below.

Among the objectives of MFWP's Drought Fishing Closure Policy is to "protect long-term health of aquatic systems from impacts of severe drought, especially waters supporting species of special concern and to "provide consistency in decisions across the state" (MFWP, 2004). The policy specifies that exceedance of threshold levels for salmonids and for bull trout will initiate a discussion for appropriate action to protect the fisheries. The MFWP thresholds for salmonids are the following:

- Flows are at the 95 percent monthly exceedence level (1-in-20-year low flows); or
- Daily maximum water temperature reaches or exceeds 73 ºF (23 degrees Celsius [ºC]) for at least some period of time during 3 consecutive days.

The temperature related MFWP threshold is used as a target.

The other two temperature targets are based on studies that investigated temperature tolerance of rainbow trout (Lee and Rinne, 1980; Bell, 1986; Cherry et al., 1977). Sixty-six degrees is a range of temperatures for optimal growth and 75 ºF is the lowest temperature found to induce mortality to rainbow trout. A maximum weekly average of 66 ºF is used to sustain long term health and survival and the absolute maximum temperature of 75 ºF is used to protect against mortality.

It is unknown if the temperature targets based on literature values can be achieved by applying reasonable land, soil, and water conservation practices. Therefore, an adaptive management approach to meeting these targets is provided (Section 10.1.4.3). Restoration and monitoring should occur in tandem to determine if these targets are achievable.

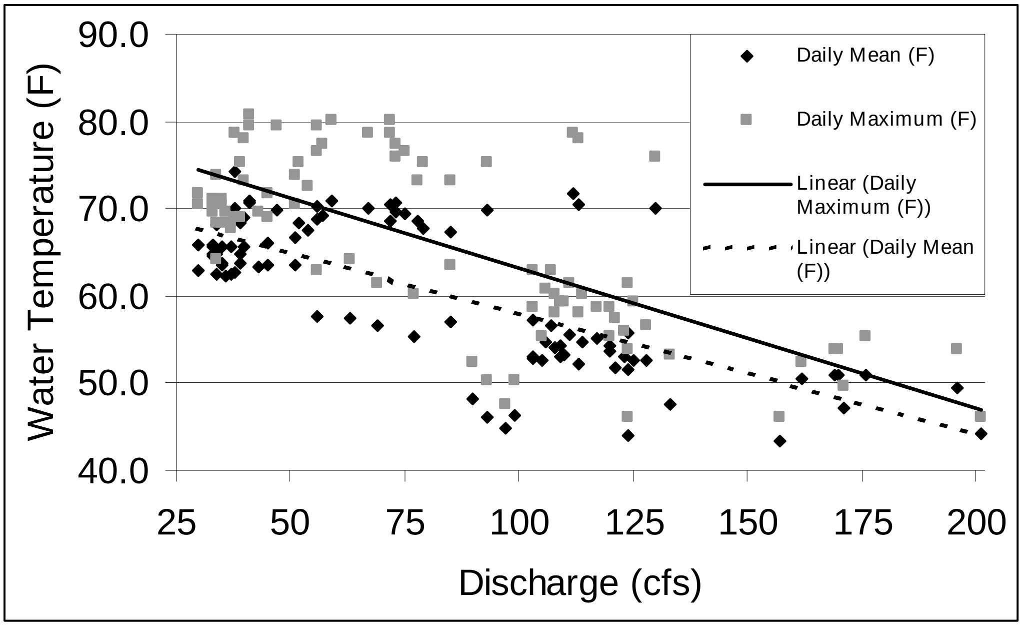
10.1.1.2 Supplemental Indicators

Supplemental indicators are to be used along with targets to provide a weight of evidence approach to determining impairment. Supplemental indicators do not in them selves stipulate that temperature impairment exists, but they do provide evidence that a healthy setting exists to support aquatic life. Therefore, they should be used in conjunction with targets to provide a holistic assessment of impairment.

In-stream Flow

Supplemental indicators are provided for in-stream discharge conditions. The in-stream discharge supplemental indicators are based on FWP wetted perimeter analysis described in Section 4.2. Increasing water volume in the stream increases the streams buffering capacity to assimilate heat. These flows are not directly calculated by using the relationship between in-stream temperatures and discharge rates. Therefore, these minimum discharge rates are provided as supplemental indicators, not targets. The in-stream flow indicators during drought conditions are 100 cfs above Elk Creek and 130 cfs below Elk Creek as absolute minimum flows. A recommended flow of 220 cfs along the whole upper Sun River is suggested by FWP during non-drought conditions. A limited analysis of discharge vs. in-stream temperature indicates that these flow conditions may inadvertently achieve a temperature condition that will support a viable salmonid fishery (Figure 10-1). This indicator is used for all TMDLs on the upper Sun River.

Figure 10-1. Temperature vs. Mean Daily Flow Graphs Comparing Flow to Water Temperature Near Simms from 21 July – 20 October 2003.



*data and analysis from MFWP

Fish Population

The fish population on the upper Sun River is severely depressed when compared to reference streams in the area. At this time, fish populations in the Sun River are depressed to the point where quantitative data is often difficult to obtain. Fish population density in the two unimpacted forks of the Sun River upstream from Gibson Reservoir provide a good reference for the potential in the main stem Sun River. Based on long term average trout populations in the two forks above the reservoir, trout densities of around 600 per mile should be achievable in the upper Sun River downstream of Gibson Dam. Optimal condition could be 600 per mile, but realistically values similar to the long-term average of trout populations in the Deep Creek Section of the Smith River (420 per mile) may be more achievable and would likely produce a suitable fishery. Thus, a value of 66% (400/mile) of the population levels in the N & S Forks Sun will be used as a supplimental indicator of impairment that may be revised during subsequent TMDL reviews. Salmonid populations in the upper Sun River are nowhere near reference level (Tables 2-4 and 2-5). This indicator is used for all TMDLs on the upper Sun River. The fishery supplemental indicator analysis is provided by MFWP.

10.1.1.3 Existing Conditions

Temperature

Continuous water temperature is available at five locations on the upper Sun River from 1996 through 2001. Temperature monitoring was not necessarily conducted annually at each site. Some annual continuous temperature data sets for specific sites are not used in for analysis in this document because data collection devices (temperature loggers) went dry during the heat of the summer. It was unknown if poor placement of temperature loggers or severe dewatering was the cause of air temperature data collection at certain sites during certain years. Data sets that measured water temperatures during the whole summer season are used for this assessment and are summarized in Table 10-2 and Appendix B.

Most sites on the upper Sun River recorded water temperatures sufficiently high to adversely affect salmonids by affecting metabolic levels, growth, and avoidance behavior (USEPA, 1976; Cherry, et al., 1977). In many cases, maximum summer temperatures exceeded the lower range (75°F) shown to be lethal for rainbow trout in a controlled setting (Columns E, F, G, Table 10-2) (Lee and Rinne, 1980). All continuous temperature monitoring sites in this segment recorded weekly averages exceeding 66°F, indicating that the upper optimal temperature limit for growth (66°F) in rainbow trout was surpassed for extended durations (Column J, Table 10-2). All bolded values in Table 10-2 are exceedances of temperature targets. Maximum daily change in temperature, 60-day average temperature, and total number of days temperature exceeded 73 ºF are provided in Table 10-2 as supporting information that is used to indicate impairment. Because existing data indicates that temperatures are exceeding criteria for a healthy salmonid fishery, a temperature TMDL is needed for the upper Sun River.

Table 10-2. Continuous Temperature Data Analysis Results Compared to Temperature Criteria and Targets for the Upper Sun River from 1997 Through 2001.

A	B	C	D	E	F	G	H	I	J	K
Site Name	**Start Date for Data Collection**	**Stop Date for Data Collection**	**Max. Daily ΔT ºF**	**Max. Temp. Value ºF**	**Days > 75 ºF**	**Hours > 75 ºF**	**Days > 73 ºF**	**Consecutive Days Above 73 ºF**	**Max. 7-Day Weekly Moving Average ºF**	**Max. 60 Day Average ºF**
Targets	**NA**	**NA**	**NA**	**< 75**	**0**	**0**	**NA**	**< 3**	**< 66**	**NA**
Sun River below Willow Cr	05/15/98	10/29/98	17.5	**78.0**	**7**	**34**	18	**11**	**69**	59.5
	07/10/99	10/17/99	14.7	73.9	0	0	3	1	**67**	61.3
	05/22/00	09/29/00	14.1	**75.8**	**4**	**10.5**	14	**9**	**70.2**	63.8
Sun River at Augusta	07/14/97	10/03/97	13.6	**75.2**	**1**	**2**	6	2	**67.2**	63.4
	06/01/98	10/27/98	15.4	**77.4**	**11**	**40**	24	**13**	**69.9**	59.9
	07/10/99	10/19/99	14.2	73.7	0	0	4	2	**67.8**	64.1
	06/02/00	09/29/00	16.9	**76.5**	**10**	**29.5**	22	**17**	**70.7**	65.1
	06/02/01	10/05/01	16.5	**76.6**	**10**	**28**	28	**5**	**68.7**	66.1
Sun River above Fort Shaw Irrigation Diversion	07/20/97	10/03/97	12.0	**75.2**	**1**	**2**	13	**8**	**69.1**	64.3
	06/01/98	10/27/98	13.7	**79.2**	**17**	**94**	27	**9**	**71**	67.7
	07/11/99	10/10/99	14.2	**76.6**	**4**	**12**	13	**4**	**69.8**	66.6
	05/27/01	08/17/01	16.6	**78.7**	**20**	**92.5**	41	**15**	**72.6**	67.8
Sun River below the Sun R Ditch Company Diversion	05/27/01	10/05/01	17.1	**76.3**	**8**	**21**	25	**5**	**68.8**	67.1
Sun River near the Town of Sun River	08/09/01	10/28/01	10.3	73.2	0	0	2	2	**69.9**	65.3

Stream Channel and Riparian Indicators

See Sections 9.4.1.1 and 9.4.1.2

Biology

The upper Sun River has a reduced fishery dominated by whitefish, rainbow and brown trout (Tables 2-4 and 2-5). Low fish populations are a result of low stream discharges that influence fishery habitat and water temperatures.

Aquatic macroinvertebrate community structure metrics were assessed at a site near the town of Sun River. The metrics that relate to temperature were compared to prairie ecoregion criteria, which is not appropriate for the site. Biological metrics at this site should be compared to foothill metrics. Also, irrigation return flows in this area create cool stream temperatures by increasing the amount of groundwater returning to the Sun River upstream of this location. Based on the continuous temperature monitoring reviewed in Table 10-2, more sensitive thermal areas are upstream of the biological monitoring location.

Discharge Conditions

See Section 4.0 for discussion about in-stream discharge conditions and water use in the Sun River Watershed. The upper Sun River regularly has flow conditions below the flow based supplemental indicators (Figure 4-3). See Section 10.1.2 for the source assessment that considers stream discharge as a source of thermal impairment. The upper Sun River is chronically dewatered (MFWP, 1997b).

10.1.2 Thermal Sources

Stream temperatures in the upper Sun River are influenced by a number of human caused activities. The most significant human influenced source is irrigation water management. Operations of Gibson and Willow Creek reservoirs can impact downstream water temperatures. Irrigation diversions affect stream temperature by reducing water volume in the stream, and thus, reducing the streams buffering capacity to assimilate heat. Irrigation return flows usually influence water in one of two ways: by reducing stream temperatures during critical timeframes by ground water return pathways, or increasing temperatures during critical timeframes by surface water return pathways.

Understanding how irrigation activities in the upper Sun River watershed affect stream temperature is difficult. Irrigation activities can influence stream temperatures both positively and negatively, depending upon many compounding factors. Discharge monitoring was conducting during the summer and fall of 2004 and is incorporated into a modeling source assessment approach discussed later in this section. The modeling source assessment scenarios consider irrigation practices as sources of increased stream temperature.

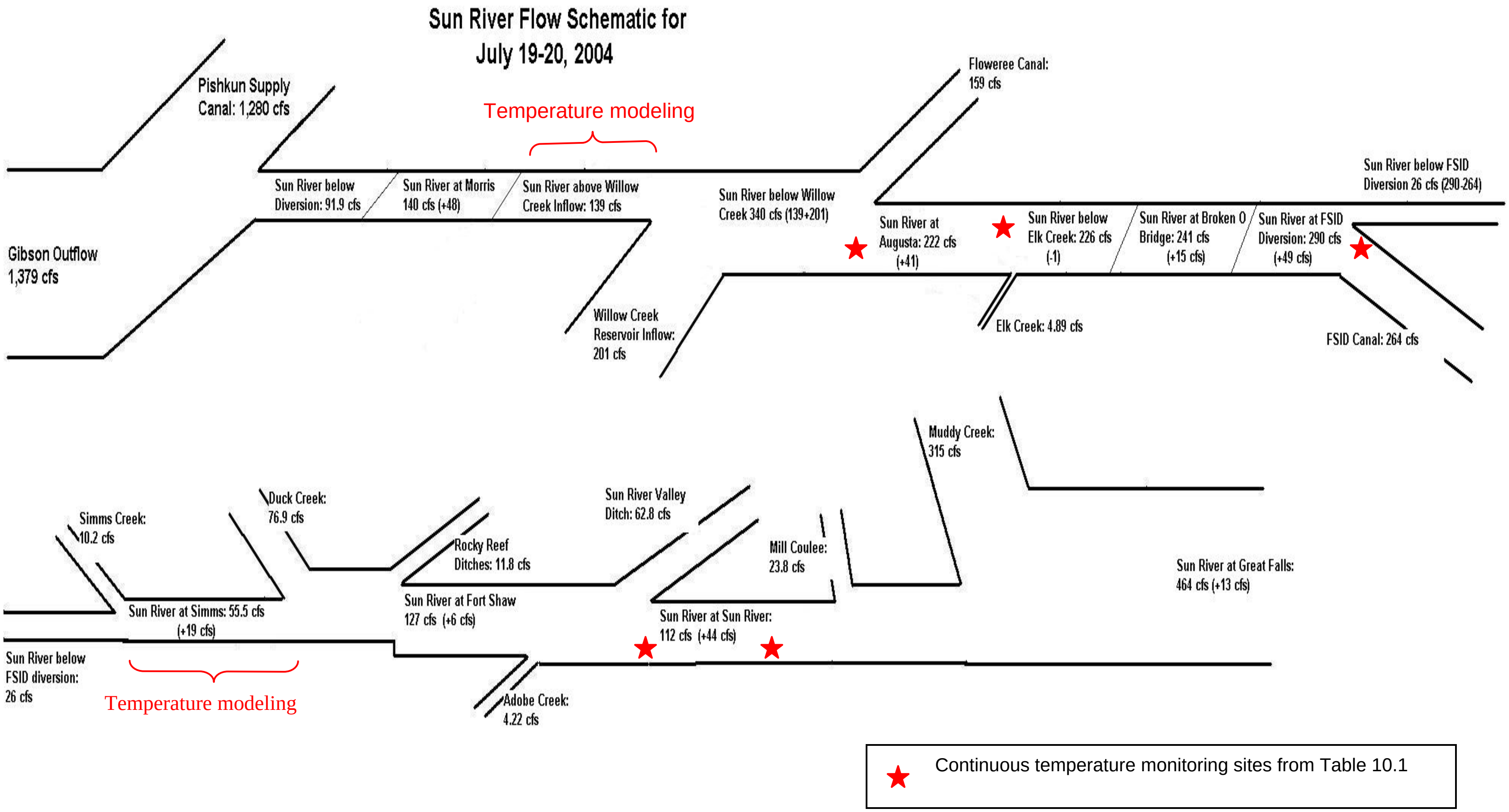
The second source of increased temperature in the Sun River watershed is riparian shading. Riparian shading is influenced by grazing and hydromodification in the upper Sun River (Section 9.3.2). Riparian vegetation intercepts direct sunlight that increases stream temperature. Riparian shade was measured and incorporated into the temperature source assessment modeling effort at 5 sites on the upper Sun River. The shade assessment determined that increased shading could not be increased significantly by grazing or water management activities above the Highway 287

Bridge. Shade in the upper section of this stream segment is naturally limited. A reference approach was used to assess stream shading potential in the segment from Highway 287 to the confluence with Muddy Creek. The reference shade was then used in temperature modeling scenarios.

The 2004 field monitoring team did not identify stream channel geometry as a potential source of increased temperatures although there was indication that dewatering causes high width to depth ratios. High width to depth ratios increase surface water area, which increases influences of latent heat and direct solar energy on stream temperature. The high width to depth ratios are addressed in the source assessment modeling by running different discharge scenarios. As discharge increases, width to depth ratios decrease in most sections of the upper Sun River.

The sites in Table 10-2 are listed in an upstream to downstream order. Gibson Reservoir outflow, the Sun River Diversion (to the Greefields Bench and Willow Creek Reservoir), Willow Creek Reservoir return flow, and Floweree Canal Diversion influence flows above the Willow Creek Site (Figure 10-2). The Augusta temperature monitoring site is only a few miles downstream from the first site with no other major surface water influences on flow between the sites. Water temperatures appear to warm slightly between these two sites. Between Augusta and Fort Shaw diversion temperature monitoring sites, Elk Creek flows into the Sun River. Once again, water temperatures appear to warm slightly between these two sites. The lowest two monitoring sites are very close to each other. Between the Fort Shaw diversion and lowest two monitoring sites, the Fort Shaw diversion, Simms Creek, Big Coulee, Rocky Reef Diversion, Adobe Creek, and Sun River Valley diversion influence flows. Water temperature appears to cool when compared to the upstream site. The cooling between these areas is likely from two factors: first, severe dewatering, and then groundwater irrigation return flow entering the river directly or via tributaries. It is likely that the warmest temperatures on the upper Sun River occur between these two areas. Mill Coulee’s confluence is downstream of the lowest temperature monitoring site.

Figure 10-2. Sun River Discharge Monitoring Results and Temperature Monitoring and Modeling Sites, Summer 2004.
(upper left is upstream, lower right is downstream)



10.1.2.1 Point Sources

In-stream and point source discharge rates are compared to each other to determine if point sources are a likely source of heat. July discharges are compared because this is a sensitive month for in-stream temperature impacts. The average July discharge (1996-2001) from Vaughn, the only POTW MPDES permit in the upper Sun River watershed, is 0.06 cfs. The July, 2004 discharge measured at the town of Sun River during a water budget assessment was 112 cfs (Figure 10-2). Using this data, Vaughn contributes approximately 0.05 % of the flow to the Sun River from its discharge. A number of temperature models use criteria of 10% inflow to the main river to determine if surface water sources have significant thermal impacts (Barthollow, 2002). Vaughn POTW is likely not a significant source of heat to the upper Sun River because it supplies only a small contribution to in-stream discharge.

10.1.2.2 Stream Segment Temperature Model (SSTEMP)

The SSTEMP model was chosen to simulate stream temperatures in the upper Sun River. The goals of the SSTEMP modeling were to create realistic temperature models; to ascertain the relative benefits of restoration measures, such as enhancing riparian vegetation; and to evaluate modeling results against naturally occurring temperature for the upper Sun River. Values for the model input parameters were assigned based on available monitoring data or on default parameters suggested in the SSTEMP User's Manual (Bartholow, 2002). This section summarizes the basis for the hydrology, channel geometry, shading, and meteorology modeling assumptions.

Modeling Assumptions, Inputs, and Calibration

Because of budget and data constraints, only two representative reaches of the upper Sun River segment were modeled. One reach was above Willow Creek's confluence; the other modeled reach was near the town of Simms. From here on, they will be referred to as the upper and lower modeled reaches. The modeling results are used to extrapolate temperature impacts to the whole upper Sun River segment. Each of the two reaches were approximately one mile in length. Discharge, stream geometry, temperature, and riparian shade were monitored on the upstream and downstream points of each modeled reach on September 9-10, 2004. Another reference area was monitored for potential shading reference downstream of Simms.

SSTEMP model calibration was performed to minimize model error in mean stream temperature by determining the percent error between modeled mean and actual stream temperatures. SSTEMP is a simplified water temperature model that requires the modeler to make assumptions about the system to be modeled. This section describes the assumptions made about the physical system and model input parameters.

The first assumption relates to Simms Creek, a tributary of the Sun River that bisects the lower modeled reach and was approximately 3 °C cooler than the Sun River. Simms Creek was thought to be less than 10% of the flow of the lower modeled reach, but after monitoring occurred, data indicated it was above the 10% discharge contribution threshold. The August 2002 revised manual for the SSTEMP model (Bartholow, 2002) recommends that if a tributary of a modeled stream segment contributes more than 10% of the overall flow in the reach, then the tributary should be modeled separately. Simms Creek contributes between 10 and 20 % of the total flow in the reach and would therefore typically be divided into two reaches, above and below Simms Creek, each modeled separately. However, because flow data were not measured for Sun River above and below the Simms Creek confluence, and only data from the mouth of Simms Creek were measured, it is not possible to model this stretch as two reaches. Therefore, it was modeled as a single reach, assuming the input from Simms Creek is spread out throughout the lower modeled reach. It is expected that the stretch of river below the Simms Creek confluence with Sun River will result in higher modeled temperatures than actually exist, while the area above the Simms Creek confluence is expected to result in cooler modeled temperatures.

The second assumption is related to the wetted width of the channel at varying flow rates. For purposes of this model it is assumed that the wetted width of each channel does not change with variations in flow rate. Typically, a width-discharge relationship would be developed for each stream segment from measurements of width at several flow rates. However, only two widths and flow rates were measured for each reach, one at the September 10 or 11, 2004 measurements and one estimated at bank-full conditions, and the bank full estimations appear to have inconsistencies. To be confident this assumption would not adversely influence results, use of a width-discharge curve was tested on the upper Sun River reach. Use of a width-discharge curve for this reach resulted in a modeled outflow temperature 0.3 °C cooler than the modeled temperature using a rectangular channel assumption, a 0.05% change. Based on the above analysis, we expect this assumption to have minimal effect on model results.

The third assumption is related to accretion temperature, which is defined as the temperature of lateral inflows, barring tributaries. The SSTEMP manual recommends use of the mean annual air temperature for the accretion temperature where geothermal activity and impacts due to irrigation are insignificant. Irrigation, however, contributes a significant amount to stream flow in the modeled reaches through conveyance losses and irrigation return flows. More accurate estimates of accretion temperature were sought through assessment of irrigation returns to the three reaches and groundwater temperatures in wells, but existing well temperature data was limited and inconsistent. The accretion temperature in the upper Sun River reach is based on the mean annual air temperature of 44.5 °F, however it was increased to 52 °F based on the idea that some of the irrigation ground water return flow comes from near the surface and would be slightly warmer that typical groundwater inflow. The accretion temperature in the lower reach is based on the combined effect of cool groundwater returns and the warmer inflow of Simms Creek.

Finally, as recommended in the SSTEMP manual (Bartholow, 2002), ground temperature is assumed to be equal to the mean annual air temperature in all three reaches, and the thermal gradient, which is defined as the rate of thermal transfer to the river from the streambed, is assumed to be 1.65 Joules/meter^2/second. Thermal gradient is identified as a possible calibration parameter in the SSTEMP manual, however, recommendations by John Bartholow, the developer of SSTEMP and SNTEMP, suggest this parameter is insensitive to change and calibration would drive the thermal gradient outside the bounds of values reported in the Forsythe (1954). Tables 10-3 and 10-4 provide input variables for calibration.

Detailed weather data for September 10, 2004 were acquired from Golf, MT Remote Automated Weather Station data. Data were available for all climate model input parameters with the exception of possible percent sun (an inverse estimate of cloud cover). The model was calibrated using two parameters: possible percent sun and wind speed. Percent sun is a subjective parameter and was varied between 1% and 100% for calibration. The resulting spread of outflow temperatures, using various values of percent sun within this range, was 0.4 °F and the resulting spread in percent error was 0.6%. The small resulting spread indicates that the model is relatively insensitive to this parameter. Therefore, a value of 75% is used for future modeling scenarios.

Wind speed was measured at Golf, MT Remote Automated Weather Station. However, due to the inherent variability of wind speed, application of this measured value can impose uncertainty. A range of wind speeds between 0 and 30 mph was used in the calibration and results indicated that wind speed had minor impact on the modeled outflow temperatures, with increased wind causing slight increases in % error. It is unlikely that there was no wind during the entire day, however lower winds provided more accurate modeled outflow temperatures. Therefore, a wind speed of 3 mph at the nearby gage will be used for modeling scenarios. Using these calibration parameters resulted in model calibration of 3.2% (2.0 °F) error for the upper reach and a 0.1% (0.1 °F) error for the lower reach.

Table 10-3. Upper Sun River Discharge and Thermal Inputs for Calibration of SSTEMP Model.

Reach	Segment Inflow (cfs)	Downstream Flow (cfs)	Inflow Temp. (°F)	Accretion Temp. (°F)	Air Temp. (°F)	Maximum Air Temp. (°F)	Total Shade (%)
Upper Sun River	94	104	60.8	52	66.2	75	4.5
Lower Sun River	93	114	66.2	54.7	71.6	75	14

Table 10-4. Upper Sun River Channel Geometry and Climate Inputs for SSTEMP Model Calibration.

Reach	Upper	Lower
Latitude	47.58	47.51
Dam at Head of Segment	no	no
Upstream Elevation	4095	3641
Downstream Elevation	4041	3569
Width's A Term	95	88
Width's B Term	See text	See text
Manning's N	0.028	0.019
Relative Humidity	38	38
Wind Speed	3	3
Ground Temperature	44.06	44.06
Thermal Gradient	1.65	1.65
Percent Possible Sun	75	75
Solar Radiation	473	473

SSTEMP Modeling Scenarios

Various SSTEMP modeling runs were conducted for the two reaches. The goals of the modeling runs were to evaluate the potential effectiveness of various reasonable restoration measures in reducing in-stream water temperatures. All modeling scenario runs were conducted at worst case scenario summer time climate condition based on July 23, 2003. The first model run scenario was to change climate conditions to reflect conditions on July 23, 2003 and change incoming water temperature to conditions on that date for both reaches. All subsequent model runs were run with the hot summer conditions and changes to input described below. Restoration measures of riparian vegetation enhancement, changes in accretion discharge, and in-stream flow augmentation were then modeled in order to assess the effectiveness of each measure alone as well as in combination.

Upper Reach (above Willow Creek) Scenarios

For the first scenario on the upper reach, in-stream flow was increased by 74%, from 94 cfs to 164 cfs. This flow scenario is based on applying savings to in-stream flows from irrigation water management practice savings to the Greefields Irrigation District, Broken O, and Fort Shaw Irrigation District delivery systems and on farm water savings. The savings are based on a 30% savings from reasonable irrigation water management practices such as ditch lining and more efficient on-farm application. Half of the saved water is applied evenly throughout the year to in-stream flow. Because irrigation efficiency increases by 30%, accretion discharge to the segment was decreased by 30% because much of the incoming groundwater is likely derived from irrigation activities. Vegetation density for upper reach was kept the same as existing conditions. Significant increases in shading are not achievable through restoration approaches in this upper reach because of natural constraints on vegetation. Appling water savings to in-stream flows during specific timeframes is likely realistic because Gibson Reservoir could potentially be used to regulate summer flows. Results for this scenario increased temperature in the upper stream segment. A higher volume of the same temperature water entering a reach that is gaining cool groundwater will buffer the cooling effects of the groundwater influence on average but will not heat up as much during the hot afternoon hours. The average modeled daily temperature increased by 0.7 °F but the maximum estimated temperature decreased by 1.9 °F (Table 10-5). In reality, the water entering the segment would likely be cooled because of upstream temperature buffering due to increased in-stream flow. Unfortunately, the existing data and modeling cannot determine the upstream buffering due to increased flow.

Because groundwater influence was found to be a major influence on stream temperature, another scenario was completed on the upper segment to determine what would happen to stream temperatures in a similar reach that is losing water to the aquifer in this general area when flows are increased. All of the above scenario inputs were used but the outflow was decreased so that the reach would be modeled to lose 3 cfs to groundwater. This scenario was run at baseline inflow of 94 cfs and at an increased inflow of 164 cfs, or a 73% increase in flow as in the scenario run above. The average modeled daily temperature decreased by 0.3 °F and the maximum daily temperature decreased by 2.3 °F (Table 10-5).

In another scenario for the upper reach, all of the conditions of the previous scenario were held the same (losing reach) except the inflow was increased to 234 cfs, which represents a 148%

increase in flow. This value represents the all the water savings being applied to in-stream flow, or half of the savings being applied to in-stream flows during the warmer half of the year. The average modeled daily temperature decreased by 0.5 °F and the maximum daily temperature decreased by 3.9 °F (Table 10-5).

Temperature standards for a B-1 state water are "A 1 ºF maximum increase above naturally occurring water temperature is allowed within the range of 32 ºF to 66 ºF; within the naturally occurring range of 66 ºF to 66.5 ºF, no discharge is allowed which will cause the water temperature to exceed 67 ºF; and where the naturally occurring water temperature is 66.5 ºF or greater, the maximum allowable increase in water temperature is 0.5 ºF (17.30.24(b))." The model calibration for the upper reach had an error of 2 ^{o}F. Modeled maximum daily temperatures are increased by 1.9 degrees in the upper reach of the upper Sun River. Although it is likely that increases in temperature occur in the upper in this reach due to irrigation, the modeled increases are within the modeling error limit when run on this reach that is gaining groundwater. On a hypothetical losing reach with all other conditions the same as this reach, an increase of the maximum daily temperature would be 3.9 ^{o}F from irrigation activities. If there are losing reaches in the area, they are likely in violation of the state standard. If a larger reach was modeled it may have provided a stronger indication of impairment. Modeling results in this segment are unclear because the model error is higher than the actual modeled increase in maximum daily temperature. It is unclear if the upper reach of the upper Sun River segment is in violation of B-1 temperature standards.

Augmenting flows by increasing irrigation efficiency will reduce daily temperature fluctuations in this area and reduce daily maximum temperatures. It is unclear how flow augmentation would affect average daily in-stream temperatures, but it appears that the combination of in-stream flow conditions and groundwater influence create the largest influence on water temperature in this area.

Lower Reach (near Simms) Scenarios

For the first scenario on the lower reach, in-stream flow was increased by 74%, from 93 cfs to 163 cfs. This flow scenario is based on applying savings to in-stream flows from irrigation water management practice savings to the Greefields Irrigation District, Broken O, and Fort Shaw Irrigation District delivery systems and on farm water savings. The savings are based on a 30% savings from reasonable irrigation water management practices such as ditch lining and more efficient on-farm application. Half of the saved water is applied evenly throughout the year to in-stream flow. Because irrigation efficiency increases by 30%, accretion discharge to the segment was decreased by 30% because much of the groundwater is likely derived from irrigation activities. Vegetation density for this scenario was kept the same as existing conditions. Appling water savings to in-stream flows during specific timeframes is likely realistic because Gibson Reservoir could potentially be used to regulate summer flows. Results for this scenario increased temperature in the upper stream segment. A higher volume of the same temperature water entering a reach that is gaining cool groundwater will buffer the cooling effects of the groundwater influence on average but will not heat up as much during the hot afternoon hours. The average modeled daily temperature increased by 0.7 °F but the maximum estimated temperature decreased by 0.3 °F (Table 10-5). In reality, the water entering the segment may be cooled because of upstream temperature buffering due to increased in-stream flow. Unfortunately, the existing data and modeling cannot determine the upstream buffering due to increased flow.

A shading scenario was run on the lower reach because the reference shading reach is comparable to this reach and had more shade than this reach. Percent shade was increased from 14% to 22%. The increased shade was applied at the existing flow of 93 cfs. The scenario results decreased average daily temperature by 1.8 °F and the maximum daily temperature also decreased by 1.8 °F (Table 10-5).

Temperature standards for a B-1 state water are "A 1 ºF maximum increase above naturally occurring water temperature is allowed within the range of 32 ºF to 66 ºF; within the naturally occurring range of 66 ºF to 66.5 ºF, no discharge is allowed which will cause the water temperature to exceed 67 ºF; and where the naturally occurring water temperature is 66.5 ºF or greater, the maximum allowable increase in water temperature is 0.5 ºF (17.30.24(b))." The model calibration for the lower reach had an error of 0.1 ^{o}F. Modeled maximum daily temperatures are increased by 1.8 degrees in the lower reach of the upper Sun River. State water quality temperature standards are exceeded in this reach because natural temperatures are above 66 ºF and the model indicates increases in temperature greater than 0.5 ºF. If a larger reach was modeled it may have provided a stronger indication of impairment. Modeling results in this segment demonstrate impairment due to temperature.

Augmenting flows by increasing irrigation efficiency will reduce daily temperature fluctuations in this area and reduce daily maximum temperatures. It is unclear how flow augmentation would affect average daily in-stream temperatures, but it appears that the combination of in-stream flow conditions, shading, and groundwater influence create the largest influence on water temperature in this area.

Table 10-5. Results of the SSTEMP Model Scenarios for the Upper Sun River.

	Reach	Restoration Measure	Parameter (Daily)	Value °F	Difference From Existing Condition °F
Comparison	Above Willow Creek (upper)	Existing condition. (July 23, 2003)	Mean	69.2	NA
			Max	85.5	NA
	Above Willow Creek	Increase inflow by 74% to reflect ½ of IWM savings applied to in-stream flow over full year. Decrease of groundwater inflows to the reach by 30%.	Mean	69.9	+0.7
			Max	83.6	-1.9
Comparison	Above Willow Creek	Change the reach to a losing reach - Hypothetical Condition (water flows from the river to groundwater).	Mean	70.9	NA
			Max	86.9	NA
	Above Willow Creek	Change the reach to a losing reach - Increase flow by 74% to reflect ½ of IWM savings applied to in-stream flow over full year (3 cfs flows from the river to groundwater).	Mean	70.6	-0.3
			Max	84.6	-2.3
	Above Willow Creek	Change the reach to a losing reach - Increase flow by 148% to reflect IWM savings applied to in-stream flow over full year (3 cfs flows from the river to groundwater).	Mean	70.4	-0.5
			Max	83.0	-3.9
Comparison	Near Simms (lower)	Existing condition.	Mean	70.0	NA
			Max	86.0	NA
	Near Simms	Increase inflow by 74% to reflect ½ of IWM savings applied to in-stream flow over full year.	Mean	71.7	+1.7
			Max	85.7	-0.3
	Near Simms	Shading increased from 14% to 22%	Mean	69.9	-1.8
			Max	84.9	-1.8

SSTEMP Modeling Conclusions

Limited in-stream field data were available to calibrate the SSTEMP models. The modeling scenarios represented worst-case climate conditions. This is especially important given the fact that air temperature is a very significant variable for the SSTEMP model. Nonetheless, the calibration models appeared to give reasonable estimates of mean and maximum temperature for the upper Sun River.

The goals of modeling with SSTEMP were to determine the relative benefits of restoration measures, such as augmenting flows, and to determine if B-1 temperature standards are violated within the suspected thermally impaired segments. The modeled maximum and average daily temperatures for lower reach violate the state standard set for B-1 class streams naturally above

67 ºF. Of the significant ‘controllable’ variables revealed in the sensitivity analysis, increasing riparian vegetation density appeared to have the greatest potential impact on reducing mean in-stream water temperatures. The other significant ‘controllable’ variable was stream flow. When flows were augmented the input flow temperatures would be even more important than air temperatures. Should the ultimate goal of restoring coldwater fisheries and associated aquatic life in the upper Sun River, it would appear that restoration measures will need to consider irrigation water management and riparian shade enhancement.

To understand the full impact of reduced in-stream flow on temperature, the SNTEMP model would need to be run for the entire upper Sun River. This was not possible with current budgetary and time constraints. It is likely that increasing in-stream flows will decrease water temperatures more than the SSTEMP modeling indicates because of cumulative upstream affects of increasing in-stream heat buffering capacity that the SSTEMP modeling could not take into account.

10.1.3 Load Limits

A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation: **TMDL = WLAs + LAs + Natural + MOS.** This section identifies load limits and the allocation section will address how each of the TMDL components are considered.

For this temperature TMDL, the source assessment is not investigated in terms of heat loads. Although temperature impacts from significant sources were modeled to assess relative impacts, the number of joules or calories coming from each source is not directly assessed. The modeling was not reliable enough to fully base allocations or a TMDL upon. Also, temperature standards exceedances that are influenced by reduced in-stream discharges are not easily addressed in terms of heat loading. Reduction in discharge does not introduce more heat to the stream, instead it reduces the streams capacity to adsorb heat. Because of the arguments above, the TMDL is expressed as a simple discharge based TMDL that relates to meeting targets. This requires a number of load limits that relate to different target temperatures and durations in Section 10.1.1.1.

10.1.3.1 Instantaneous Load Limit

An acute TMDL is provided to ensure that heat accumulation does not contribute to temperatures that cause short-term death of salmonids. This load-based limit is calculated by the second. The limit depends upon the in-stream discharge rate. The load limit can be calculated for any flow condition in the upper Sun River. The basis for an acute load limit is meeting the absolute maximum temperature target of 75°F at all discharge rates. Heat loading should not surpass the load for any discharge rate based upon the following loading equation:

Maximum Load (in kilocalories/second) = Discharge (cfs) * 676.206

The factor of 676.206 is a combination of volume and temperature conversion factors. If the absolute maximum target of 75 °F of is not met, the maximum load limit is exceeded.

10.1.3.2 Average Weekly Load Limit

A chronic load limit is provided to ensure that heat accumulation does not contribute to temperatures that cause long-term health affects in salmonid populations. This load limit is calculated for an average load over a week's time. This load limit calculation is based upon average weekly discharge. The basis for a chronic load limit is meeting the seven-day average temperature target of 66°F at all seven-day average discharge rates. Heat loading should not surpass the load for any seven-day average discharge rate based upon the following loading equation:

Maximum Load (in mega calories/week) = Discharge (7-day average discharge in cfs) * 32351.07

The factor of 32351.07 is a combination of volume, time, and temperature conversion factors. If the maximum seven-day average target of 66°F is not met, the weekly load limit is not met. Both the weekly and instantaneous load limits are exceeded on the upper Sun River. Any bolded existing conditions in Table 10-2 Columns E, F, G, and J would be an exceedance of a load limit.

10.1.4 Allocations and Margin of Safety

Waste Load Allocation (point sources)

No temperature data is available for determining the thermal waste load allocation from Vaughn. The heat waste load is thought to be very small based on comparison of Vaughn POTW and in-stream discharge rates. The allocation to Vaughn's POTW will be phased into future TMDL revisions that are authorized by state law. Until that time, Vaughn should not significantly increase heat loading to the upper Sun River. Vaughn should keep their discharge less than 1% of the in-stream flow during the months of July and August until a true heat allocation can be made during a future TMDL review. During the next permit review, MDEQ will require Vaughn to monitor continuous temperatures (1/2 hour increments) in their discharge and also monitor continuous ambient in-stream conditions immediately upstream of their discharge for one year, during July, August, and September. This data will be used to allocate a load to Vaughn during future TMDL review.

Load Allocation (nonpoint sources) and Natural Loading

The TMDL is based upon meeting temperature targets that represent attainment of in-stream beneficial uses. Excluding the waste load, which is likely insignificant, the remainder of the TMDL is derived from nonpoint sources and natural sources. The methodologies used in the source assessment do not allow for a partitioning of natural and nonpoint source heat loads. The source assessment identified stream shading and flow modification, both due to agricultural activities, as the significant nonpoint sources. Therefore, the full reduction of heat load or reduction of in-stream buffering capacity needed to attain the instantaneous and weekly average load limits will be allocated to agricultural activities that increase stream temperatures by modifying in-stream flow conditions and shading. These agricultural activities include irrigation water withdrawals, overland irrigation return to the Sun River and tributaries, hydromodification that affects riparian vegetation shading, and riparian grazing that affects riparian vegetation shading. If these agricultural sources are addressed by restoration management actions identified in Section 10.1.5, the targets and loads will likely be achieved.

Phased Load Allocation Approach

Phase I

A performance based allocation is currently provided for phase I to reduce in-stream temperatures by providing increased shade on the segment of the Sun River between highway 287 and Muddy Creek. Shading in a reference area was found at 22% while in an impacted area it was 14%. Therefore, the performance based allocation to restore shading to 22% along this reach of the sun river is provided. SSTEMP modeling identified that there is a significant decrease in temperature due to a 8% change in shading. Riparian grazing and extremely low summer flows were identified as impacting riparian vegetation growth. Shading above highway 287 can not be increased with restoration approaches. Riparian vegetation is at or very close to it's potential in this area.

Phase II

The Sun River discharge requirements identified by MFWP for survival of salmonids in Table 4-2 in conjunction with the phase I allocation will likely achieve temperature targets in the upper Sun River (Figure 10-1). The second phase of a load allocation will be to do the following:

1. Conduct a feasibility analysis of meeting MFWP discharge requirements for survival of a salmonid population.
2. Use results of the feasibility analysis to collaborate with irrigation system operation personnel to attain irrigation conveyance efficiencies.
3. Use results of the feasibility analysis to collaborate with irrigators to attain on-farm irrigation efficiencies.
4. Use results of the feasibility analysis to apply savings to in-stream use.
5. Continue monitoring in-stream discharge and fishery.

The phase II allocation strategy has to consider Montana's water law that prohibits the taking or imperilment of any existing water right in order to attain water quality standards. This indicates that a locally coordinated approach to restoring in-stream flow is essential for achiving the goals of phase II allocation process.

10.1.4.3 Margin of Safety, Adaptive Management, and Seasonality Considerations

A margin of safety for this TMDL is provided in an adaptive management approach. The uncertainty of the Sun River temperature TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 10.1.6 to aid in future TMDL review and the phased allocation for the point source.

The upper Sun River temperature TMDL is based on targets that protect in-stream uses. While this may be protective of the use, it is unknown if reasonable land, soil, and water conservation practices can actually achieve the TMDL. Therefore, identified nonpoint source conservation practices in Section 10.1.5 should be tracked over time to determine if and where implementation occurs. If implementation occurs and does not achieve targets or the TMDL, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil, and water conservation practices are in place, targets, TMDL and allocations may need to be revised.

Sensitive seasons are addressed by setting year round targets. For the most part the targets will be a concern in July or August when hot summer weather conditions persist. The temperature targets and load limits provide protection over two different time durations. This load limit and allocation timeframe should adequately protect the uses. If targets or loads need to be broken into daily, monthly, or other load timeframes because future knowledge indicates that uses are being impacted over different timeframes than those addressed in this document, the load limit timeframe should be addressed in future TMDL reviews.

10.1.5 Restoration Strategy

10.1.5.1 Irrigation Water Management

Irrigation water management activities that will reduce temperatures in the upper Sun River ultimately reflect back to one idea: leaving more water in-stream. Reducing or discontinuing surface irrigation water returns to the upper Sun River or tributaries is also essential. The recovered water from the irrigation water management activities identified below should be left in the Sun River to promote riparian vegetation growth by stabilizing in-stream water levels. Increased discharges in the upper Sun River will provide restoration approaches that address inefficient irrigation water delivery are vital. Increasing on-farm irrigation and delivery system efficiency will be useful to reduce summer groundwater return flow to tributaries and divert less water from the Sun River. The following activities are provided as irrigation water management practices:

- Capture all or most of the surface irrigation waste water and devise a more efficient approach to water delivery on all major conveyance ditches.
- Study water loss in ditches, prioritize ditch lining using water loss study, and line ditches in areas that leak the most, especially near the periphery of the Greenfields Bench.
- Prevent on-farm or conveyance irrigation water runoff from exiting fields or ditches and entering state waters via overland flow.
- Use evapotranspiration or soil moisture monitoring for irrigation scheduling.
- Install head gates that can be fully controlled, if not already in use.
- Apply irrigation savings to in-stream use.

10.1.5.2 Riparian Grazing Management

Application of grazing management tools can reduce sediment loads from bank erosion sources. Grazing management practices that may help to avoid acceleration of stream bank erosion on the upper Sun River and tributaries are:

- Use riparian browse and grazing indictors to manage riparian grazing pressure and rotate riparian pasture appropriately.
- Time grazing to coincide with dry or freezing weather to reduce erosion.
- Time pasture use to promote grazing, not browse.
- Place supplemental feed or salt in upland areas to promote even grazing in pastures without riparian fencing.
- If needed, fence riparian areas and provide water gaps.
- Employ weed control.

Riparian Buffer Zones

Allowing a riparian buffer between the river and agricultural fields will promote growth of riparian vegetation with better soil binding properties. The riparian species root mass will protect banks better than shallow rooted field grasses.

10.1.6 Monitoring Strategy

10.1.6.1 Existing Condition and Trend Monitoring

Continuous temperature monitoring should continue yearly at sites identified in Table 10-2 to track existing conditions and any trends. The Bureau of Reclamation should begin monitoring continuous temperature conditions on an annual basis during the summer time below Gibson Reservoir and below the Sun River Diversion.

10.1.6.2 Water Budget Analysis

Discharge monitoring along the Sun River, major diversions, and major tributaries was conducted during the summer and fall of 2004 to determine existing flow conditions in the Sun River Watershed. A feasibility analysis of basin wide irrigation management practices, associated water savings, and the feasibility of applying saved water to in-stream flow should be conducted. The water budget and feasibility analysis could be used in conjunction to solidify how much water can be applied to in-stream uses and to identify where BMPs should be applied in the irrigation systems.

10.1.6.3 Phased Waste Load Allocation

No temperature data is available for determining the thermal waste load allocation from Vaughn. The allocation to Vaughn's POTW will be phased into future TMDL revisions that are authorized by state law. During the next permit review, MDEQ will require Vaughn to monitor continuous temperatures (1/2 hour increments) in their discharge and also monitor continuous ambient in-stream conditions immediately upstream of their discharge for one year, during July, August, and September. This data will be used to allocate a load to Vaughn during future TMDL review.

10.1.6.4 Restoration Management Tracking

All restoration management projects that fall into categories provided in Sections 10.4 should be tracked using a Sun River Watershed BMP spatial database. Project location, size, type, and restoration results should be attributed.

10.2 Muddy Creek

Muddy Creek's general watershed description is provided in Section 2.8.5. Muddy Creek's water quality standards and use classification are provided in Section 3.0.

10.2.1 Targets

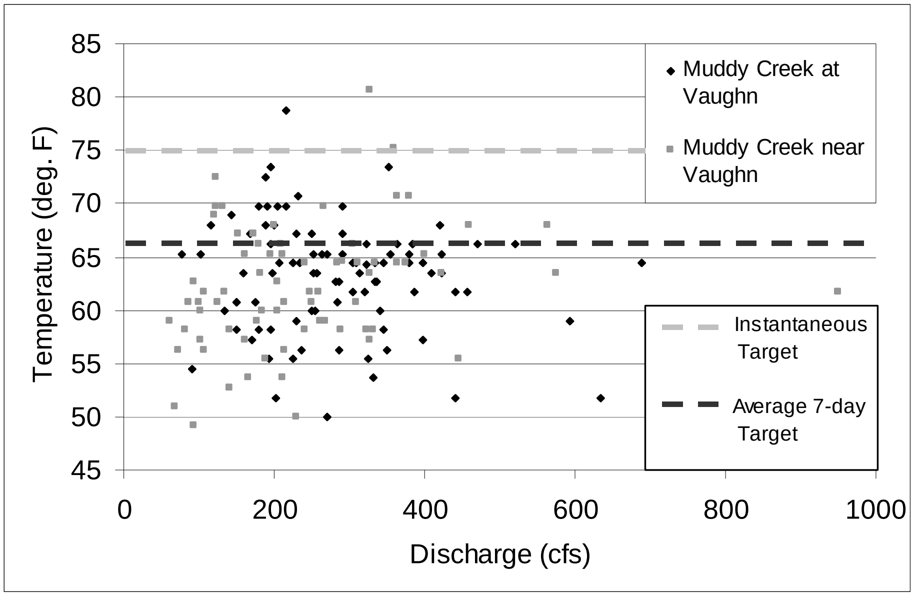
It is Montana's goal to attain the same uses in Muddy Creek as the upper Sun River. Therefore, the temperature targets for Muddy Creek are the same as those provided for the upper Sun River in Section 10.1.1. The Sun River supplemental indicators are not applicable to Muddy Creek.

10.2.2 Existing Conditions

10.2.2.1 Temperature

Continuous temperature data from Muddy Creek is not available at this time. The available instantaneous temperature USGS data for Muddy Creek indicates that water temperatures during the hottest period of the year are usually compatible for rainbow and brown trout. The average of July and August instantaneous temperature data is 63.7 °F. The maximum recorded value is 80.6 °F. Only three of the 162 data points at the two USGS stations were above 75 °F (Figure 10-3). Weekly average temperatures above 66 °F affect growth and exceed the values preferred by fry and fingerling rainbows (USEPA, 1976; Coutant, 1977; Cherry et al., 1977; Bell, 1986). About 26 percent of the 162 data points at the two USGS stations were above 66 °F. Little can be concluded from instantaneous temperature data when compared to a weekly average temperature for growth, but exceedances of the 75 °F target and human influenced sources of heat indicate that a temperature TMDL is needed for Muddy Creek.

Figure 10-3. Muddy Creek at Vaughn and Muddy Creek Near Vaughn Summer (July - August) Discrete Water Temperature vs. Discharge Relationship.



Stream Channel and Riparian Indicators

When irrigation was initiated on the Greenfields Bench, the increased stream flow and energy created a larger stream channel by eroding down into the soft silts and clays of the lower Muddy Creek Valley. Riparian grazing also had a role in eliminating riparian areas that support willow species. Efforts to reduce erosion in Muddy Creek have resulted in a more stable stream channel, an improved riparian condition and temperature regime, especially on the lower 10 stream miles where most of the past damage had occurred. Trout and aquatic life habitat in this lower section of Muddy Creek has improved and continues to move toward more stable condition. This helps enable the stream to maintain a cool base flow.

Stream channel and riparian conditions are described in Section 9.4.1.

10.2.2.2 Biology

Old fisheries data indicate that Muddy Creek has a reduced fishery dominated by whitefish and brown trout (Table 2-3). Although there has been no recent fishery data collected in Muddy Creek, local reports indicate that the stream currently supports a minimal population of large brown trout above Gordon. Low fish populations are a result of physical conditions and flow fluctuations that influence fishery habitat and water temperatures. If destructive, high, summer flows and over-heated surface returns are prevented in the future, Muddy Creek shows promise for a rehabilitated cold-water fishery. No aquatic insect or periphyton data are available for Muddy Creek.

10.2.2.3 Discharge Conditions

Historically, much of Muddy Creek was intermittent before the initiation of irrigation within the watershed. The initiation of irrigation in the watershed brought increased flows to Muddy Creek. Groundwater from the Greenfields Bench has a beneficial influence on the temperature regime for Muddy Creek and is a significant source of cool water supporting a cold-water fishery.

Muddy Creek tributaries draining the Greenfields Bench show significant increases in base-flow about a week after irrigation water application begins. Although the Greenfields Bench composes only 25 percent of the watershed, its irrigated lands contribute over 90 percent Muddy Creek's total discharge (Systems Technology Inc, 1979). Of the total water originating from irrigation on the Bench, Osborn (1983) estimates that 65 percent occurred as ground water base flow entering Muddy Creek. An estimated 35% of Greenfields Bench irrigation water returns to Muddy Creek via surface wasting.

Irrigation derived surface return flows are usually heated by solar energy in open conveyance ditches and also by contact with soils in fields. Muddy Creek water temperatures rise in response to these inflows and the warmest summer values are recorded under these circumstances. Surface irrigation return flow is the largest human influenced contributor of heat to Muddy Creek during the critical summer timeframe.

See Section 4.0 for discussion about in-stream discharge conditions and water use in the Sun River Watershed.

10.2.3 Thermal Sources

Increased stream temperatures in Muddy Creek are influenced by a couple of human caused activities. The most significant human influenced source is overland return of irrigation water from the Greenfields Bench to Muddy Creek and it's tributaries. The second is agricultural encroachment and overgrazing along Muddy Creek and tributary corridors. There are no permanent point sources in the Muddy Creek Watershed.

10.2.3.1 Stream Segment Temperature Model (SSTEMP)

The SSTEMP model was chosen to simulate stream temperatures in Muddy Creek for source assessment purposes. The goals of the SSTEMP modeling were to create realistic temperature models; to ascertain the relative benefits of restoration measures, such as enhancing riparian vegetation or reducing irrigation overland return flow; and to evaluate modeling results against naturally occurring temperatures. Values for the model input parameters were assigned based on available monitoring data or on default parameters suggested in the SSTEMP User's Manual (Bartholow, 2002). This section summarizes the basis for the hydrology, channel geometry, shading, and meteorology modeling assumptions.

Modeling Assumptions, Inputs, and Calibration

Because of budget and modeling constraints, only a representative reach of Muddy Creek was modeled. The modeled reach ran was between Gordon Road and Vaughn. The modeling results are used to extrapolate temperature impacts to all of Muddy Creek. The reach is approximately one mile in length. Discharge, stream geometry, temperature, and riparian shade were monitored on the upstream and downstream points of the reach on September 10, 2004.

SSTEMP model calibration was performed to minimize model error in mean stream temperature by determining the percent error between modeled mean and actual stream temperatures. SSTEMP is a simplified water temperature model that requires the modeler to make assumptions about the system to be modeled. This section describes the assumptions made about the physical system and model input parameters.

The second assumption is related to the wetted width of the channel at varying flow rates. For purposes of this model it is assumed that the wetted width of each channel does not change with variations in flow rate. Typically, a width-discharge relationship would be developed for each stream segment from measurements of width at several flow rates. However, only two widths and flow rates were measured for each reach, one at the September 10 or 11, 2004 measurements and one estimated at bank-full conditions, and the bank full estimations appear to have inconsistencies. To be confident this assumption would not adversely influence results, use of a width-discharge curve was tested on a modeled reach. Use of a width-discharge curve for one reach resulted in a modeled outflow temperature 0.3 °C cooler than the modeled temperature using a rectangular channel assumption, a 0.05% change. Based on the above analysis, we expect this assumption to have minimal effect on model results.

The third assumption is related to accretion temperature, which is defined as the temperature of lateral inflows, barring tributaries. The SSTEMP manual recommends use of the mean annual air temperature for the accretion temperature where geothermal activity and impacts due to irrigation are insignificant. Irrigation, however, contributes all of the accretion flow to the modeled Muddy Creek reach. The accretion temperature in the lower reach is based on the combined effect of cool groundwater returns and the warmer inflow of Simms Creek.

Finally, as recommended in the SSTEMP manual (Bartholow, 2002), ground temperature is assumed to be equal to the mean annual air temperature in all three reaches, and the thermal gradient, which is defined as the rate of thermal transfer to the river from the streambed, is assumed to be 1.65 Joules/meter^2/second. Thermal gradient is identified as a possible calibration parameter in the SSTEMP manual, however, recommendations by John Bartholow, the developer of SSTEMP and SNTEMP, suggest this parameter is insensitive to change and calibration would drive the thermal gradient outside the bounds of values reported in the Forsythe (1954). Tables 10-6 and 10-7 provide input variables for calibration.

Detailed weather data for September 10, 2004 were acquired from Golf, MT Remote Automated Weather Station data. Data were available for all climate model input parameters with the exception of possible percent sun (an inverse estimate of cloud cover). The model was calibrated using two parameters: possible percent sun and wind speed. Percent sun is a subjective parameter and was varied between 1% and 100% for calibration. The resulting spread of outflow temperatures, using various values of percent sun within this range, was 0.4 °F and the resulting spread in percent error was 0.6%. The small resulting spread indicates that the model is relatively insensitive to this parameter. Therefore, a value of 75% is used for future modeling scenarios.

Wind speed was measured at Golf, MT Remote Automated Weather Station. However, due to the inherent variability of wind speed, application of this measured value can impose uncertainty. A range of wind speeds between 0 and 30 mph was used in the calibration and results indicated that wind speed had minor impact on the modeled outflow temperatures, with increased wind causing slight increases in % error. It is unlikely that there was no wind during the entire day, however lower winds provided more accurate modeled outflow temperatures. Therefore, a wind speed of 3 mph at the nearby gage will be used for modeling scenarios. Using these calibration parameters resulted in model calibration of 2.7% (1.5 °F) error for Muddy Creek.

Table 10-6. Muddy Creek Discharge and Thermal Calibration Inputs for SSTEMP Model.

Reach	Segment Inflow (cfs)	Downstream Flow (cfs)	Inflow Temp. (°F)	Accretion Temp. (°F)	Air Temp. (°F)	Maximum Air Temp. (°F)	Total Shade (%)
Muddy Creek	163	178	54.5	54.5	71.6	87	43

Table 10-7. Muddy Creek channel geometry and climate inputs for SSTEMP model calibration.

Reach	Muddy Creek
Latitude	47.61
Dam at Head of Segment	no
Upstream Elevation	3498
Downstream Elevation	3434
Width's A Term	33.1
Width's B Term	See text
Manning's N	0.038
Relative Humidity	38
Wind Speed	3
Ground Temperature	44.06
Thermal Gradient	1.65
Percent Possible Sun	75
Solar Radiation	473

SSTEMP Modeling Scenarios

Various SSTEMP modeling runs were conducted. The goals of the modeling runs were to evaluate the potential effectiveness of various reasonable restoration measures in reducing in-stream water temperatures. All modeling scenario runs were conducted at worst case scenario summer time climate condition based on July 23, 2003. The first model run scenario was to change climate conditions to reflect conditions on July 23, 2003 and also changes incoming water temperature to conditions on that date for both reaches. All subsequent model runs were run with the hot summer conditions. Restoration measures of riparian vegetation enhancement, changes in accretion discharge, and in-stream flow augmentation were then modeled in order to assess the effectiveness of each measure alone as well as in combination.

A scenario was run that simulated increases in overland irrigation return from the Greenfields Bench. A mixing calculation was used to add 45 cfs of incoming, 79 °F, water to the upper end of the segment. This raised the average daily temperature by 4.8 °F and the maximum daily temperature by 3.6 °F (Table 10-8).

Another scenario was run that simulated a decrease in warm discharge from Greenfields Bench of 30 cfs when compared to the baseline model run. This lowered the average daily temperature by 3.8 °F and the maximum daily temperature by 2.6 °F (Table 10-8).

The monitoring on Muddy Creek did not identify a reference riparian condition to use for reference shading for an increased shading scenario. Shading is not influenced greatly by riparian vegetation management on this segment because current stream channel condition is not conductive to growing shrubs and much of the shading is provided from the old terrace that Muddy Creek created during the past 40 years.

Table 10-8. Results of the SSTEMP Model Scenarios for Muddy Creek.

	Reach	Restoration Measure	Parameter	Value °F	Difference From Existing Condition °F
Comparison	Muddy Creek	Baseline Condition	Mean	55.0	NA
			Max	62.5	NA
	Muddy Creek	Increased warm irrigation overland flow by 45 cfs when compared to Baseline.	Mean	59.8	+4.8
			Max	66.1	+3.6
	Muddy Creek	Decreased warm irrigation overland flow by 30 cfs when compared to Baseline.	Mean	51.2	-3.8
			Max	59.9	-2.6

SSTEMP Modeling Conclusions

Limited in-stream field data were available to calibrate the SSTEMP model. The modeling scenarios represented worst-case climate conditions. This is especially important given the fact that air temperature is a very significant variable for the SSTEMP model. Nonetheless, the calibration models appeared to give reasonable estimates of mean and maximum temperature for Muddy Creek.

The goals of modeling with SSTEMP were to determine the relative benefits of restoration measures, such as augmenting flows, and to determine if B-1 temperature standards are violated within the suspected thermally impaired segments. The modeled maximum and average daily temperatures for lower reach violate the state standard set for B-1 class streams. Model output indicates that overland irrigation return flow can significantly impact water temperatures in Muddy Creek. Significant increases in stream temperature were modeled from this source.

10.2.4 Load Limits

A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation: **TMDL = WLAs + LAs + Natural + MOS.** This section identifies load limits and the allocation section will address how each of the TMDL components are considered.

For this temperature TMDL, the source assessment is not investigated in terms of heat loads. Although temperature impacts from significant sources were modeled to assess relative impacts, the number of joules or calories coming from each source is not directly assessed. The modeling was not reliable enough to fully base allocations or a TMDL upon. Also, temperature standards exceedances that are influenced by reduced in-stream discharges are not easily addressed in terms of heat loading. Reduction in discharge does not introduce more heat to the stream; instead it reduces the streams capacity to adsorb heat. Because of the arguments above, the TMDL is expressed as a simple discharge based TMDL that relates to meeting targets. This requires a number of load limits that relate to different target temperatures and durations in Section 10.1.1.1.

10.2.4.1 Instantaneous Load Limit

An instantaneous load limit is provided to ensure that heat accumulation does not contribute to temperatures that cause acute fatality in salmonids. This load-based limit is calculated by the second. The limit depends upon the in-stream discharge rate. The load limit can be calculated for any flow condition in Muddy Creek. The basis for an acute based load limit is meeting the absolute maximum temperature target of 75°F at all discharge rates. Heat loading should not surpass the load for any discharge rate based upon the following loading equation:

Maximum Load (in kilocalories/second) = Discharge (cfs) * 676.206

The factor of 676.206 is a combination of volume and temperature conversion factors. If the absolute maximum target of 75 °F of is not met, the maximum load limit is exceeded.

10.2.4.2 Average Weekly Load Limit

A chronic load limit is provided to ensure that heat accumulation does not contribute to temperatures that cause long-term health affects in salmonid populations. This load limit is calculated for an average load over a week’s time. This load limit calculation is based upon average weekly discharge. The basis for a chronic load limit is meeting the seven-day average temperature target of 66 °F at all seven-day average discharge rates. Heat loading should not surpass the load for any seven-day average discharge rate based upon the following loading equation:

Maximum Load (in mega calories/week) = Discharge (7-day average discharge in cfs) * 32351.07

The factor of 32351.07 is a combination of volume, time, and temperature conversion factors. If the maximum seven-day average target of 66°F is not met, the weekly load limit is not met. The instantaneous load limit is exceeded in Muddy Creek. Continuous water temperature is lacking and comparison of existing conditions to the average weekly load limit cannot be completed.

10.2.5 Allocations and Margin of Safety

10.2.5.1 Waste Load Allocation (point sources)

There are no permanent point sources in Muddy Creek's watershed.

10.2.5.2 Load Allocation (nonpoint sources) and Natural Loading

The TMDL is based upon meeting temperature targets that represent attainment of in-stream beneficial uses. Excluding the waste load, which is likely insignificant, the remainder of the TMDL is derived from nonpoint sources and natural sources. The methodologies used in the source assessment do not allow for a partitioning of natural and nonpoint source heat loads. The source assessment identified overland irrigation water return from the Greenfields Bench as the only significant source. Therefore, the full reduction of heat load needed to attain the instantaneous and weekly average load limits will be assessed to this source. If irrigation water management activities identified in Section 10.2.6 are implemented, the load limits and targets will likely be met.

10.2.5.3 Margin of Safety, Adaptive Management, and Seasonal Considerations

A margin of safety for this TMDL is provided in an adaptive management approach. The uncertainty of the Sun River temperature TMDL analysis is addressed by future TMDL reviews as provided for in Montana law. A monitoring plan is identified in Section 10.2.7 to aid in future TMDL review and the phased allocation for the point source.

Muddy Creek's temperature TMDL is based on targets that protect in-stream uses. While this may be protective of the use, it is unknown if reasonable land, soil and water conservation practices can actually achieve the TMDL. Therefore, identified nonpoint source conservation practices in Section 10.2.6 should be tracked over time to determine if and where implementation occurs. If implementation occurs and does not achieve targets or the TMDL, further strategies to meet these goals should occur in future TMDL planning. If the goals of this document appear to be unachievable after reasonable land, soil, and water conservation practices are in place, targets, TMDL and allocations may need to be revised.

Sensitive seasons are addressed by setting year round targets. For the most part the targets will be a concern in July or August when hot summer weather conditions persist. The temperature targets and load limits provide protection over two different time durations. This load limit and allocation timeframe should adequately protect the uses. If targets or loads need to be broken into daily, monthly, or other load timeframes because future knowledge indicates that uses are being impacted over different timeframes than those addressed in this document, the load limit timeframe should be addressed in future TMDL reviews.

10.2.6 Restoration Strategy

10.2.6.1 Irrigation Water Management

Irrigation water management activities that will reduce temperatures in Muddy Creek ultimately reflect back to one idea: restricting overland irrigation water wasting to Muddy Creek. A strategy to do capture a large portion of overland irrigation waste is currently being contemplated. A “reregulation reservoir” is being investigated for installation in a coulee on the east side of Greenfields Bench. The reservoir can easily be controlled with reasonable practices to reduce erosion in Muddy Creek. The reservoir should be constructed and managed in a way that allows for cool water discharge that will lead to compliance of the Muddy Creek temperature TMDL at Vaughn.

10.2.6.2 Riparian Grazing Management

Application of grazing management tools can reduce sediment loads from bank erosion sources. Grazing management practices that may help to avoid acceleration of stream bank erosion on the upper Sun River and tributaries are:

- Use riparian browse and grazing indictors to manage riparian grazing pressure.
- Time grazing to coincide with dry or freezing weather to reduce erosion.
- Time pasture use to promote grazing, not browse.
- Place supplemental feed or salt in upland areas to promote even grazing in pastures without riparian fencing.
- If needed, fence riparian areas and provide water gaps.
- Employ weed control.

10.2.7 Monitoring Strategy

10.2.7.1 Existing Condition and Trend Monitoring

Continuous temperature monitoring should occur annually at Gordon Road, Muddy Creek at Vaughn USGS station, and if built, below the “reregulation reservoir”.

10.2.7.2 Water Budget Analysis

Greenfields Irrigation District, USBR, SRWG, and Montana State University are currently coordinating a study to determine where surface and groundwater discharges originate on the Greenfields Bench. The data from study should be used for further source assessment if necessary during future TMDL reviews.

10.2.7.3 Restoration Management Tracking

All restoration management projects that fall into categories provided in Section 10.2.6 should be tracked using a Sun River Watershed BMP spatial database. Project location, size, type, and restoration results should be attributed.

10.3 Lower Sun River

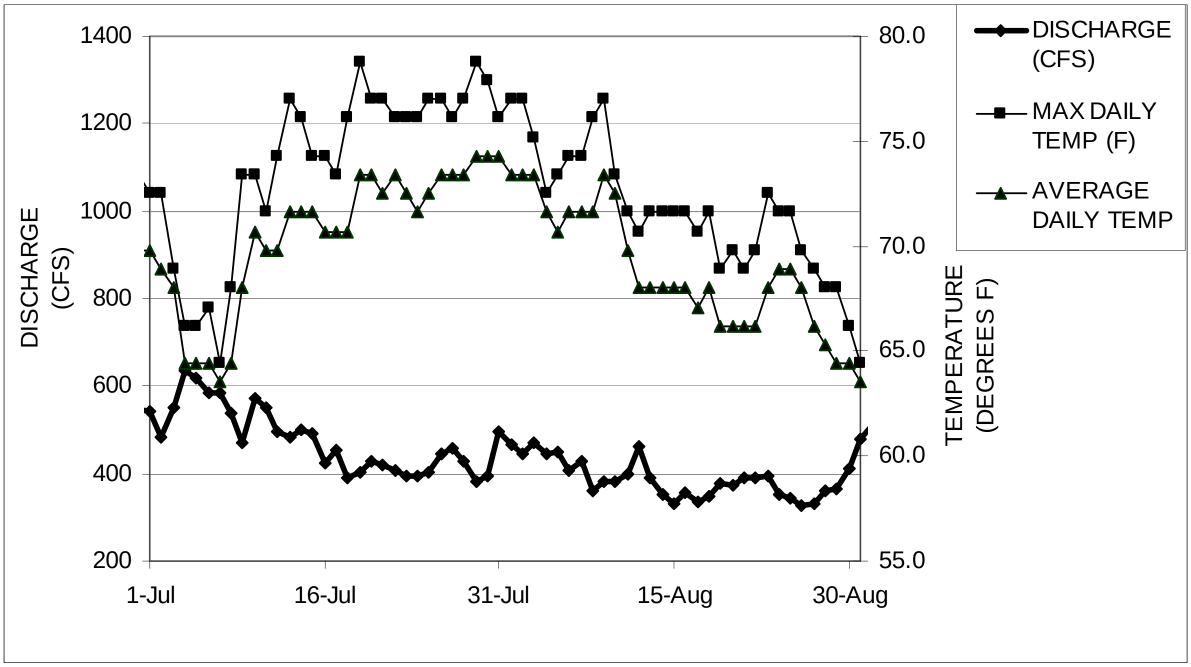
The lower Sun River supports a limited cold-water fish population below Muddy Creek even though it is classified as a warm water stream (Table 2-3). The increase in sediment loading to the Sun River at Muddy Creek is partially responsible for the change in the fishery population and water quality in the lower part of the river from predominately a salmonoid fishery above Muddy Creek to a non-salmonoid fishery in the lower reach (Chrest et al., 1987). MFWP's MFISH website rates brown trout as common in the lower 17 miles of the Sun River, with about 95 brown trout per 1,000 feet of river in 1988. This number of brown trout exceeds that of the upper Sun River between river mile 62 and 66, which had 28 brown trout per 1,000 feet. Rainbow trout were rated as rare in the lower Sun River, with 13 fish per 1,000 feet of river. The upper Sun River between river between miles 62 and 66 held 46 rainbows per 1,000 feet of river. Reclassification of at least a portion of the lower Sun River will be examined in the future. Under current standards classification the lower Sun River is considered a warm water fishery and the and therefore, no TMDL is needed at this point.

As the channel stability, riparian condition and thermal regime of Muddy Creek continue to improve as a result of conservation efforts and improved land use practices, the lower segment of the Sun River may support a healthier cold-water fishery. The health of the cold-water fishery in this segment of the Sun River also depends upon flow from the upper Sun River and climatic conditions.

The relationship of temperature to discharge during the summer of 2000 is demonstrated in Figure 10-4. During the warmest months of the year, as flow volumes decline, increases in water temperature generally occur. Below 500 cfs, average daily temperatures are reached that cause avoidance behavior in rainbow trout. Below 400 cfs, temperatures as high as 78.8 °F occurred during August 2000. Temperatures in this range have potential to affect survival, stifle growth, and cause trout to seek thermal refuge in cooler water.

A temperature TMDL is not required for the lower segment of the Sun River. This 17-mile length of the river is currently classified as B-3 and must support the growth propagation of warm-water fish. Northern Pike are used to compare existing conditions to a temperature threshold because they are a warm water species that preferres cooler temperatures than most warm water fish. The maximum weekly average temperature for growth of northern pike is 82 ºF. The short-term maximum for survival for pike is 86 ºF. It is doubtful that either of these values is surpassed. The highest in-stream temperature recorded at the Sun River near Vaughn in 2000 was 78.8 ºF (Figure 10-4). Also, the presence of brown trout and a limited number of rainbow trout is evidence that temperature conditions are suitable for salmonids at least during a portion of the year. A portion of this segment should be considered for reclassification because of the limited cold-watery fishery present here. Because the lower Sun River appears to be meeting a warm water fishery thermal regime, no TMDL is presented at this time.

Figure 10-4. Relationship Between Water Temperature and Discharge at Sun River at Vaughn USGS Site (2000).



SECTION 11.0
ROADMAP FOR ONGOING AND FUTURE RESTORATION ACTIVITIES

The Sun River Watershed is an interactive system of rivers, streams, irrigation delivery ditches, irrigation drains, lakes, reservoirs, and groundwater. Water use in one locale can impact uses in another area. This portion of the TMDL plan is intended to look at tools to restore the watershed's impaired waterbodies. At the same time, the restoration practices should fit into the regions economic and cultural characteristics and also follow all state and federal laws.

Restoration strategies for each impaired waterbody are presented below. Where information gaps exist for identifying the best restoration approaches, more knowledge will be pursued to make the best management decisions possible. Areas that are not identified as impaired in the states 303(d) list but should be addressed in order to benefit the entire watershed are Duck Creek, Big Coulee, Adobe Creek, Mill Coulee, and Willow Creek.

11.1 Ford Creek, lower segment

The landowner is engaged in a proactive land management improvement program that benefits the uplands and riparian area. By continuing to manage grazing along the stream banks, the erosion and bank instability should improve. Applying riparian grazing practices for the long term on this reach of Ford Creek is essential to meeting the TMDL.

11.2 Gibson Reservoir

Since all the land that drains into the reservoir is within national forest boundaries and most of it is a protected area, the critical component to keep sediment loading to a minimum rests with the Forest Service. The USFS continues to improve the trail system. The USFS has planned a number of controlled burn areas in the South Fork of Sun River Watershed to reduce fuels that could contribute to larger and more intense fires that could burn, in part, due to historic fire suppression.

11.3 Willow Creek Reservoir

The land surrounding this reservoir is primarily owned by the Bureau of Reclamation and managed for grazing by a group of individuals. It is crucial that the BOR continue to ensure the range health when allocating AUM levels. The Willow Creek Feeder Canal System currently contributes a significant amount of sediment to the reservoir. Under the leadership of the Lewis & Clark Conservation District and in cooperation with Bureau of Reclamation, Greenfields Irrigation District, Montana Fish, Wildlife & Parks, local landowners, and many others, an erosion control program has begun. The project began at the upper end of the erosion area and is working downstream on stabilizing techniques that will reduce erosion into the reservoir. The Reservoir was not listed for sediment in 1996 or 2002, but a restoration plan is already underway to reduce sedimentation.

11.4 Freezeout Lake

Improving the cropland management on sensitive soils and geology in the Freezeout Lake Watershed is necessary to reduce salinity, selenium and nutrient loading to the system. Irrigation water management activities such as ditch lining and improving irrigation water application efficiency will reduce loading to Freezeout Lake. If the total amount of water entering Freezeout Lake decreases, dilution and flushing rates in the Lake will be decreased and pollutant concentrations would likely increase. Therefore, irrigation water savings from the irrigation water management activities in the Freezeout Lake watershed should be monitored and the unused water should be diverted to Freezeout Lake so the overall water budget for the Lake does not decrease. If all of the water savings are not needed to meet beneficial uses and targets, unused water should be left in the Sun River. Increased diversions from the Sun River should not be used for dilution in Freezeout Lake. Monitoring the effectiveness of irrigation water management activities is crucial for furthering the understanding of restoration effects on Freezeout Lake. The Conservation Reserve Program should continue to address resting the fallow cropped lands in the Freezeout Lake watershed, and if possible, increase the percentage of land in CRP to address saline and selenium seepage from fallow cropped areas.

11.5 Upper Sun River - above Vaughn

Low in-stream flow is the biggest obstacle for meeting all uses and achieving sediment and temperature targets in the upper Sun River. In general, irrigation water management practices (IWMs) such as ditch lining and on-farm efficiency would reduce irrigation water use. The best locations to complete IWM BMP should be identified in a watershed wide water budget and irrigation efficiency analysis. Savings from any irrigation water management activities should be utilized for in-stream flow. In order to achieve in-stream flows that are likely to support aquatic life in the upper Sun River, water savings on existing irrigated acreage should not be allocated to newly irrigated land. A minimum flow regime should be achieved through the voluntary cooperation of Sun River Watershed Group members, without jeopardizing established water rights.

Improving irrigation efficiency, curbing overland irrigation water waste and improving riparian buffers on upper Sun River tributaries (Duck Creek/Big Coulee, Simms Creek, Adobe Creek, and Mill Coulee) are essential in restoring uses of the upper Sun River. Tributaries are a significant source of sediment. Adobe Creek may be a major contributor of salts. Riparian management and vegetation improvements will help stabilize stream channels. Structural components of stream channel work may be needed as a last resort in very limited areas on Duck Creek/Big Coulee. Also, irrigation diversions on the Sun River should be compatible to a healthy stream channel.

- The Duck Creek/Big Coulee tributary system has been assessed and riparian improvements and IWM are sorely needed. Stream channel degradation has occurred and mass wasting of stream banks continues.
- Adobe Creek is a contributor of salinity to the Sun River. Riparian improvements and continued lining of canals along with other IWM practices within Fort Shaw Irrigation District will reduce saline water seepage into Adobe Creek.

- Elk Creek is a minor contributor of pollution to the Sun River so any improvements to this system will be primarily a fishery habitat benefit to the Elk Creek watershed.
- Mill Coulee is also a contributor of salinity, nutrients, and sediment. Initially, addressing livestock impacts and implementing irrigation water management practices to the stream would address the largest impacts.

11.6 Muddy Creek

Many restoration activities have occurred in the Muddy Creek watershed during the past 15 years. Irrigation water management, riparian management, and stream channel work have contributed to significant improvements in water quality in Muddy Creek. Continuing these activities where cost effective approaches are feasible will further improve water quality. Muddy Creek continues to be the largest sediment contribution to the Sun River. The Greenfields Irrigation District is continuing its efforts to reduce erosion causing peak flows. A “reregulation reservoir” is being investigated to capture overland irrigation waste that currently enters Muddy Creek. Because sediment is being addressed, nutrients and salinity will begin to emerge as limiting factors. Fertilizer application on the Greenfields Bench should be inventoried and further characterized. Nutrient management planning should be implemented in the Muddy Creek Watershed. The Conservation Reserve Program should continue to address resting the crop-fallow lands in Muddy Creek watershed, and if possible, increase the percentage of land in CRP to address saline and selenium seepage from fallow cropped areas.

11.7 Lower Sun River, below Vaughn

Improving water quality in this segment depends upon improving the water quality in Muddy Creek and the upper Sun River. Land management that addresses erosion along the river corridor is still important and should be improved. The extreme lower end of this segment with unsightly urban impacts can be restored to a less spoiled setting and could be used for urban recreation. If restoration occurs in the urban area, it would be a habitat restoration issue instead of a pollutant loading issue.

SECTION 12.0
PUBLIC INVOLVEMENT

Public and stakeholder involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. Public and stakeholder involvement is desirable to ensure development of high quality, feasible plans and increase public acceptance. Montana MDEQ and the Sun River Watershed Group have collaborated throughout the duration of the Sun River Watershed TMDL development. Many of the technical citations that reference local data were funded through the Sun River Watershed Group by US EPA grants. A technical review committee that represents stakeholders in the Sun River Watershed was provided a stakeholder review draft and allowed to provide comment. See Appendix C for a list of technical committee participants. A presentation was given to the Sun River Watershed Group reviewing the contents of this document.

An additional opportunity for public involvement is the 30-day public comment period. This public review period was initiated on October 15th and closed on November 16, 2003. A stakeholder comment session and formal public meeting were held on October 22, 2003 in Great Falls. Montana provided an overview of the Water Quality Protection Plan and TMDLs for the Sun River Watershed and an opportunity to solicit public input and comments on the plan. Appendix C includes review of the public comments received from this meeting and via mail, as well as the MDEQ response to each of these comments. Many of the public comments were incorporated into this plan. MDEQ also received technical comments from USEPA and incorporated USEPA's comments into the final document.

REFERENCES

Andrews, John P. 1985a. Stream Inventory, Muddy Creek Drainage, Cascade and Teton Counties, Great Falls, Montana, 16p.

Andrews, John P. 1985b. Muddy Creek Special Water Project Final Report, Great Falls, Montana, 35p.

Apfelbeck, R. 1996. Developing Preliminary Bioassessment Protocols for Montana Wetlands. Montana Department of Environmental Quality Technical Report.

Bahls, L. 1999. Support of aquatic life uses in Ford Creek Based on Periphyton Composition and Community Structure. Report Prepared for Montana Department of Environmental Quality, 11p.

Bartholow, J. M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). U.S. Geological Survey Computer Model and Documentation. Available on the Internet at http://www.fort.sgs.gov/.

Bauder, J. Dr. 2002. Soil and Water Quality Specialist in the Department of Land Resources and Environmental Sciences at Montana State University Extension. Verbal Communication about Ongoing Water Quality and Quantity Monitoring in the Muddy Creek Watershed.

Barnes, G., and T. D. Nudds. 1991. Salt Tolerance in American Black Ducks, Mallards, and their F1 Hybrids. The Auk 108:89-98.

Bell, M. C. 1986. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fishe Passage Development and Evaluation Program. U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

Bengeyfield, P. 1999. Analysis of Reference Reach Data and the Prediction of Stream Types. Proceedings of American Water Resources Association Special Symposium of Wildland Hydrology. Bozeman, MT.

Bengeyfield, P. 2002. Unpublished Draft Analysis of Yellowstone National Park Reference Reach Data. U.S. Forest Service.

Bennatt, Todd. 2003. Permit Writer for MDEQ, Water Protection Bureau. Verbal Communication.

Bollman, W. 1998. Improving Stream Bioassessment Methods for the Montana Valley and Foothill Prairies Ecoregion. Master's Thesis (MS), University of Montana, Missoula, Montana.

Bollman, W. 1999. Biotic Health of Ford Creek: Macroinvertebrate Bioassessment. Report Prepared for Montana Department of Environmental Quality, 11p.

Bollman, W. 2001. Aquatic Invertebrates and Habitat at a Fixed Station on the Sun River, Cascade County, MT, 3p.

Bollman, W. 2002. Aquatic Invertebrates and Habitat at a Fixed Station on the Sun River, Cascade County, MT, 4p.

Chapman, D. W. 1988. Critical Review of Variables Used to Define Effects of Fines in Redds of Large Salmonids. Transactions of the American Fisheries Society 117.

Chapra, Steven C. 1997. Surface Water-Quality Modeling. WCB McGraw-Hill. 844p. Chippewa Cree Tribe. 2000. Non-point Source Assessment Report and Management Plan. Box Elder, MT.

Cherry, D. S.; K. L. Dickinson; J. Cairns, Jr., and J. R. Stauffer. 1977. Preferred, Avoided, and Lethal Temperatures of Fish During Rising Temperature Conditions. J. Fish Res. Board Can., 34: 239-246.

Chrest, K.; J. Thomas; and T. F. Wheeler. 1987. Sun River Corridor Inventory Report: United States Department of Agriculture. Soil Conservation Service, Bozeman, Montana, 25p.

Coutant, C. C. 1977. Compilation of Temperature Preference Data, J. Fish Res. Board Can. 34: 739-745.

DeMooy, C. J. and W. T. Franklin. 1977. Determination of Maximum Tolerable Salinity Levels for Continuous Irrigation on Various Soils Along the Powder River. Yellowstone-Tongue APO. Fort Collins, CO.

Everaert, Ed. 2001. Sun River: River Operating System Model. Monthly Time Step Hydrologic Model.

Everaert, Ed. 2002. Manager of the Greenfields Irrigation District, Fairfield MT. Verbal Communication.

Exner, M. E. and R. F. Spalding. 1994. N-15 Identification of Nonpoint Sources of Nitrate Contamination Beneath Cropland in the Nebraska Panhandle: Two Case Studies. Applied Geochamistry, v. 9, p. 73-81.

The Fairfield Times. 1954. Freezeout Lake, Fairfield, Montana.

The Fairfield Times. 1978. Boots and Shovels, A History of the Greenfields Irrigation District, Division of the Sun River Project, Fairfield, Montana.

Felchle Tim. 2003. USBR, Billings, MT. Reservoir Opporations. Verbal Communication.

Ferrari, R. L. 1997. Gibson Reservoir 1996 Sedimentation Survey. U.S. Bureau of Reclamation (USBOR), U.S. Department of Interior.

Forsythe, W. E. 1954. Smithsonian Physical Tables. Smithonian Miscellaneous Collections Volume 120. Publicaton 4169.

Froelich, P. N. 1988. Kinetic Control of Dissolved Phosphate in Natural Rivers and Estuaries: A Primer on the Phosphate Buffer Mechanism. Limnology and Oceanography, v. 33 (number 4 part 2), p. 649-668.

Gordon, N. D.; T. A. McMahon; and B. L. Finlayson. 1992. Stream Hydrology. An Introduction for Ecologists. John Wiley & Sons. 526p.

Gray, J. R.; G. D. Glysson; L. M. Turcios; and G. E. Schwartz. 2000. Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data. U.S. Geological Survey Water-Resources Investigations Report. 00-4191. 14p.

Hansen, B. R.; S. R. Grattan; and A. Fulton. 1999. Agricultural Salinity and Drainage. University of California Irrigation Program, University of California. Davis, Revised 1999.

Hansen, P. L.; R. D. Pfister; K. Boggs; B. J. Cook; J. Joy; and D. K. Hinckley. 1995. Classification and Management of Montana's Riparian and Wetland Sites. University of Montana. Misc. Publication #54. 646p.

Harrelson, C. C.; C. L. Rawlins; J. P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA Forest Service. General Technical Report RM-245. Fort Collins, CO.

Hill, William J. 1976. Water Quantity and Quality of the Sun River from Gibson Dam to Vaughn, 1973-1974, Helena, Montana: Montana Department of Fish and Game, F-5-R-23 & F-5-R-24, 25p.

Hill, William J.; and Alfred H. Wipperman. 1981. Northcentral Montana Fisheries Study: Inventory and Survey of Waters in the Western Half of Region Four, Montana Fish, Wildlife and Parks, F-5-R-30 I-a, 23p.

Horn, Tim. 2002. U.S. Forest Service, Lewis and Clark NF, AFMO/GIS/TIMBER Specialist, Verbal Communication.

Ingman, G. L.; E. E. Weber; and L. L. Bahls. 1984. The Effects of Muddy Creek on the Biology of the Lower Sun River, 1977-78. Helena, Montana Department of Health and Environmental Sciences, 49p.

Kendy, Eloise; David A. Nimick; John C. Malloy; and Bill Olsen. 1999. Detailed Study of Selenium in Glacial-Lake Deposits, Wetlands, and Biota Associated with Irrigation Drainage in the Southern Freezeout Lake Area, West-Central Montana, 1994-95. U.S. Geological Survey Water-Resources Investigations Report 99-4019, 59p.

Kendy, Eloise; and Bill Olsen. 1997. Physical, Chemical, and Biological Data Associated with Irrigation Drainage in the Southern Freezeout Lake Area, West-Central Montana, 1994-95. U.S. Geological Survey Open-File Report 97-349, 48p.

Klarich, D. A. and S. M. Regele. 1980. Structure, General Characteristics, and Salinity Relationships of Benthic Macroinvertebrate Associations in Streams Draining the Southern Fort Union Coalfield Region of Southeastern Montana. Montana DHES, Water Quality Bureau, Billings Regional Office, Environmental Sciences Division. USGS grant number 14-08-0001-G-503. November 1980. 148 p.

Knapton, J. R.; W. E. Jones; and J. W. Sutphin. 1988. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Sun River Area, West-Central Montana, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 87-4244, 78p.

Knopp, C. 1993. Testing Indices for Cold Water Fish Habitat. Final Report for the North Coast Regional Water Quality Control Board.

Lambing, J. H.; D. A. Nimick; J. R. Knapton; and D. U. Palawski. 1994. Physical, Chemical, and Biological Data for Detailed Study of the Sun River Irrigation Project, Freezout Wildlife Management Area, and Benton Lake National Wildlife Refuge, West-Central Montana, 1990-92. U.S. Geological Survey Open-File Report 94-120, 171p.

Leathe, Stephen A. Regional Fisheries Manager. Montana Fish, Wildlife and Parks. Great Falls. Personal Communication.

Leathe, Stephen A.; William J. Hill; Alfred Wipperman. 1988. Statewide Fisheries Investigations, Survey and Inventory of Coldwater Streams, Northcentral Montana Trout Stream Investigations. Montana Fish, Wildlife and Parks, F-46-R-1 I-g, 26p.

Lee, R. M.; and J. N. Rinne. 1980. Critical Thermal Maxima of Five Trout Species in the Southwestern United States. Trans. Amer. Fish Soc. 109: 632-635.

Lemke, R. W. 1977. Geologic Map of the Great Falls Quadrangle, Montana. U.S. Geological Survey Geologic Quadrangle map GQ-1414, scale 1:62,500.

Lemy, A. D. and G. J. Smith. 1987. Aquatic Cycling of Selenium—Implications for Fish and Wildlife. U.S. Fish and Wildlife Leaflet 12, 10p.

Leopold, L. B.; M. G. Wolman; J. P. Miller. 1964. Fluvial Processes in Geomorphology. Dover Publications, Inc., New York. 522 p.

Margalef, R. 1952. Diversidad de Espicies en las Communidades Naturales. Proc. Inst. Biol., Apl. 9: 5-27.

Maughn, C. K. 1961. Geology of the Vaughn Quadrangle, Montana. U.S. Geological Survey Map GQ-135, U.S. Geological Survey.

McDonald, C. 2000. Assessment of Water Quality for the Sun River and Muddy Creek, Sun River Watershed, West-Central Montana, Montana Bureau of Mines and Geology, Open-file Report 412, 41p.

McKee, J. E.; and H. W. Wolf, Editors. 1963. Water Quality Criteria. Second Edition. Publication 3-A, California State Water Resources Board, Sacramento. 548 p.

Miller, K. J., 2002. Ground-Water and Surface-Water Quality, Herbicide Transport, and Irrigation Practices: Greenfields Bench Aquiter, Teton County, Montana. Montana Bureau of Mines and Geology, Open-file Report 463, 178p.

McMahon, T. E.; B. A. Bear; A. V. Zale; and B. Krise. 2004. Thermal Requirements of Westslope Cutthroat Trout. Wild Fish Habitat Initiative. Montana State University. Bozeman, MT.

Mitcham, S. A. and G. Wobeser. 1998. Effects of Sodium and Magnesium Sulfate in Drinking Water on Mallard Ducklings. Journal of Wildlife Diseases. Vol. 24, p. 30-44.

Moeckel, Jason B. 1997. An Inventory of Streams on Theodore Roosevelt Memorial Ranch, Dupuyer, Montana: Implications for Livestock Grazing and Ranch Management. B.S. San Jose State University, Environmental Studies 1994 Presended in Partial Fulfillment of the Requirements for the Degree of Master of Science in Resource Conservation. The University of Montana.

Montana Department of Environmental Quality (MDEQ). 1999a. Standard Operating Procedures: Helena, Montana, Monitoring and Data Management Bureau, Available on the World Wide Web at http://deq.state.Montana.us.

Montana Department of Environmental Quality (MDEQ). 1999b. Design Standards for Wastewater Facility. Section 93.422 Cited.

Montana Department of Environmental Quality (MDEQ). 2002. Technical Basis for Draft EC and SAR Standards with Allocation. July, 2002. Helena, MT. 14 p.

Montana Department of Environmental Quality (MDEQa). State Revolving Fund- Wastewater Facility Operation and Management Inspection Files.

Montana Department of Environmental Quality (MDEQb). Montana Safe Drinking Water Information System.

Montana Fish, Wildlife, and Parks (MFWP), 1986 and 1971 fisheries data compilation in a letter from Bill Hill to John Cobb dated 2/19/98.

Montana Fish, Wildlife, and Parks (MFWP), 1989, Application for Reservations of water in the Missouri River Basin above Fort Peck Dam.

Montana Department of Fish, Wildlife and Parks (MFWP). 1997a. Water Management Plan for Freezout Wildlife Management Area. Fairfield, MT. 36 p.

Montana Department of Fish, Wildlife and Parks (MFWP). 1997b. Dewatered Streams List. Montana Department of Fish, Wildlife and Parks, Helena, MT 16p.

Montana Department of Fish, Wildlife and Parks (MFWP). 2002. Montana's Fishery Information System Reporting Database. Website Accessed on Nov, 2002. Web address: http://nris.state.mt.us/scripts/esrimap.dll?name=MFISH&Cmd=INST.

Montana Department of Fish, Wildlife and Parks (MFWP). 2004. MFISH. Montana Fisheries Information System Database Query.Available at http://nris.state.mt.us/scripts/esrimap/dll?name=MFISH&Cmd=INST (March 30, 2004).

Mount, D. R.; D. D. Gulley; J. R. Hockett; T. D. Garrison; and J. M. Evans. 1997. Statistical Models to Predict the Toxicity of Major Ions to Ceriodaphnis Dubia, Daphnia Magna and Pimephales Promelas (Fathead Minnows). Environmental Toxicology and Chemistry. Vol. 16. No. 10, pp. 2009-2019.

Mudge, M. R.; R. L. Earhart; J. W. Whipple; and J. E. Harrison. 1982. Geologic and Structure Map of the Choteau 1°x2° Quadrangle, Western Montana. Montana Bureau of Mines and Geology Montana Atlas Series MA 3-A, scale 1:250,000.

Mueller, D. K., P. A. Hamilton; D. R. Helsel; K. J. Hitt; and B. C. Ruddy. 1995. Nutrients in Ground Water of the United States - An Analysis of Data Through 1992. U.S. Geological Survey, Water Resources Investigation Report 95-4031, 74p.

Nanson, C. G.; and E. J. Hickin. 1986. A Statistical Analysis of Bank Erosion and Channel Migration in Western Canada. GSA Bulletin, v.97, p.497-504.

National Academy of Sciences, 1972. Environmental Studies Board, Water Quality Criteria.

National Technical Advisory Committee (NTAC). 1968. Water Quality Criteria. Report of the National Technical Advisory Committee on Water Quality Criteria, Federal Water Pollution Control Administration, United States Department of Interior, Washington, D.C. 234 p.

New Mexico Environmental Department (NMED). 2002. Protocol for the Assessment of Stream Bottom Deposits on Wadable Streams. New Mexico Environmental Department, Surface Water Quality Bureau. Santa Fe, New Mexico. Available at http://www.nmenv.state.nm.us/swqb/TMDL_Library.html.

Nimick, David A. 1998. Hydrologist at the U.S. Geological Survey, U.S. Department of Interior. Helena, MT. Written Communication.

Nimick, David A. 2003. Hydrologist at the U.S. Geological Survey, U.S. Department of Interior. Helena, MT. Orral Communication.

Nimick, David A.; J. H. Lambing; D. U. Palawski; and J. C. Malloy. 1996. Detailed Study of Selenium in Soil, Water, Bottom Sediment, and Biota in the Sun River Irrigation Project, Freezout Wildlife Management Area, and Benton Lake National Wildlife Refuge, West-Central Montana, 1990-92. U.S. Geological Survey Water Resources Investigations Report 95-4170, 120p.

Nystrom, K. K. G.; O. Pehrsson. 1988. Salinity as a snstraint affecting food and habitat choice of mussel feeding diveing ducks. Ibis 130:94-110.

Osborne, T. J.; R. A. Noble; M. H. Zaluski; and F. A. Schmidt. 1983. Evaluation of the Ground-Water Contribution to Muddy Creek from the Greenfields Irrigation District. Montana Bureau of Mines and Geology Open-File Report 113, 141p.

Pictorial History of the Sun River Valley. 1989. Promoter Publishing. Shelby, MT. 281p.

Pospahala, R. S.; D. R. Anderson; and C. J. Henny. 1974. Population Ecology of the Mallard, II. Breeding Habitat Conditions, Size of Breeding Populations, and Production Indicies. Bureau of Sport Fisheries and Wildlife Resource Publication 115, 73p.

PRISM Rainfall Model (Parameter-elevation Regressions on Independent Slopes) Spatial Climate Analysis Service, Directed by Dr. Christopher Daly, Assistant Professor, and the Oregon Climate Service Directed by George Taylor, State Climatologist. Both the SCAS and OCS are Located on the Oregon State University Campus in Corvallis.

Redfield, A. C. 1958. The Biological Control of Chemical Factors in the Environment. Am. Sci. 46: 205-221.

Rosgen, Dave. 1996. Applied River Morphology, Pagosa Springs, Co.

Rosgen, Dave L. 2001. A Practical Method of Computing Stream bank Erosion Rate. Published by the Federal Interagency Sedimentation Conference.

Schlepp, Mark. 2002. Montana Fish Wildlife and Parks, Wildlife Area Manager, Fairfield. Verbal Communication.

Shannon, C. E.; and W. Weaver. 1964. The Mathematical Theory of Communication. University of Illinois Press, Urbana. 135 p.

Skarr, D. 2003. Background Paper on the Effects of Sodium Salts on Aquatic Life. Montana FWP Unpublished Report. Helena, MT. 11p.

Skorupa, J. P.; and H. M. Ohlendorf. 1991. Contaminants in Drainage Water and Avian Risk Thresholds, *in* Dinar, A., and Zilberman, D., eds. The Economics and Management of Water and Drainage in Agriculture. Boston, Kluwer Academic Publishers, p. 345-368.

Sessoms H. N. and J. W. Bauder. 2002. A TMDL Approach to Muddy Creek. Unpublished. Montana State University, Department of Land Resources and Environmental Sciences. Bozeman, MT. http://waterquality.montana.edu/docs/waterquality/muddycreek.shtml.

Smith, R.A.; R.B. Alexander; G.E. Schwarz. 2003 Natural Background Concentrations of Nutrients in Streams and Reviers of the Conterminous United States. Environmental Science and Technology. 137(14):3039-3047.

Smith, R.A., G.E. Schwarz, and R.B. Alexander. 1997. Regional Interpretation of Water-Quality Monitoring Data, Water Resources Research, v. 33, no. 12, pp. 2781-2798.

Sun River Plan of Work. 1996. Prepared by NRCS and Local Sponsors.

Suplee, Mike. 2002. Milk River Nutrient Study - Preliminary Data. Montana Department of Environmental Quality (MDEQ). 2001. Helena, MT.

Swanson, G. A.; V. A. Adomaitis; F. B. Lee; J. R. Serie; and J. A. Shoesmith. 1984. Limnological Conditions Influencing Duckling Use of Saline Lakes in South-Central North Dakota. J. Wildl. Manage. 48:340-349.

Systems Technology, Inc. 1979. Muddy Creek Special Water Quality Project.Systems Technology, Inc., Helena, Montana, 88p.

Trewartha, G. T. 1968. An Introduction to Climate. McGraw Hill. New York.

U.S. Bureau of Reclimation (USBR), 2001. Standard Operating Procedure: Gibson Dam. Prepaired by MT Area Office USBR Billings Office.

U.S. Department of Inerior (USDI). 1998. A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Action at the Bull Trout Subpopulation Watershed Scale. Region 1, USFWS.

U.S. Environmental Protection Agency (USEPA). 1976. Quality Criteria for Water. Washington D.C. 256p.

U.S. Environmental Protection Agency (USEPA). 1998. Report on the Peer Consultation Workshop on Selenium Toxicity and Bioaccumulation. EPA-822-R-98-007. 57p.

U.S. Fish & Wildlife Service (USFWS). 1952. Fish Stranded by the Closure of the Pishkun Supply Canal, North Fork of the Sun River, Montana. A Cooperative Report by Missouri River Basin Studies, Fish & Wildlife Service, and the Montana Fish & Game Dept., Covering the Years of 1950 and 1951. Billings, Montana. 20 pages.

U.S. Forest Service. US Department of Agriculture. 1997. Sun Canyon Range Analysis Environmental Assessment. June, 1997.

U.S. Geologic Survey (USGS), US Department of Interior. 1998. Guidelines for Interpretations of the Biological Effects of Selected Constituents in Biota, Water, and Sediment. National Irrigation Water Quality Program Information Report #3.

U.S. Geological Survey (USGS), U.S. Department of Interior. 2002. USGS Water Resources of Montana. Internet website: http://mt.water.usgs.gov/.

Walther, K. C. 1982. Nitrates in Wells of the Greenfields Irrigation District, Fairfield, Montana: Montana Water Quality Bureau Report No. 81-1. Montana Department of Health and Environmental Sciences, Helena, Montana, 14p.

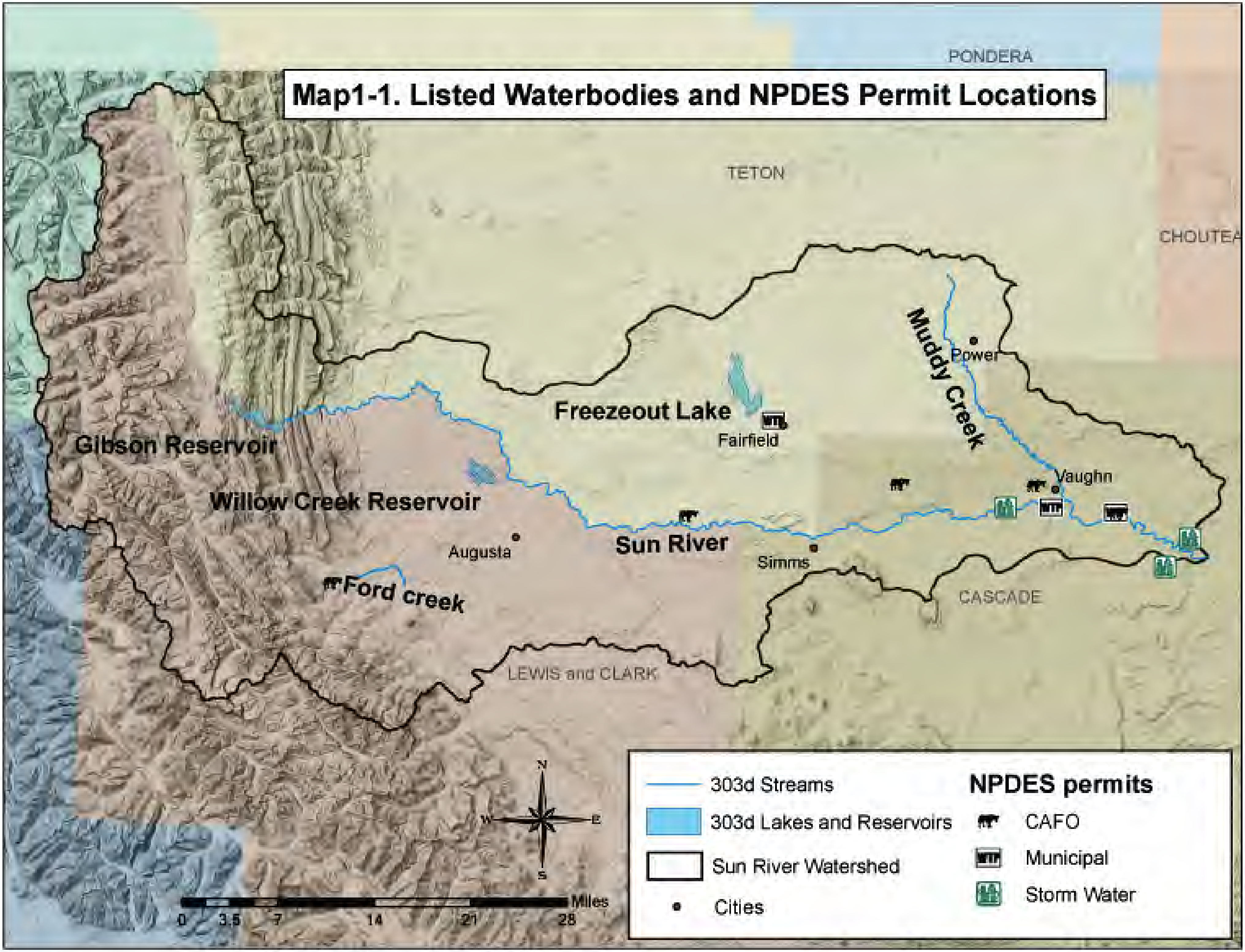
Washington Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis, Version 4.0. Washington Department of Natural Resources, Olympia, Washington.

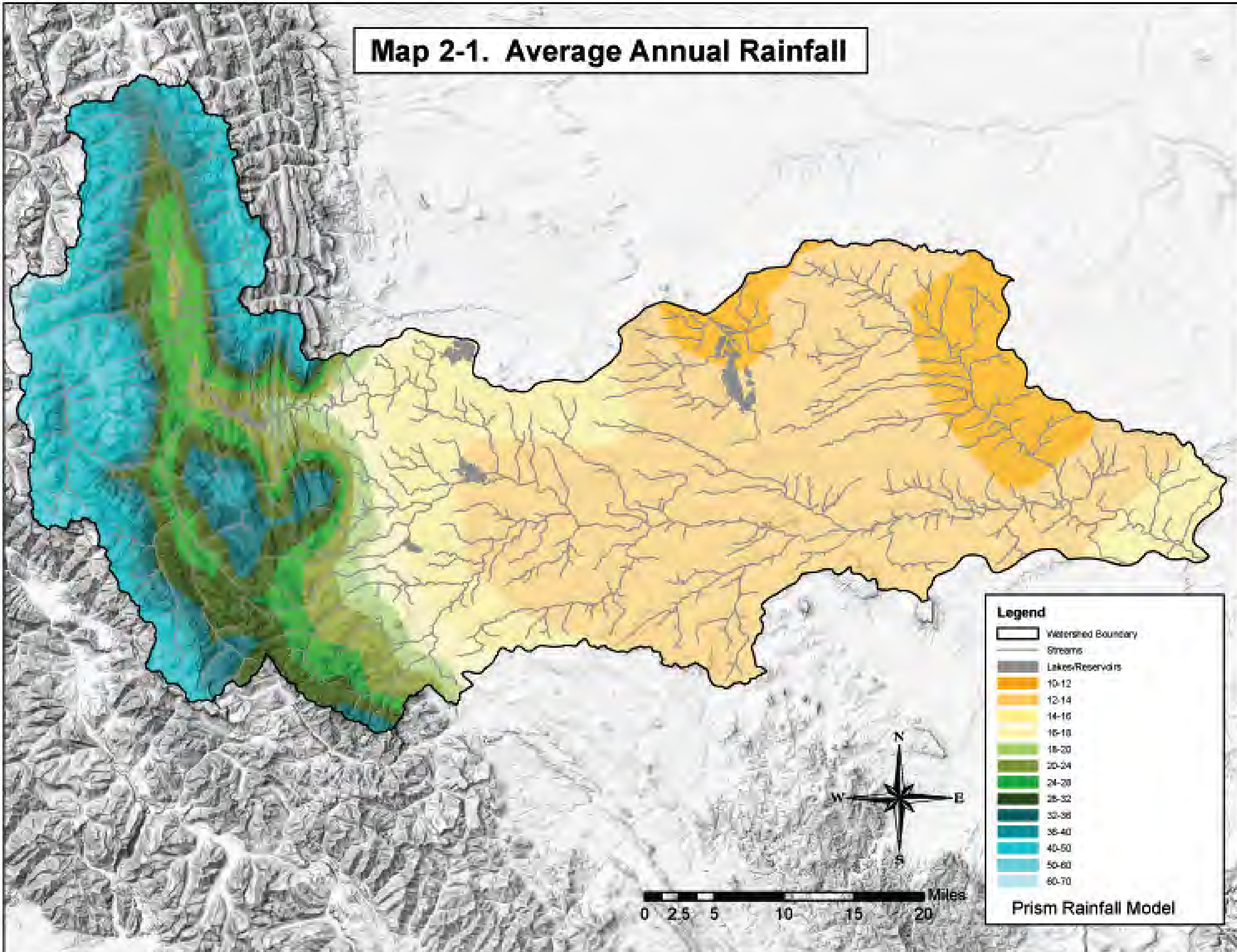
Wittler, R. J.; S. D. Keeney; A. W. Rollo. 1996. Initial Analysis of Water Quality Changes on Muddy Creek. Proceedings of the North American Water and Environmental Congress. Anaheim CA.

Wolman, M. G. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union (EOS), v. 35, p. 951-956.

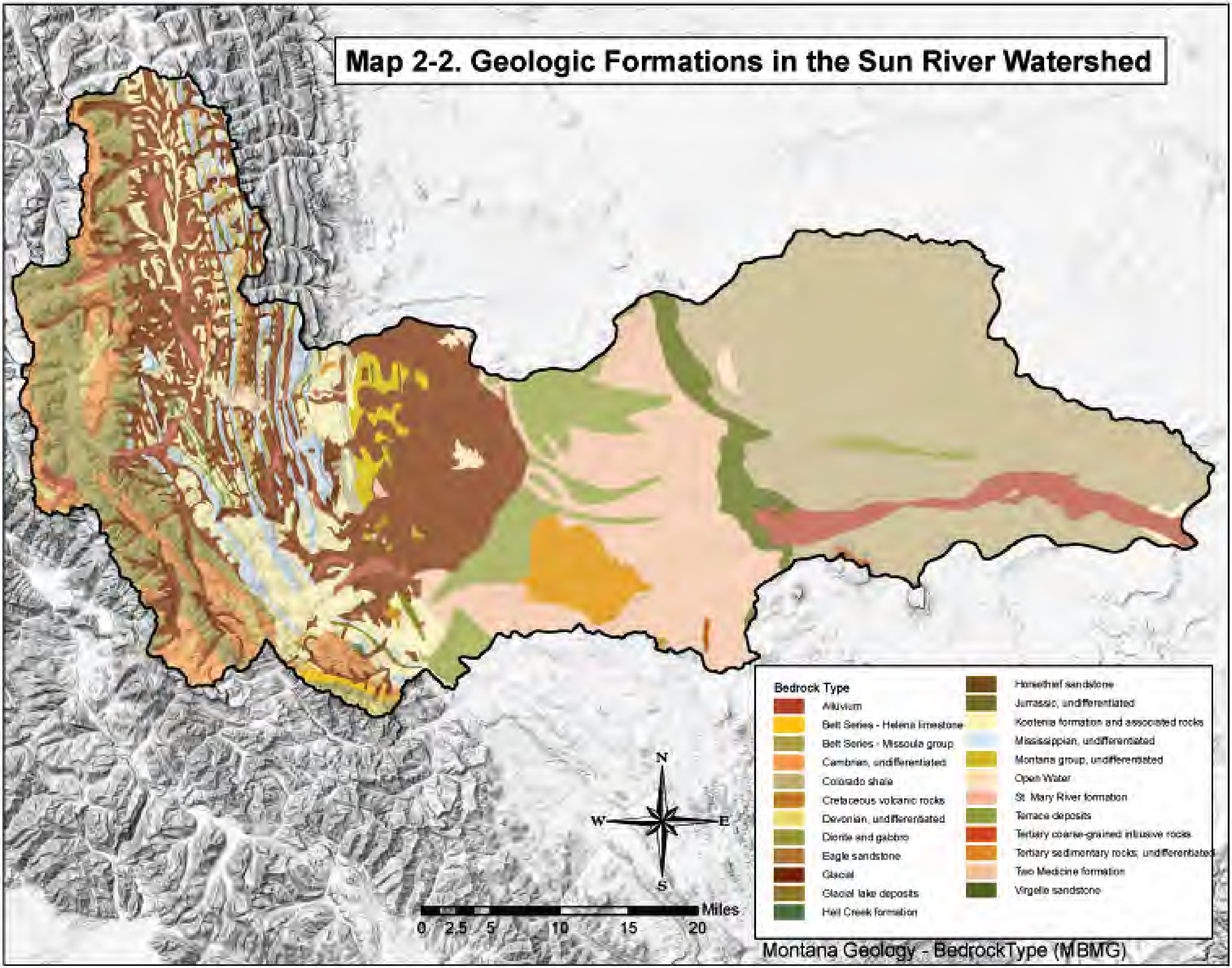
Woods, A. J.; J. M. Omernick; J. A. Nesser; J. Shelden; and S. H. Azevedo. 1999. Ecoregions of Montana (Color Poster with Map, Descriptive Text, Summary Tables, and Photographs): Reston, VI, USGS (map scale 1:1,500,000).

Zaroban, D. W.; and D. D. Sharp. 2001. Palisades Subbasin Assessment and Total Maximum Daily Load Allocations. Idaho DEQ, Appendix C.

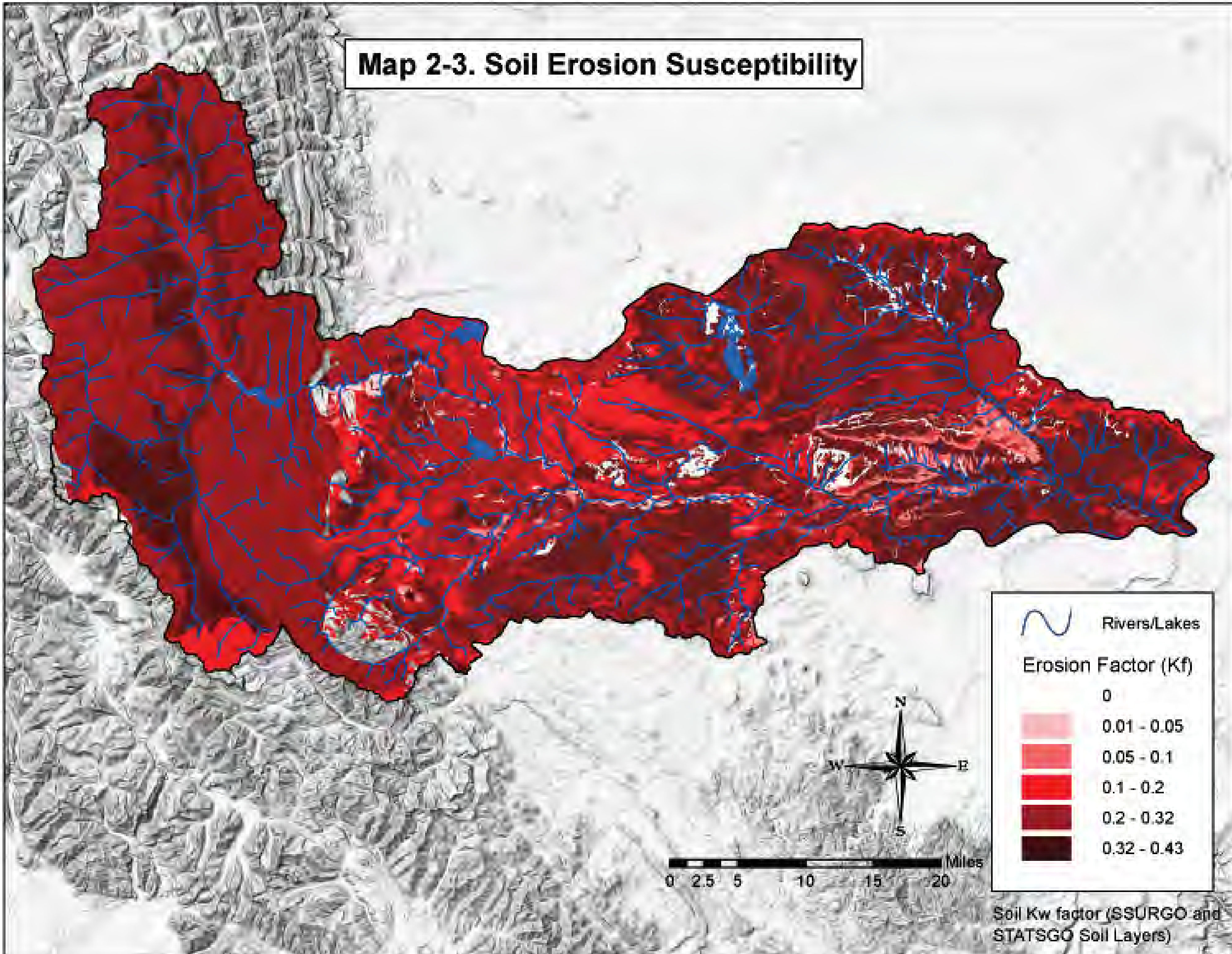

Map1-1. Listed Waterbodies and NPDES Permit Locations
PONDERA
TETON
CHOUTEA
Muddy Creek
Power
Freezeout Lake
Fairfield
Gibson Reservoir
Willow Creek Reservoir
Vaughn
Sun River
Augusta
Simms
Ford creek
CASCADE
LEWIS and CLARK
N
W
E
S
0
3.5
7
14
21
28
Miles
303d Streams
303d Lakes and Reservoirs
Sun River Watershed
Cities
NPDES permits
CAFO
Municipal
Storm Water



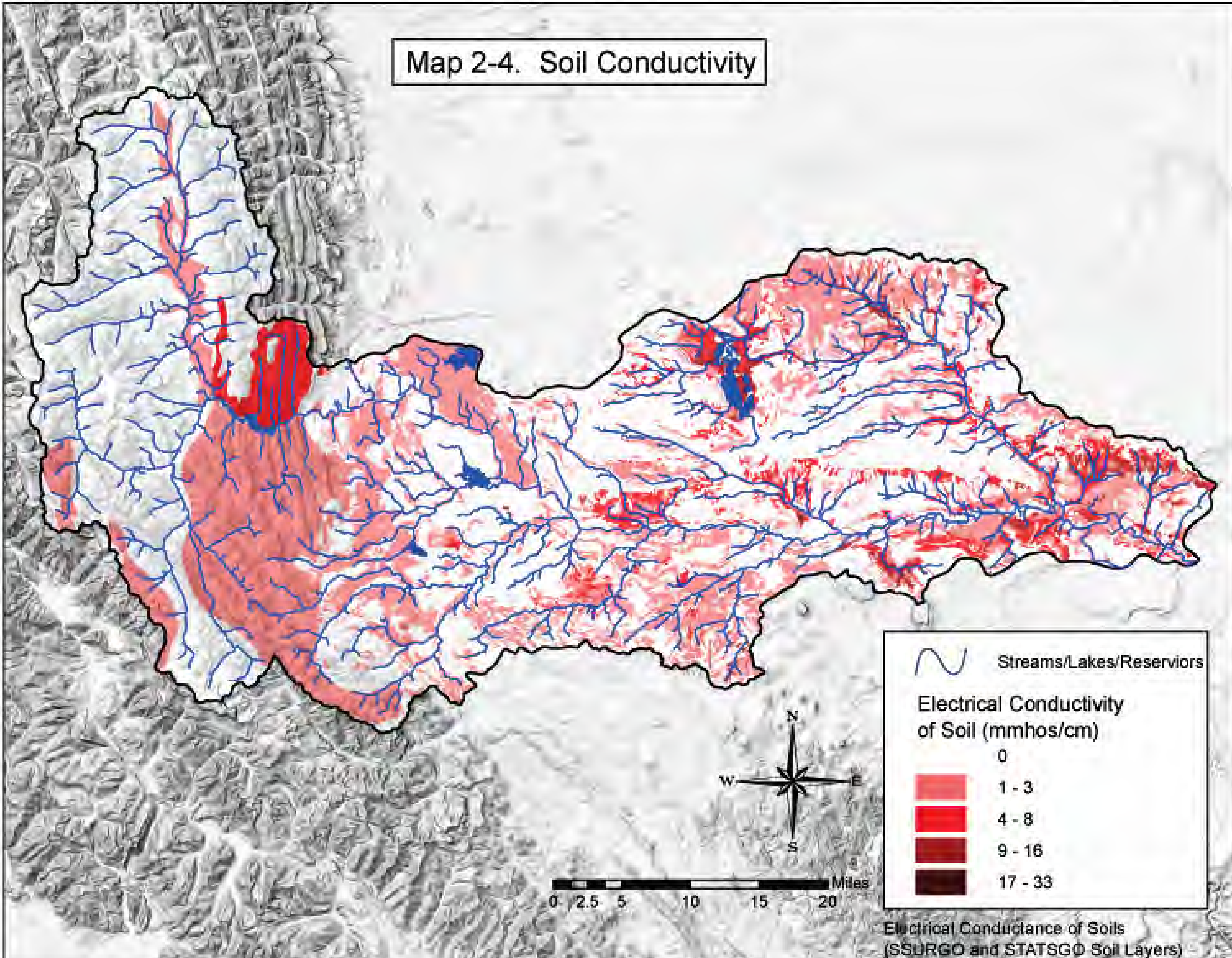
Map 2-1. Average Annual Rainfall
Legend
Watershed Boundary
Streams
Lakes/Reservoirs
10-12
12-14
14-16
16-18
18-20
20-24
24-28
28-32
32-36
36-40
40-50
50-60
60-70
Prism Rainfall Model
N
W
E
S
Miles
0
2.5
5
10
15
20



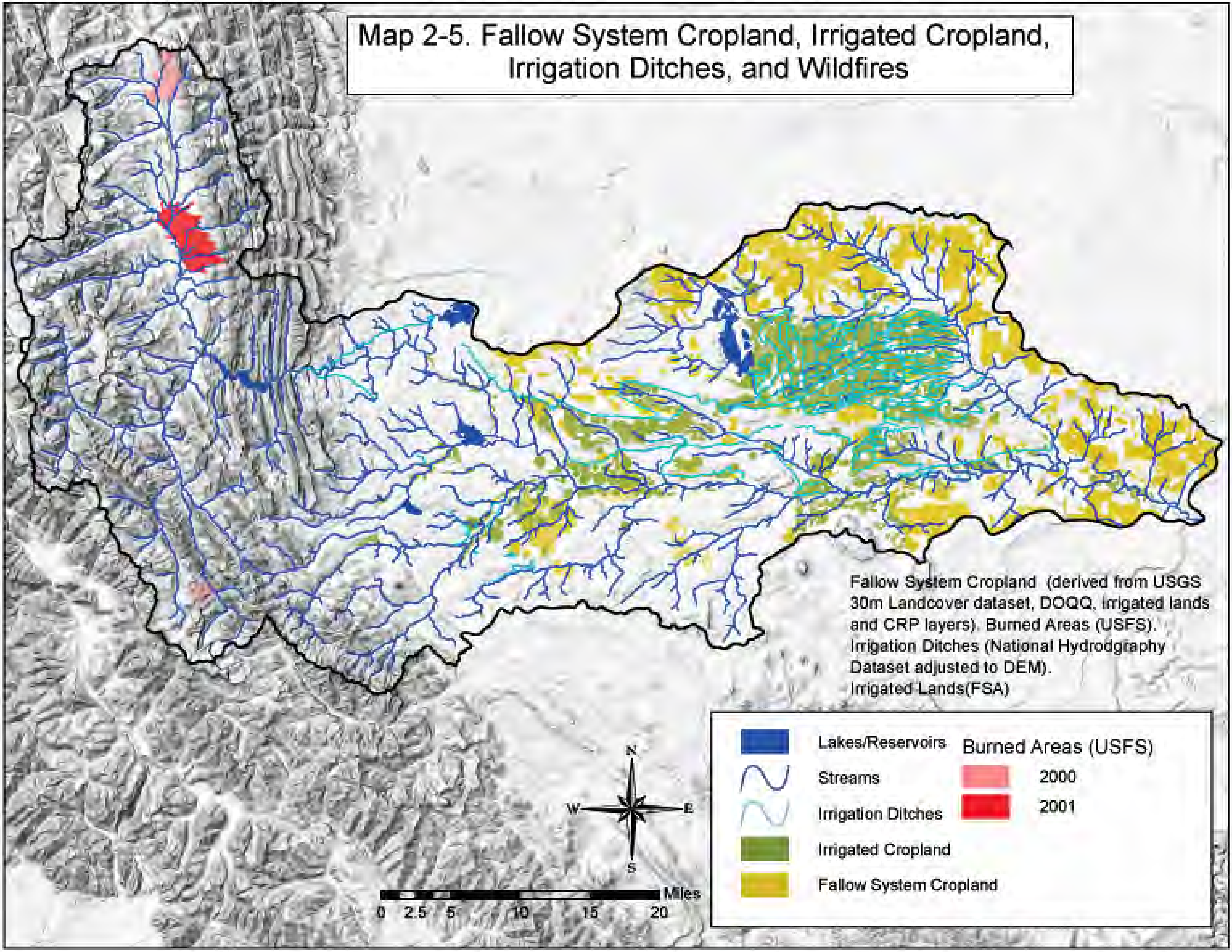
Map 2-2. Geologic Formations in the Sun River Watershed
Bedrock Type
Alluvium
Belt Series - Helena limestone
Belt Series - Missoula group
Cambrian, undifferentiated
Colorado shale
Cretaceous volcanic rocks
Devonian, undifferentiated
Diorite and gabbro
Eagle sandstone
Glacial
Glacial lake deposits
Hell Creek formation
Horsethief sandstone
Jurassic, undifferentiated
Kootenia formation and associated rocks
Mississippian, undifferentiated
Montana group, undifferentiated
Open Water
St. Mary River formation
Terrace deposits
Tertiary coarse-grained intrusive rocks
Tertiary sedimentary rocks, undifferentiated
Two Medicine formation
Virgelle sandstone
N
W
E
S
Miles
0 2.5 5 10 15 20
Montana Geology - BedrockType (MBMG)

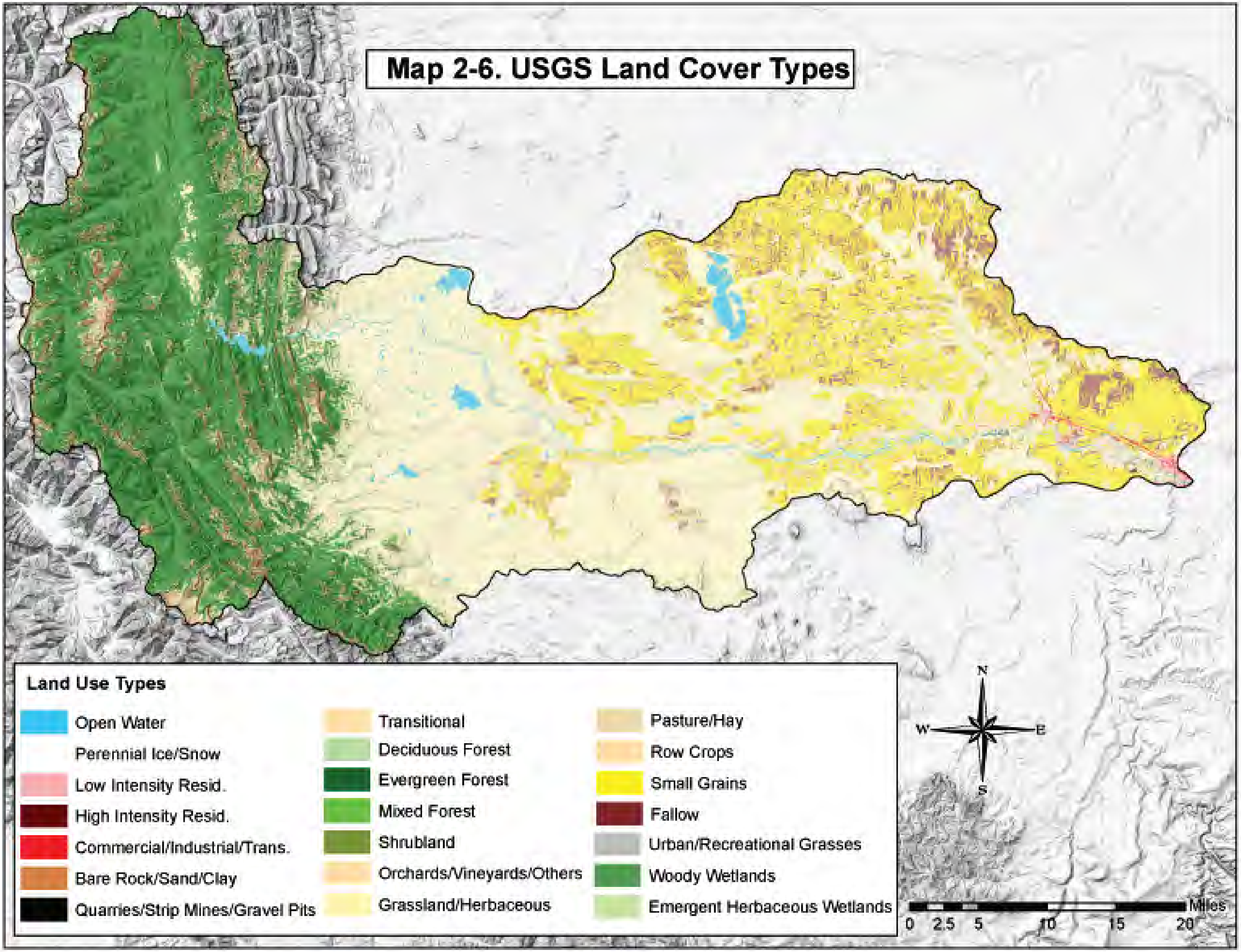


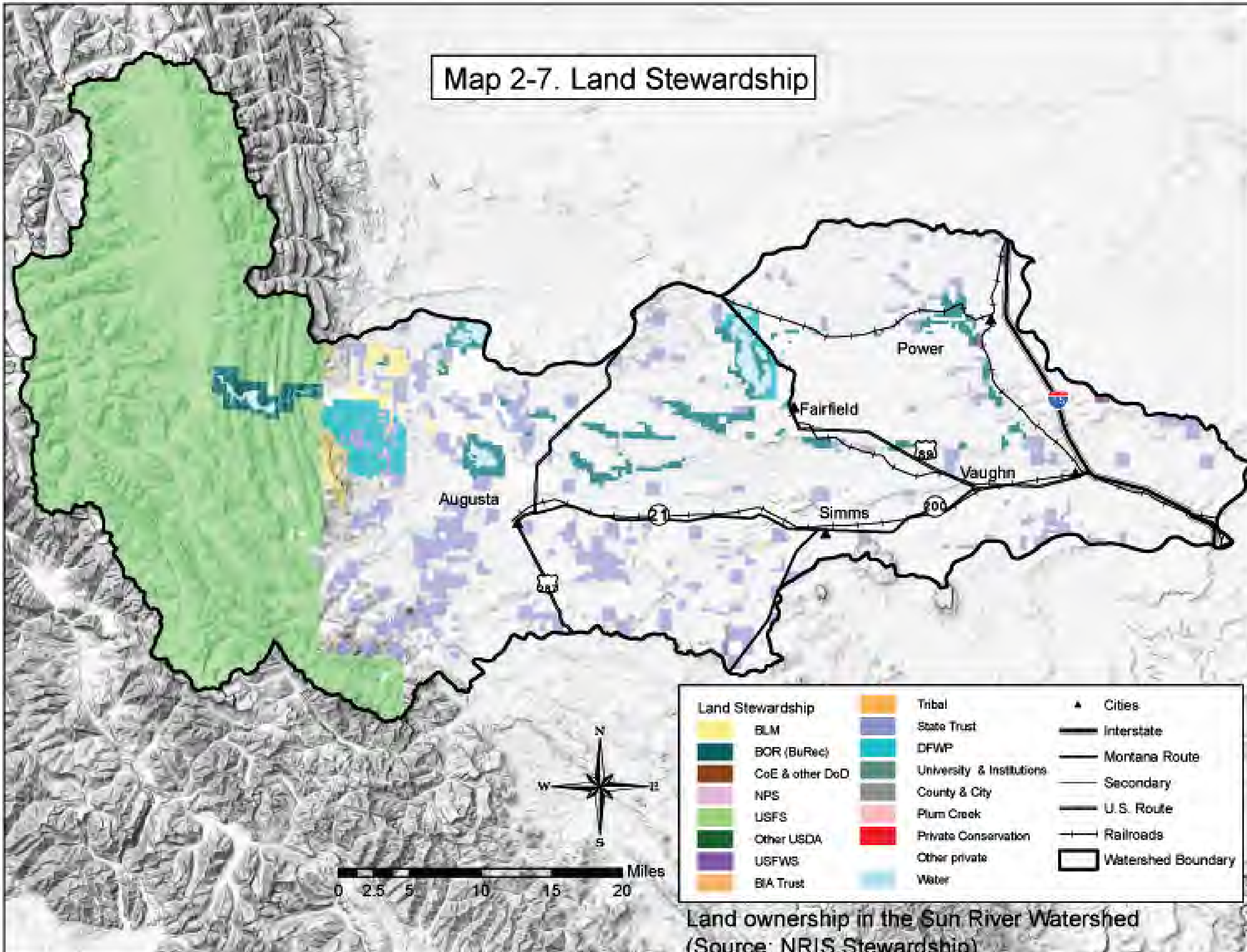
Map 2-3. Soil Erosion Susceptibility
Rivers/Lakes
Erosion Factor (Kf)
0
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.32
0.32 - 0.43
N
W
E
S
Miles
0 2.5 5 10 15 20
Soil Kw factor (SSURGO and STATSGO Soil Layers)



Map 2-4. Soil Conductivity
Streams/Lakes/Reserviors
Electrical Conductivity
of Soil (mmhos/cm)
0
1 - 3
4 - 8
9 - 16
17 - 33
N
W
E
S
Miles
0
2.5
5
10
15
20
Electrical Conductance of Soils
(SSURGO and STATSGO Soil Layers)

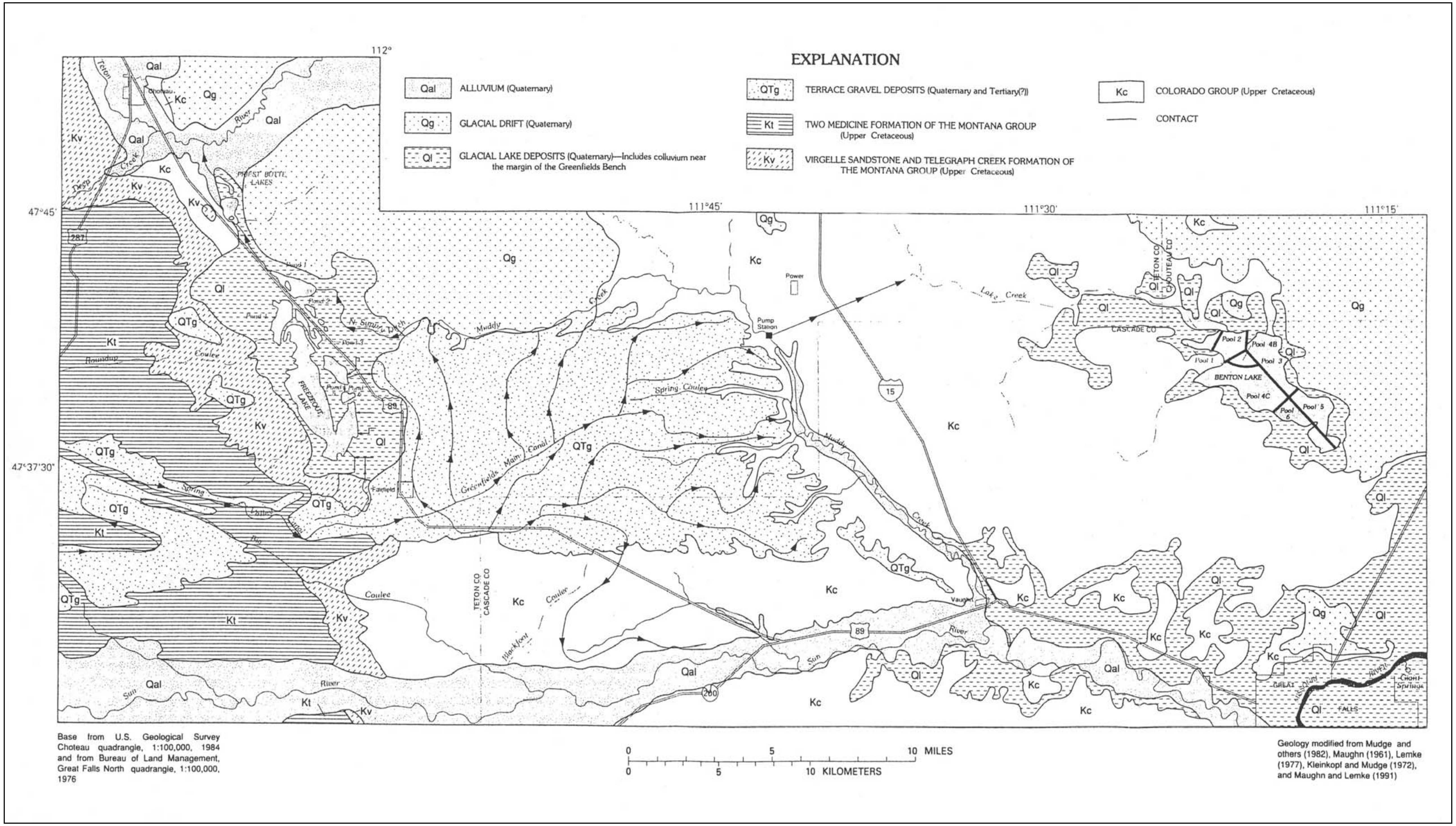

Map 2-5. Fallow System Cropland, Irrigated Cropland, Irrigation Ditches, and Wildfires
Fallow System Cropland (derived from USGS 30m Landcover dataset, DOQQ, irrigated lands and CRP layers). Burned Areas (USFS). Irrigation Ditches (National Hydrodgraphy Dataset adjusted to DEM). Irrigated Lands(FSA)
Lakes/Reservoirs
Streams
Irrigation Ditches
Irrigated Cropland
Fallow System Cropland
Burned Areas (USFS)
2000
2001
N
W
E
S
Miles
0
2.5
5
10
15
20


Map 2-6. USGS Land Cover Types
Land Use Types
Open Water
Perennial Ice/Snow
Low Intensity Resid.
High Intensity Resid.
Commercial/Industrial/Trans.
Bare Rock/Sand/Clay
Quarries/Strip Mines/Gravel Pits
Transitional
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrubland
Orchards/Vineyards/Others
Grassland/Herbaceous
Pasture/Hay
Row Crops
Small Grains
Fallow
Urban/Recreational Grasses
Woody Wetlands
Emergent Herbaceous Wetlands
N
W
E
S
Miles
0 2.5 5 10 15 20

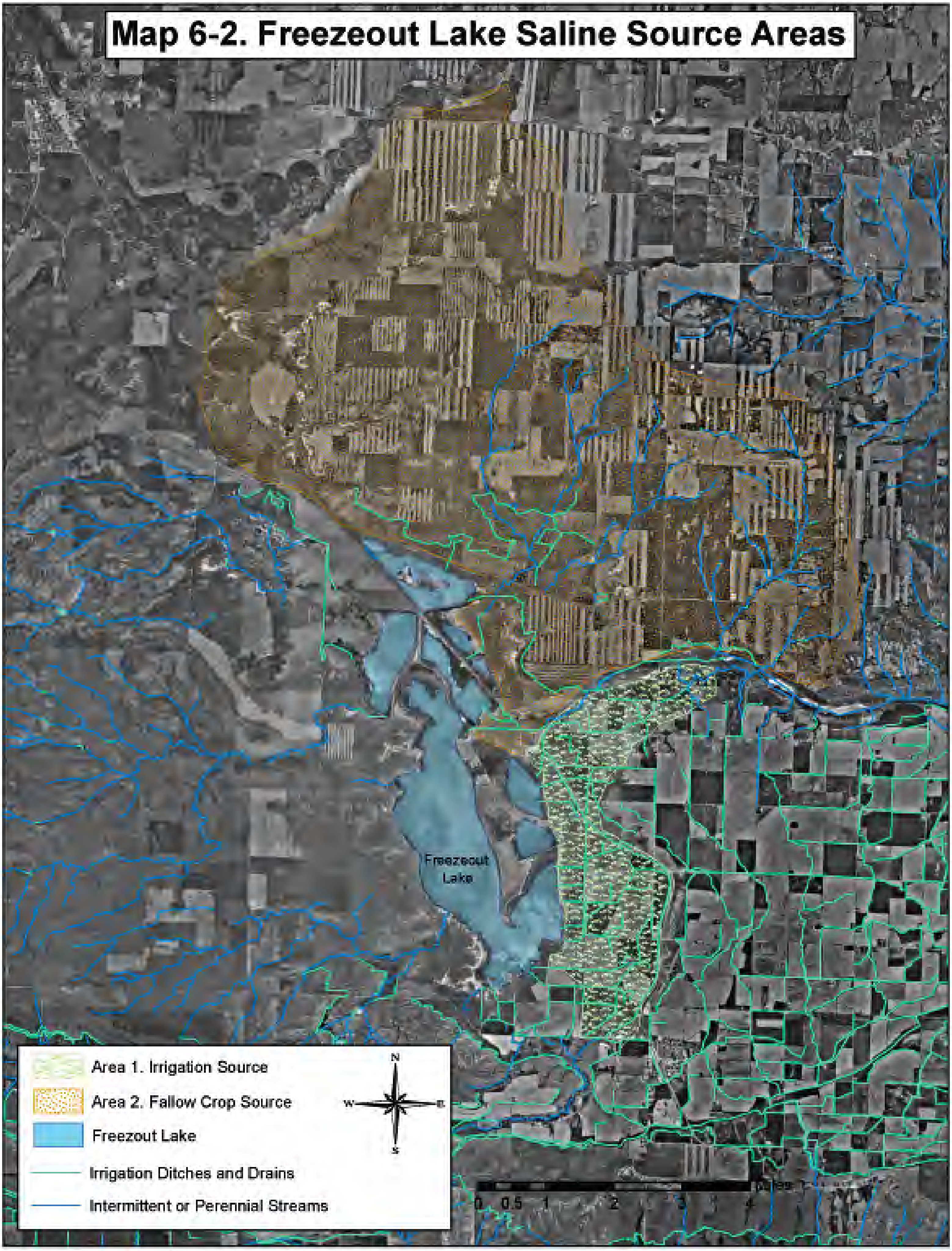


Land ownership in the Sun River Watershed
(Source: NRIS Stewardship)

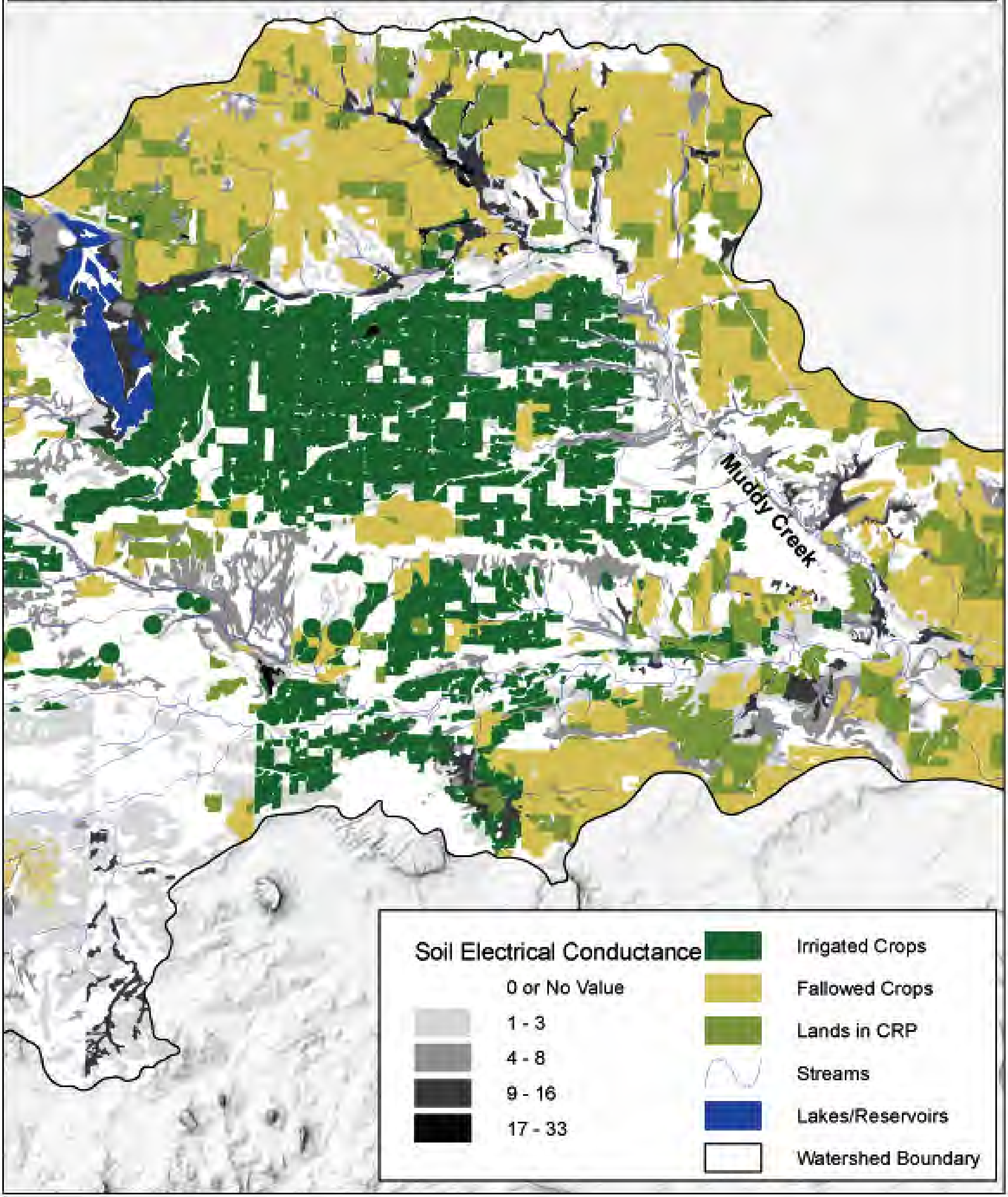
Map 6-1. Geology of the Greenfield Bench, Freezeout Lake and Muddy Creek areas. (from Nimick et al, 1996)

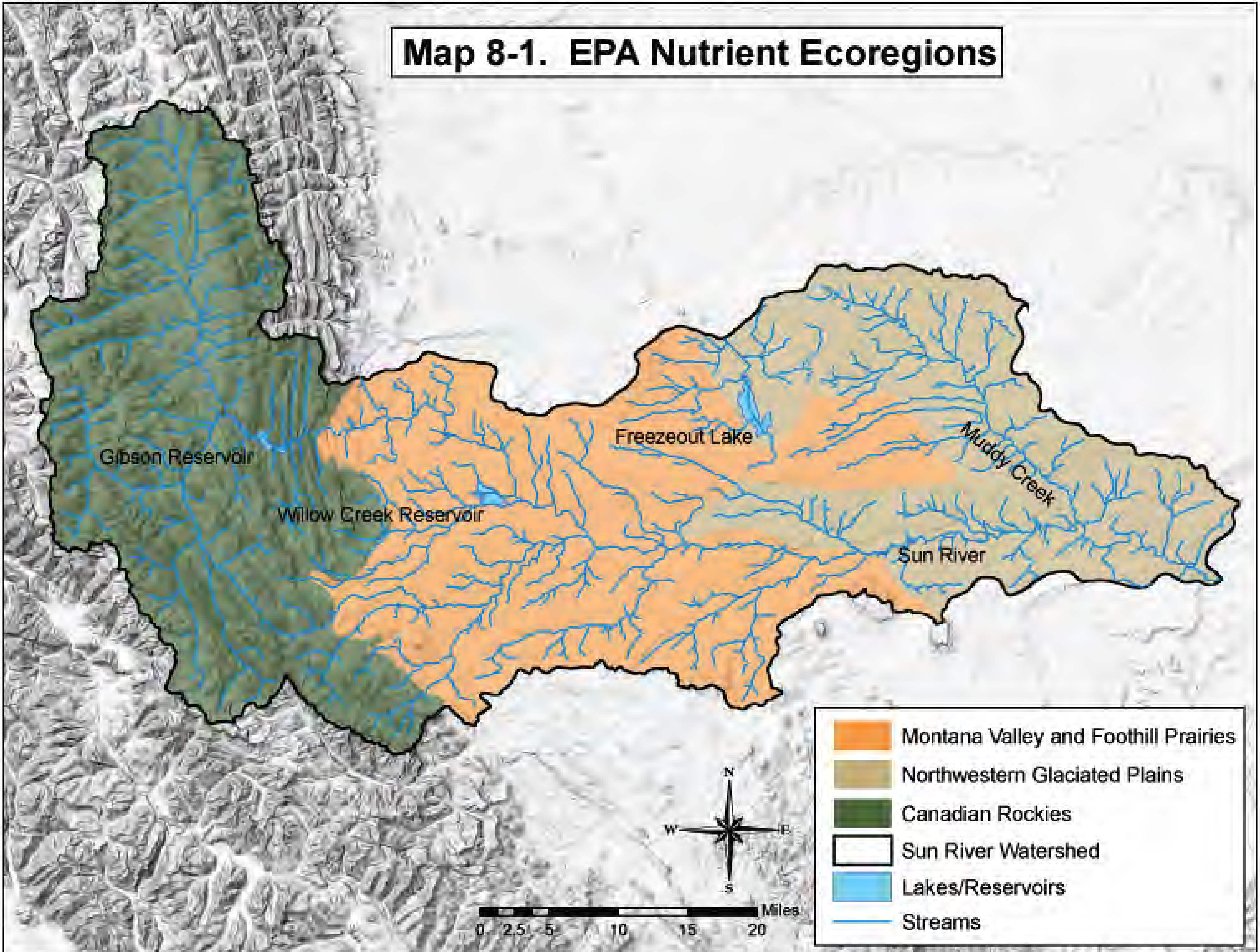


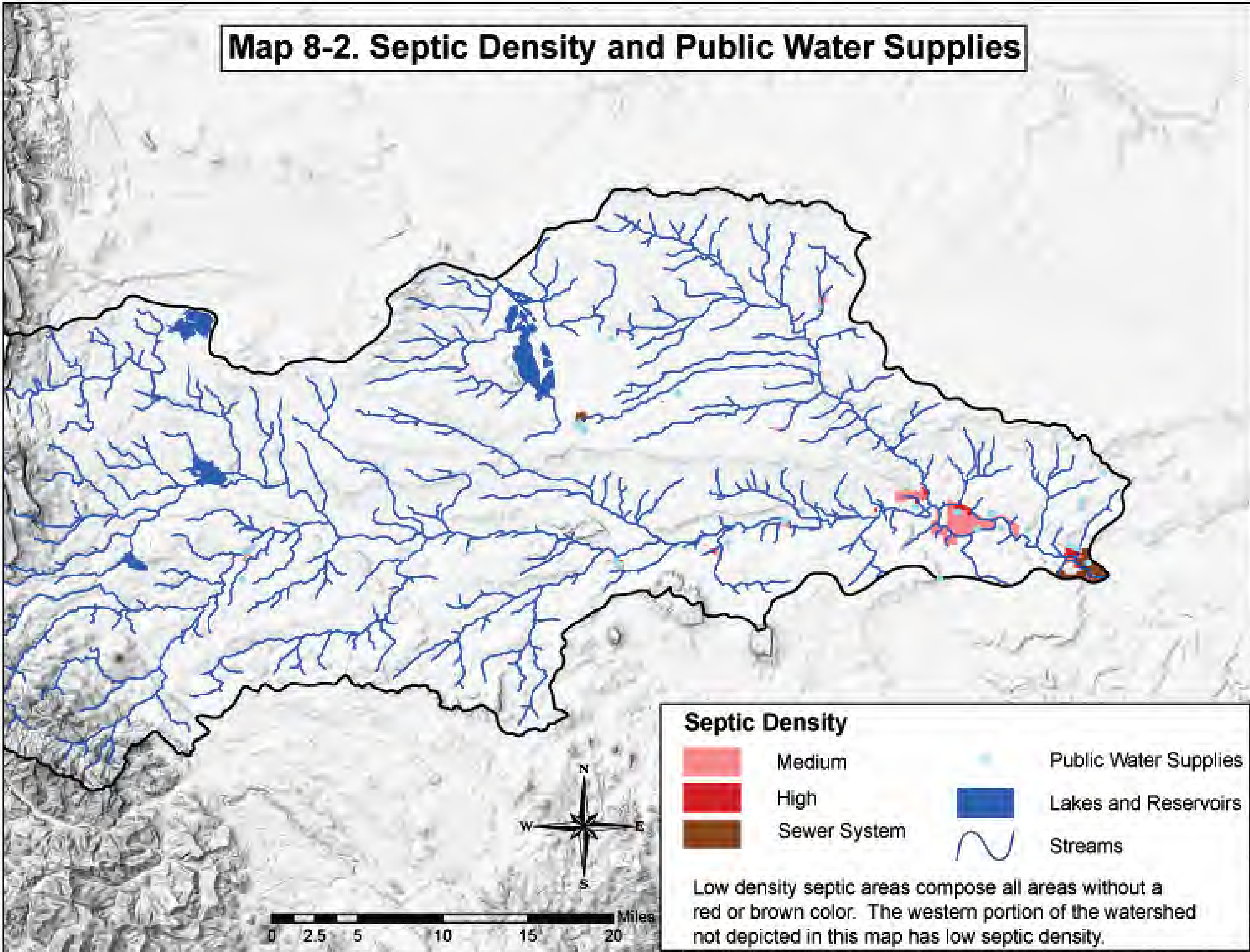
Map 6-2. Freezeout Lake Saline Source Areas



Map 6-3. Saline Sources and Soil Electrical Conductance in Muddy Creek and Freezout Lake Watersheds




Map 8-1. EPA Nutrient Ecoregions
Gibson Reservoir
Willow Creek Reservoir
Freezeout Lake
Muddy Creek
Sun River
Montana Valley and Foothill Prairies
Northwestern Glaciated Plains
Canadian Rockies
Sun River Watershed
Lakes/Reservoirs
Streams
N
W
E
S
Miles
0 2.5 5 10 15 20


Map 8-2. Septic Density and Public Water Supplies
Septic Density
Medium
High
Sewer System
Public Water Supplies
Lakes and Reservoirs
Streams
Low density septic areas compose all areas without a red or brown color. The western portion of the watershed not depicted in this map has low septic density.
N
W
E
S
Miles
0
2.5
5
10
15
20

APPENDIX A
EPA NUTRIENT ECOREGION DESCRIPTIONS

Montana Valley and Foothill Prairies (nutrient region II / ecoregion 16):
The *Montana Valley and foothill Prairies* is a region characterized by short grass prairie but is unlike other grassland-type ecoregions in the Great Plains because of the close proximity to nearby high forested mountains which feed the region with many perennial streams, resulting in a different mosaic of terrestrial and aquatic fauna. Most of the region is farmed and many parts of the valleys have been irrigated. Grazing of beef cattle and sheep is prevalent in the region, even in the forested parts of the foothills. The middle 3rd of the Sun River Watershed lies within this ecoregion.

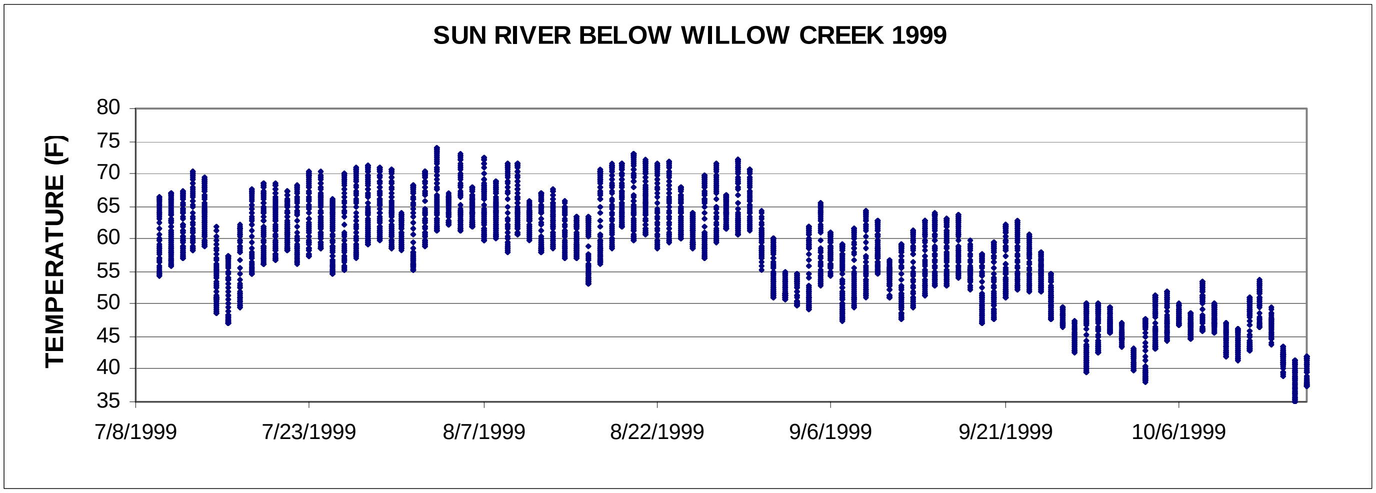
Canadian Rockies (nutrient region II / ecoregion 41):
Most of this region is located in Canada and extends southeast into northwestern Montana. This region is generally higher and more ice covered than the Northern Rockies ecoregion. Vegetation is mostly Douglas fir, spruce, and lodgepole pine at lower elevations and alpine fir at middle elevations. The higher elevations are treeless alpine. A large part of the region is in national parks where tourism is the major use. Forestry and mining occur on the non-park lands. The western 3rd of the Sun River Watershed lies in this ecoregion, much of this area is designated as wilderness. Nutrient criteria are not used from this region because of the extreme contrast from the *Northwestern Glaciated Plains* ecoregion in which the Lower Sun River lies.

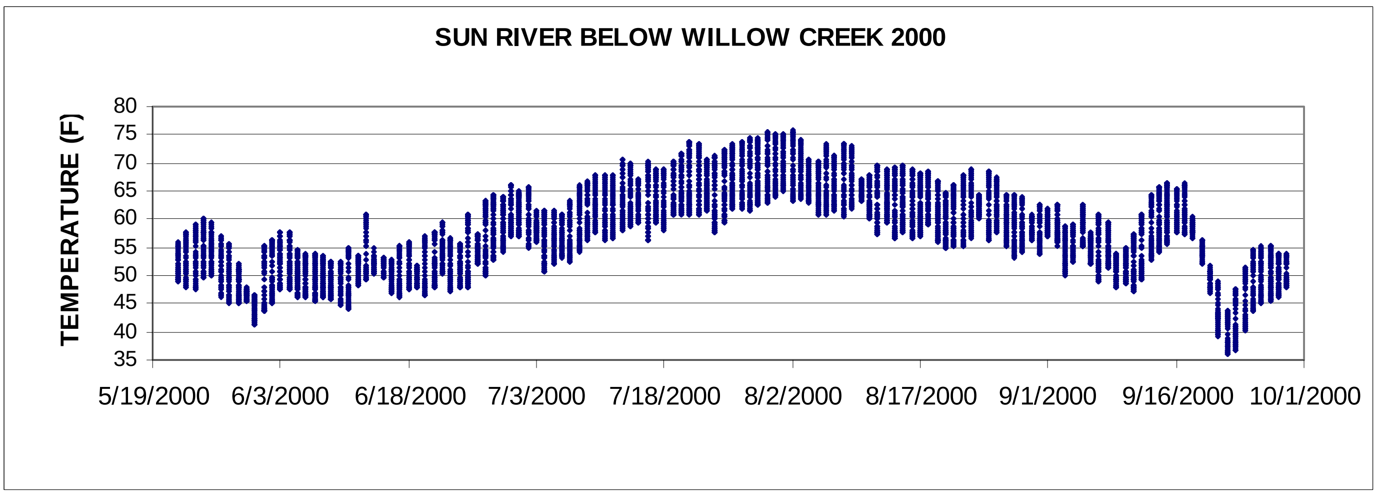
Northwestern Glaciated Plains (nutrient region V / ecoregion 42):
The *Northwestern Glaciated Plains* are transitional between the generally more level, moister, more agricultural *Northern Glaciated Plains* to the east, the typically more irregular and drier *Northwestern Great Plains* to the south, and the more hilly *Montana Valley and Foothill* Prairies to the west. The southern boundary of the *Northwestern Glaciated Plains* is near the limit of continental glaciation and its soils are derived from glacial drift. Hummocky moraines locally occur and are characterized by seasonal and semi-permanent ponds and wetlands. Land use is devoted to cattle and small grain ranching and farming. The eastern 3rd of the Sun River lies within this ecoregion. The Lower Sun River lies in this region. Sample sizes available to EPA for this ecoregion are very small and therefore the criteria given by EPA are inexact.

Northwestern Great Plains (nutrient region VI/ ecoregion 43):
The *Northwestern Great Plains Ecoregion* encompasses the Missouri Plateau section of the Great Plains. It is a semiarid rolling plain of shale and sandstone punctuated by occasional buttes. Native grasslands, largely replaced on level ground by spring wheat and alfalfa, persist in rangeland areas on broken topography. Agriculture is restricted by the erratic precipitation and limited opportunities for irrigation. This ecoregion lies to the southwest of the Sun River Watershed and is being used as a supplement to the weakly supported nutrient guidance of the *Northwestern Glaciated Plains*.

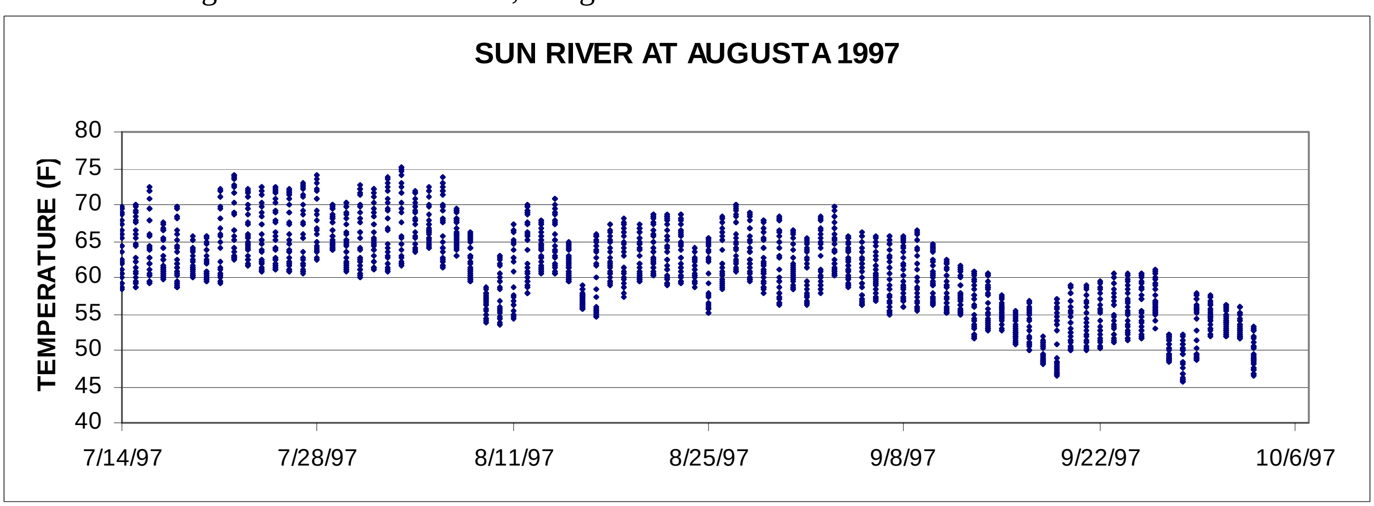
APPENDIX B
CONTINUOUS TEMPERATURE DATA ANALYSIS

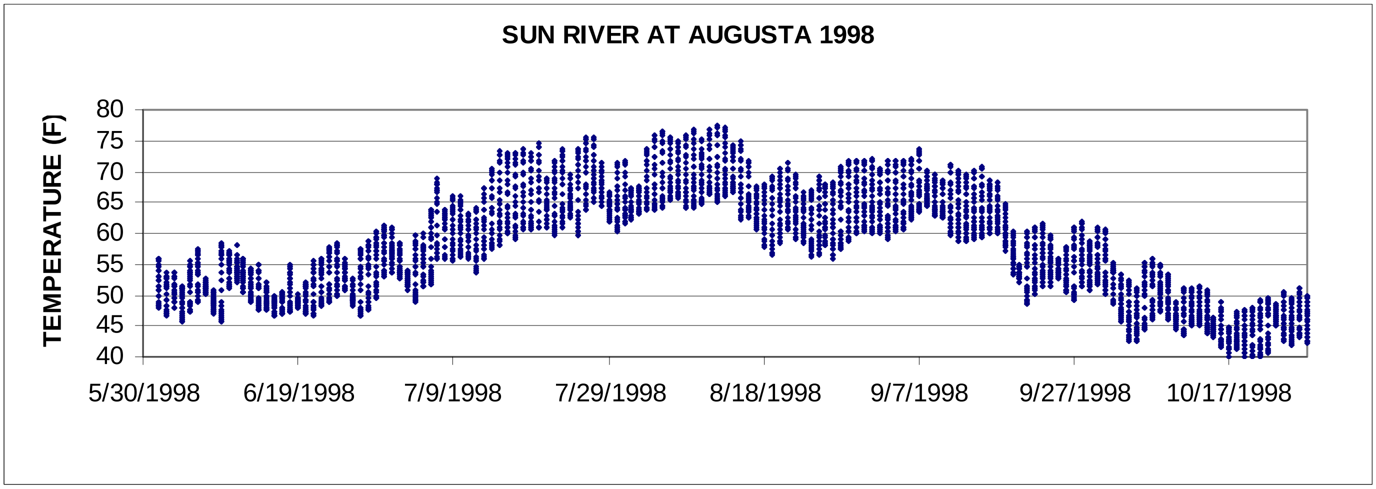
Sun River below Willow Creek. Latitude 47-36-14, Longitude 112-25-45

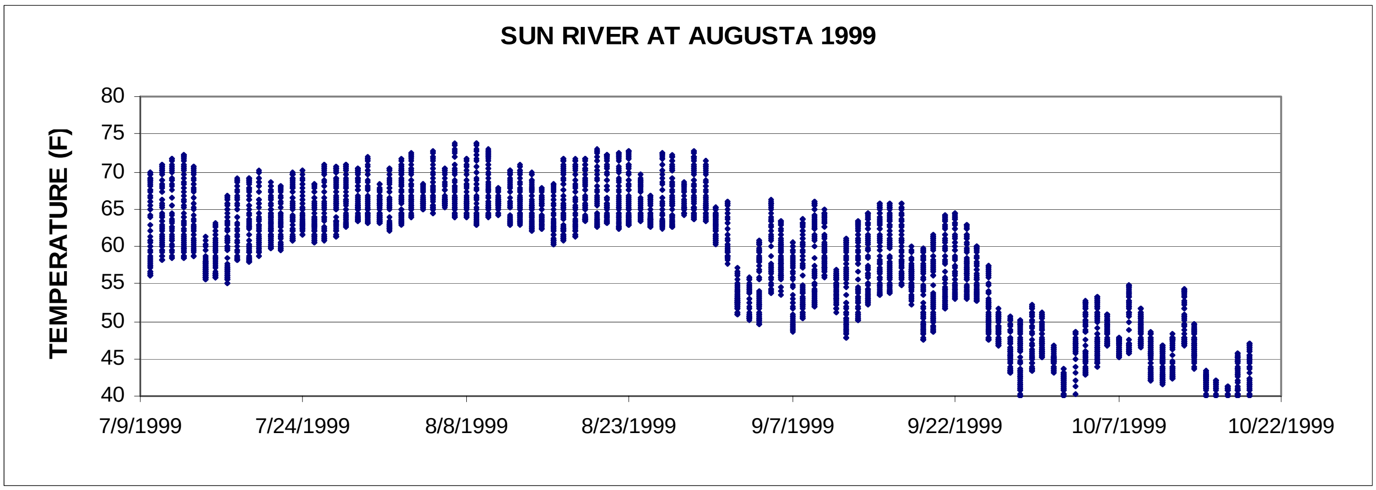


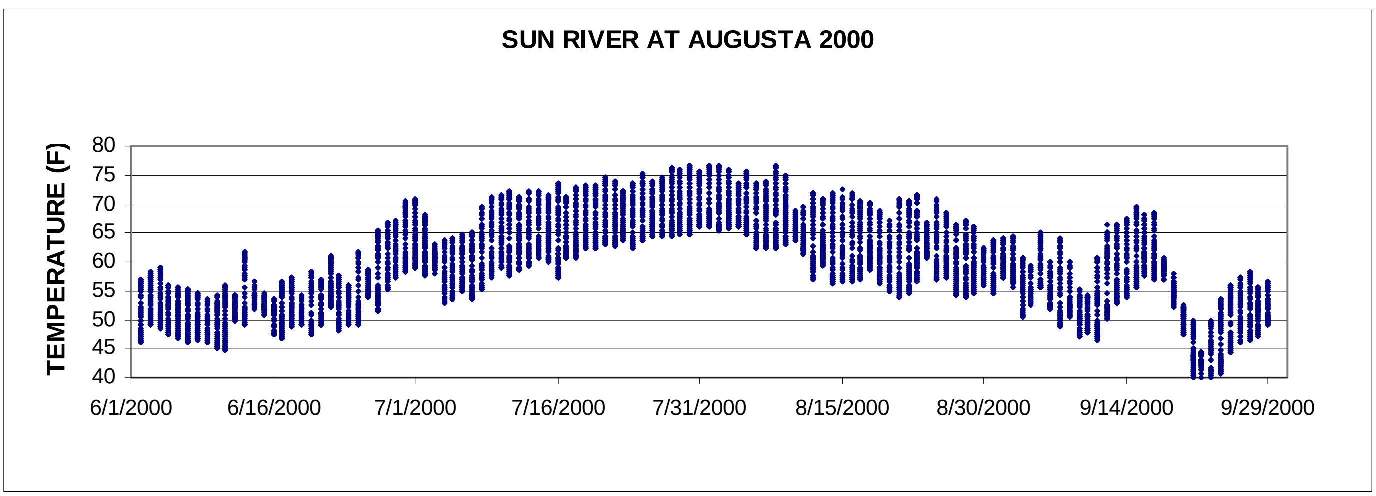


Sun River at Augusta. Latitude 47 32 50, Longitude 112 21 44




SUN RIVER AT AUGUSTA 1998
TEMPERATURE (F)
80
75
70
65
60
55
50
45
40
5/30/1998
6/19/1998
7/9/1998
7/29/1998
8/18/1998
9/7/1998
9/27/1998
10/17/1998


SUN RIVER AT AUGUSTA 1999
TEMPERATURE (F)
80
75
70
65
60
55
50
45
40
7/9/1999
7/24/1999
8/8/1999
8/23/1999
9/7/1999
9/22/1999
10/7/1999
10/22/1999


SUN RIVER AT AUGUSTA 2000
TEMPERATURE (F)
80
75
70
65
60
55
50
45
40
6/1/2000
6/16/2000
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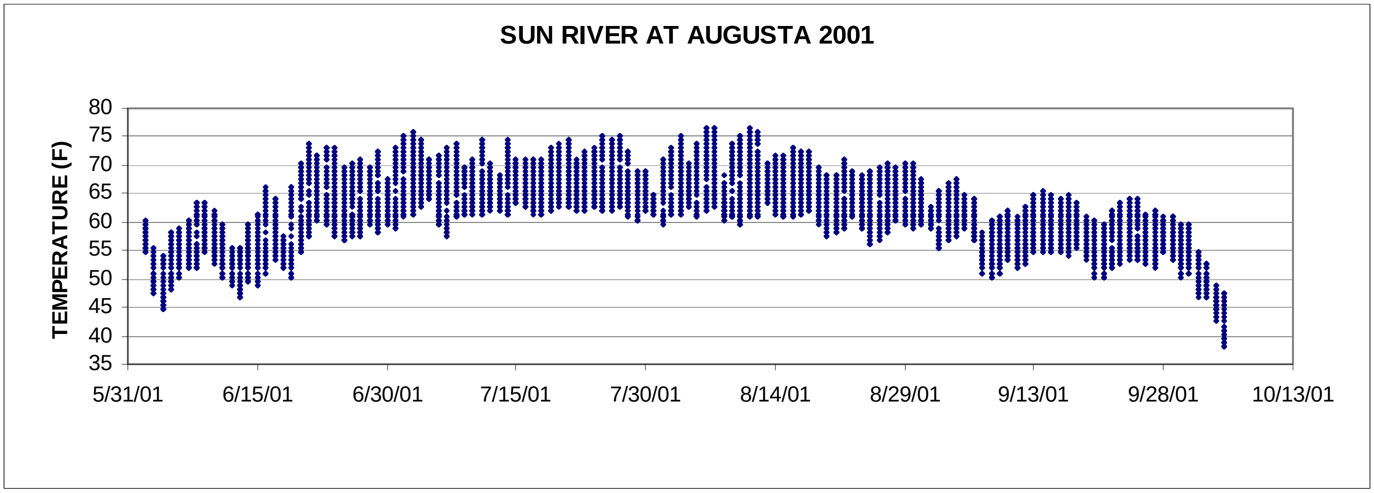
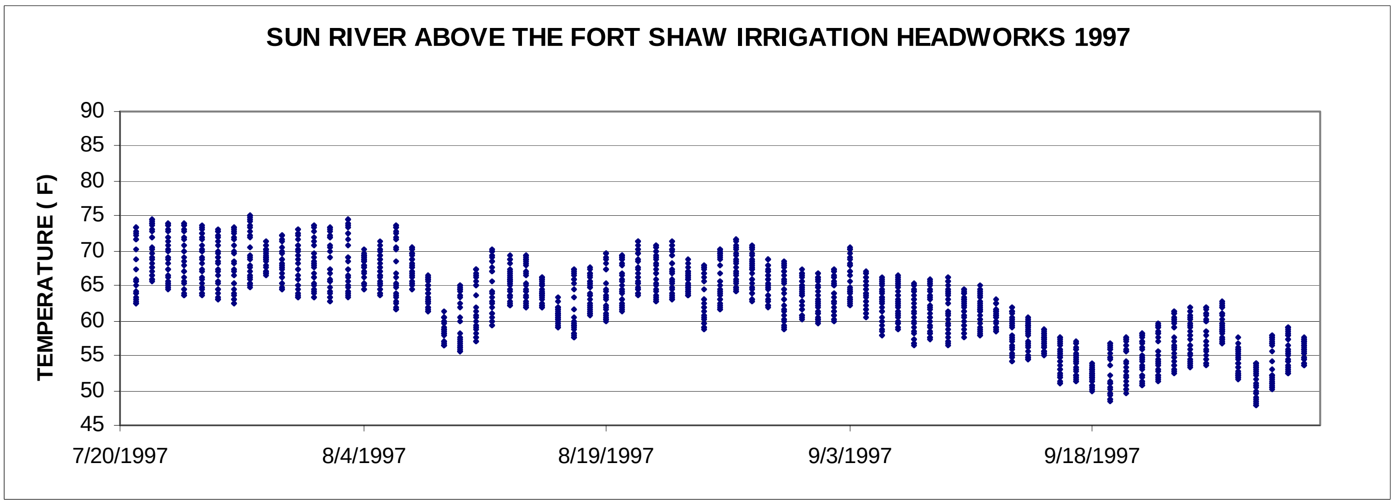
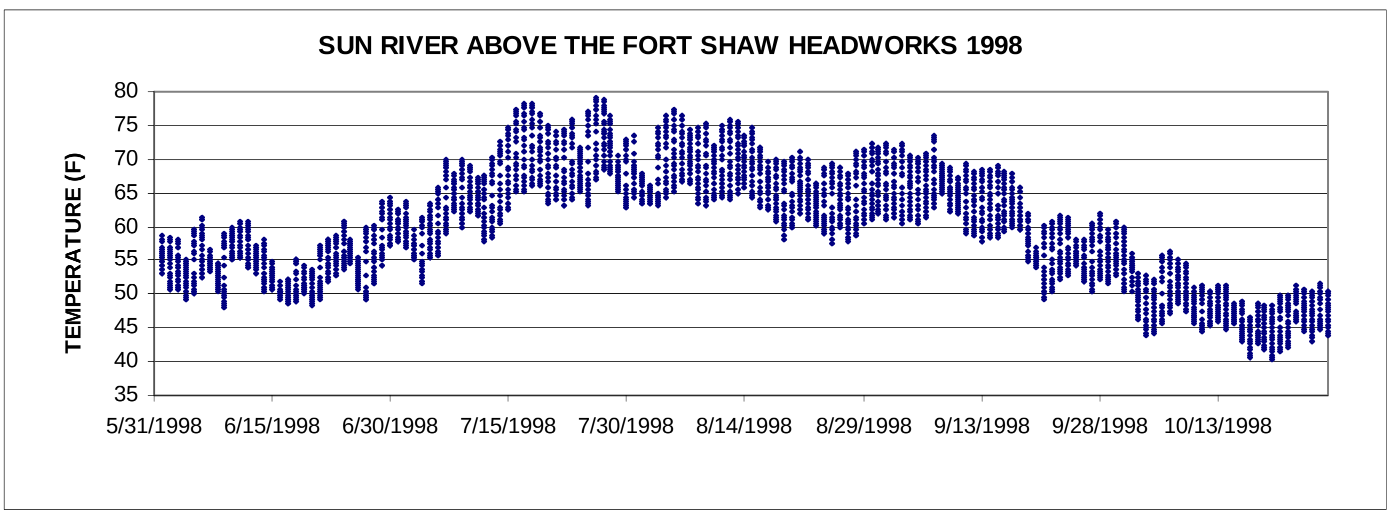
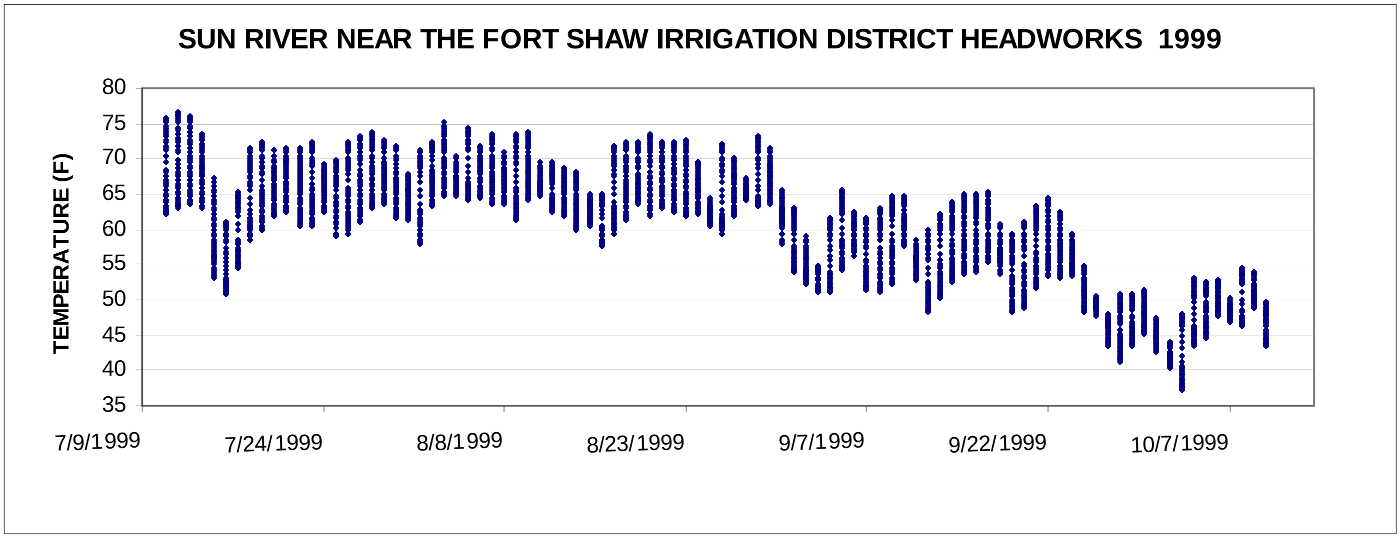
8/15/2000
8/30/2000
9/14/2000
9/29/2000

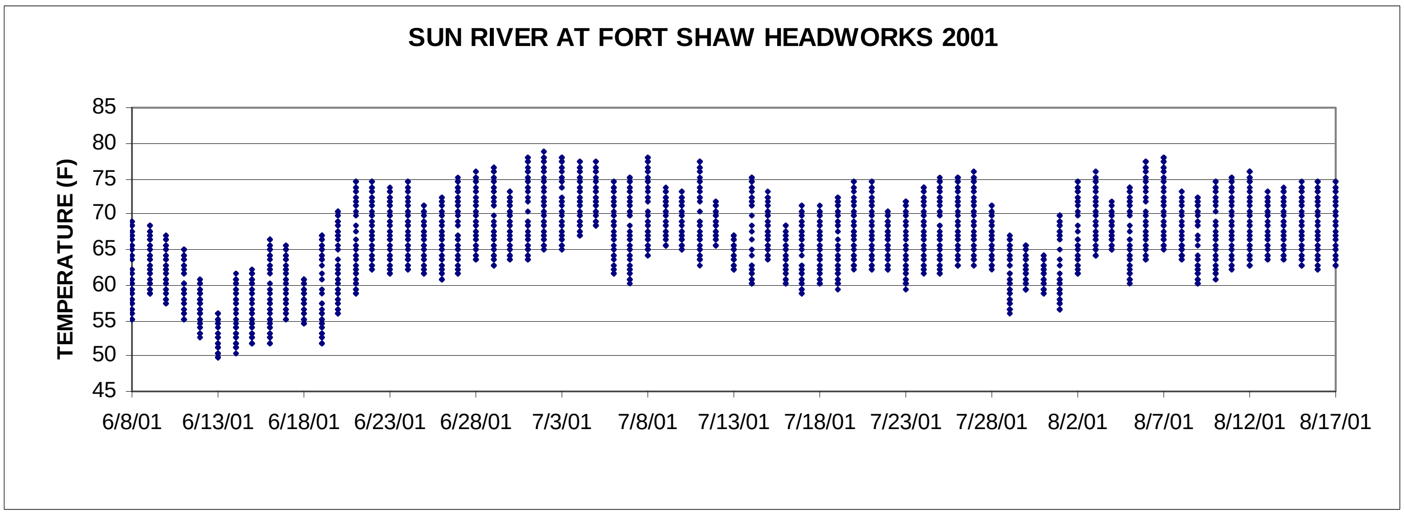


Sun River at the Fort Shaw Irrigation Diversion. Latitude 47 30 43, Longitude 112 04 23

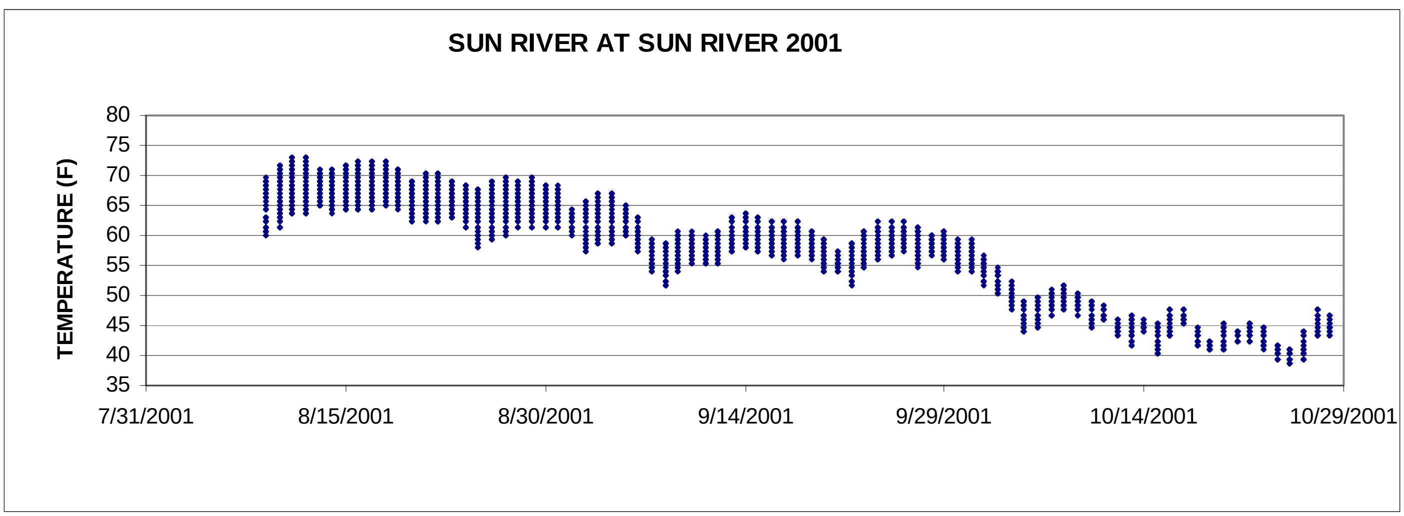




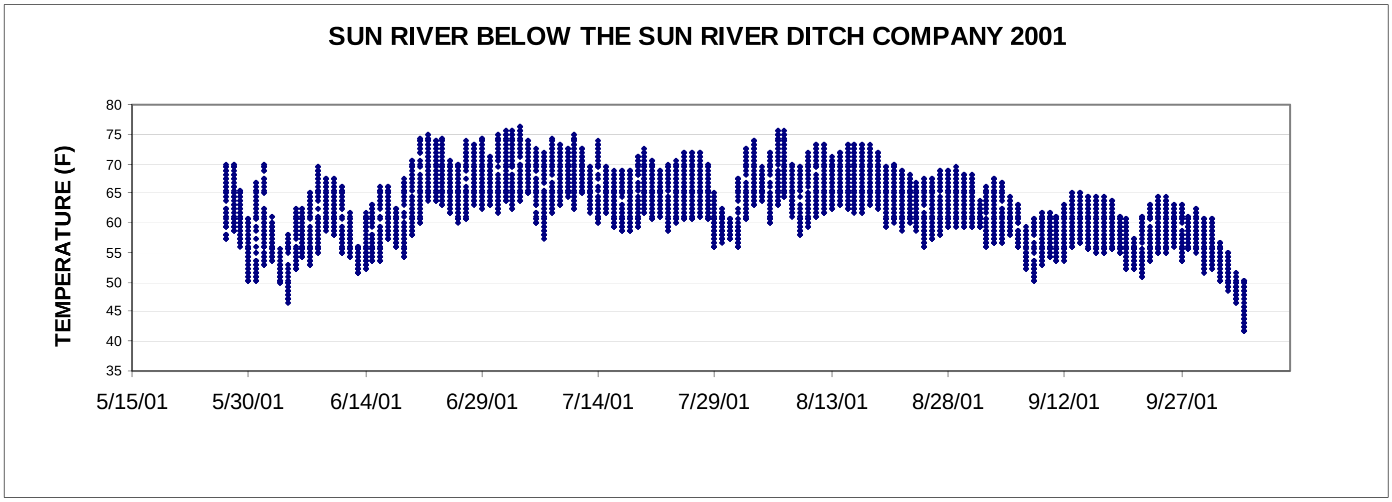




Sun River at Sun River. Latitude 47 31 59, Longitude 111 42 56



Sun River below the Sun River Ditch Company. Latitude and Longitude not recorded



APPENDIX C
RESPONSE TO PUBLIC COMMENTS

A stakeholder public comment review was provided and the following individuals that represent differing water user groups in the Sun River were provided a chance to review the draft document prior to public review.

Alan Rollo, Coordinator
Sun River Watershed Group
Great Falls

Ed Everaert, Manager
Greenfields Irrigation District
Fairfield

Steve Leathe, Fisheries Biologist
Montana Fish, Wildlife & Parks
Great Falls

Mark Schlepp, Wildlife Biologist
Montana Fish, Wildlife & Parks
Fairfield

Rick Blaskovich, Resource Specialist
U.S. Bureau of Reclamation
Billings

Don Skaar, Toxicologist
Montana Fish, Wildlife & Parks
Helena

Donna Rise, Ground Water Specialist
Montana Department of Agriculture
Helena

Kate Miller, Senior Research Hydrogeologist
Montana Bureau of Mines & Geology
Butte

John Streich, Resource Conservationist
Natural Resource Conservation Service
Great Falls

Dan Clark, MSU Extension Agent
Teton County Extension Office
Choteau

Significant public comments were received. Montana DEQ and the U.S. Environmental Protection Agency also collaborated on restructuring the final document to meet all requirements of the federal TMDL program. Therefore, the final document reflects significant efforts to address public comments and to meet the intent of the federal clean water act.

1) COMMENT: On page 113, 8.1.2, the draft states, "Chlorophyll a data should be used as the basis for determining if high nutrient concentrations are affecting beneficial uses…." The chlorophyll a standard, originally developed for the Clark Fork River, is not sufficient as the sole determining measure of nutrient impacts in the Upper Sun River. The Clark Fork River is a significantly larger waterbody than the Upper Sun, and utilizing the same nutrient measurement standard is inappropriate. Nutrient organization will be completely different in a small order stream and the DEQ must utilize other additional measurements to determine the nutrient health of the Upper Sun River. We suggest that the DEQ also study the presence and community composition of periphyton and macroinvertebrates.

> **RESPONSE:** The most sensitive beneficial use relating to nutrient impairment is aesthetics. The amount of benthic algal chlorophyll *a* is a measurement that directly relates to aesthetics. At the time the draft was written, chlorophyll *a*, macroinvertebrate, and periphyton data was not available. Macroinvertebrate and Chlorophyll *a* data from the lower end of the upper Sun River segment was discovered while addressing the public

comments. Chlorophyll a, water chemistry, and macroinvertebrate data are used to determine impairment for the upper Sun River in the final document.

Portions of the upper Sun River segment and the Clark Fork River flow with approximately the same discharge during the summer months. Both streams are encompassed by the same EPA nutrient ecoregion. While there are distinctions between the two streams, significant similarities between the to streams yield a reasonable comparison.

2) COMMENT: A critical concern is that the Sun River Watershed TMDL draft does not clearly state who will implement the restoration strategies nor how the restoration plans will be facilitated. The restoration proposal must detail a responsible party to facilitate, guide and monitor the watershed restoration process. Without clear specifications of how the restoration process will be facilitated, the proposals in this TMDL document do not carry much weight. Please detail exactly how the restoration process will be carried out and held accountable.

RESPONSE: Federal and State regulations do not require a responsible party be identified to implement non-point source restoration sections of the plan. Any reference to point source permit changes in the plan will be reflected in the next review of the permit by MDEQ. The State of Montana suggests that the commenter collaborate with watershed stakeholders and local interest groups to ensure a higher likelihood of implementing the voluntary, non-point source sections of plan.

3) COMMENT: Restoring a minimum flow regime on the upper and lower Sun River is essential to meeting sediment and thermal TMDL targets. This type of minimum flow regime can be achieved through the voluntary cooperation of Sun River Watershed Group members, without regulatory control of or interference with state water rights. However, further study, basin modeling, and some combination of capital investments in irrigation efficiencies, reservoir re-operations, and new water management techniques will undoubtedly be required to meet this goal. TU is committed as a watershed group member to help put the pieces in place that will make a minimum flow regime possible on the Sun River. The restoration of a minimum flow regime on the upper and lower Sun River is critical to a successful TMDL plan.

RESPONSE: Thank you for your comment.

4) COMMENT: The draft TMDL's discussion of in-stream flows on the Sun River in Section 4.2 requires some clarification and improvement in at least two important respects. First, the draft discussion in Section 4.2, page 34, identifies the upper inflection point of FWP's wetted perimeter analysis as "*ideal*" flow conditions for a fishery. This is incorrect. Rather, flows *exceeding* the upper inflection point are considered to provide near optimal conditions for fish. This distinction is important. The *upper* inflection point identifies the *lowest* flow level that will still provide for adequate aquatic habitat and support consistently healthy aquatic populations. The *lower* inflection point of the wetted perimeter analysis identifies the flow below which essential habitat characteristics and aquatic food production capacity decline rapidly, to the point of failing to provide any capacity for supporting a multi-age class fishery.

Second, Section 4.2 states that flows of 50 cfs "will have impacts to fisheries and aquatic life." While technically correct, this statement fails to characterize the depth of the *adverse* impact to fisheries when Sun River flows fall to 50 cfs or below. Flows of 50 cfs on the Sun River mainstem are well below the identified *lower* inflection point of FWP's wetted perimeter analysis. As noted above, flows of 100 cfs and 130 cfs for the upper and lower Sun River, respectively, provide a minimum of aquatic habitat function. Flows sustained at only this minimum level of aquatic habitat function will not achieve full support of the designated beneficial use of coldwater fishery. Flows of 50 cfs on the Sun River mainstem are less than half of the identified minimum. Flows of 50 cfs mean that fish riffle habitat is greatly diminished, aquatic food production is severely compromised, and pools for thermal refuge and cover from predators are very rare. The discussion in Section 4.2 should acknowledge these adverse effects to the fishery at the 50 cfs flow level.

RESPONSE: The final document has been revised to reflect the comment.

5) COMMENT: Trout Unlimited strongly urges the Department of Environmental Quality (DEQ) to incorporate specific minimum flow levels as part of the sediment targets. These flow targets should be adopted in Section 10.2.4: 220 cfs in normal and wet years for both the upper and lower Sun River. In drought years, to accommodate a reduced hydrograph, the minimum flow should be set at 130 cfs downstream of Elk Creek, and 100 cfs from diversion dam to Elk Creek. Moreover, triggers for the definition of a "drought year" must also be adequately defined in the final TMDL plan.

The incorporation of these minimum flow levels in the development of the Sediment Targets is important to the normal development of riparian zone vegetation and stream morphology that only balanced stream sediment transport can provide. We have incorporated into these comments FWP's amended Table 38 in Section 10.2.4, where FWP has identified the discharge recommendations that over time would best serve sediment transport and provide a more functional riparian system and aquatic community. This in turn would improve support of designated in-stream beneficial uses. TU urges the adoption of the amended Table 38, set forth below.

10.2.4 Lower Sun River Sediment Targets

Table 38. Sediment Targets.

Water Body	**Targets**				
	Flow (Discharge)	**SSC**	**Riparian**[2]	**Channel Indicators**	**Biology**
Ford Creek	12 cfs[1]	NA	Achieve PFC for 85% of stream length with no non-functioning riparian areas. Allow beaver	W/D ratio ≤ 40 Entrenchment ratio ≥ 2.2 Sinuosity ≥ 1.2 Meander	Aquatic macroinvertebrate biotic index of 2.88

Table 38. Sediment Targets.

Water Body	Targets				
	Flow (Discharge)	**SSC**	**Riparian[2]**	**Channel Indicators**	**Biology**
			activity.	width ratio <20 and >4	
Upper Sun River	Absolute minimum - 100 cfs above Elk Creek[1] Absolute minimum - 130cfs Below Elk Creek[1] Normal minimum – 220 cfs	Address erosion in and reduce sediment loading from Big Coulee/ Duck Creek	Achieve PFC for 85% of stream length with no non-functioning riparian areas.	W/D ratio ≤ 40 Entrenchment ratio ≥ 2.2 Sinuosity ≥ 1.2 Meander width ratio <20 and >4	Begin monitoring cold water fishery biomass. Increase cold water fish biomass in 5 years. Set refined target for biology in 5 years.
Muddy Creek	See Figure 52	Reduce 5 year average SSC Load at Vaughn to 59,918 lbs/year.	Achieve PFC for 85% of stream length along Muddy Creek and Major Tributaries with less than 5% non-functioning riparian areas.	Limit new channel constrictions. Allow the channel adequate space to **slowly** erode a new floodplain.	Monitor Muddy Creek fishery for review. Consider reclassification if fishery indicates uses are in the range of an impaired B1 classification. Set biological targets during TMDL review.

Table 38. Sediment Targets.

Water Body	Targets				
	Flow (Discharge)	**SSC**	**Riparian[2]**	**Channel Indicators**	**Biology**
Lower Sun River	Absolute minimum - 130cfs [1] Normal minimum – 220 cfs	Reduce SSC load from Muddy Creek	Achieve PFC for 85% of stream length with no non-functioning riparian areas.	W/D ratio ≤ 40 Entrenchment ratio ≥ 2.2 Sinuosity ≥ 1.2 Meander width ratio <20 and >4	Monitor Lower Sun River fishery to determine if portions of this stream segment should be reclassified to a marginal cold water fishery (B2). Set biological targets during TMDL review.

[1]In-stream Flow Reservation granted to MFWP – Minimum Flows for Survival of aquatic community.
[2]Using NRCS/BLM/USFS Riparian Area Management Technical Reference 1737-15, 1998.
NA = Not Applicable

RESPONSE: Using these flow rates as TMDL targets is problematic because the suggested discharge rates are not calculated to provide vegetation a consistent environment to grow on stream banks and thus stabilize the banks. Instead, they were calculated using a method described in Section 4.0 of the TMDL to provide enough water for fish and their primary food sources to survive. While MDEQ agrees that increasing water volume in the stream will help reduce sediment production. These flows are not directly calculated by using the relationship between instream temperatures and discharge rates. Therefore, these minimum discharge rates are provided as supplemental indicators, not targets, in the sediment impairment condition in Section 9.0. Hydromodification is addressed as a source of increased bank erosion in Section 9.0 of the final document. An allocation of sediment to a combination of hydromodification and riparian grazing is included in Section 9.0.

6) COMMENT: We (MT FWP) appreciate the modifications to Section 4.0 (Instream Flow/Discharge) made as a result of the comments we provided (attached) on the Stakeholder Review Draft. However, we urge DEQ to utilize those comments in the development of the Sediment Targets in Section 10.2.4 and Table 38. These targets need to be adopted in Section 10.2.4 for consistency between the flow and sediment targets and for the normal development of riparian zone vegetation and stream morphology that only balanced stream sediment transport would provide. Please also find the enclosed Table 10.2.4 where we have identified the discharge recommendations that over time would best serve sediment transport and provide a more functional riparian system and aquatic community, which would improve support of designated in-stream beneficial uses.

> **RESPONSE:** See response to Comment #5.

7) COMMENT: We strongly urge the DEQ to incorporate specific minimum flow levels as part of the thermal TMDL targets. These flow targets should be adopted: 220 cfs in normal and wet years for both the upper and lower Sun River. In drought years, to accommodate a reduced hydrograph, the minimum flow should be set at 130 cfs downstream of Elk Creek, and 100 cfs from diversion dam to Elk Creek. Moreover, triggers for the definition of a "drought year" must also be adequately defined in the final TMDL plan.

> **RESPONSE:** Using these flow rates as TMDL targets is problematic because the suggested discharge rates are not calculated to provide cool temperatures. Instead, they were calculated using a method described in section 4 of the TMDL to provide enough water for fish and their primary food sources to survive. While MDEQ agrees that increasing water volume in the stream increases the streams buffering capacity to assimilate heat. These flows are not directly calculated by using the relationship between in-stream temperatures and discharge rates. Therefore, these minimum discharge rates are provided as supplemental indicators, not targets, in the temperature impairment condition in Section 10. In-stream flow conditions are also addressed as a source of increased temperature in the in Section 10 of the final document. An allocation of heat loading to low summer time in-stream flow condition is included in Section 10.0.

8) COMMENT: We have attached Mean and Maximum Temperature vs. Mean Daily Flow graphs comparing flow from the USGS gage at Simms to water temperature at Lowry Bridge from 21 July – 20 October 2003. These graphs examine a discharge-temperature relationship over a much lower range of flows as that shown in Figure 62 of the Public Review Draft. There does appear to be an inverse relationship between flow and temperature. Please also note that water temperatures exceeding 80F were recorded, which appears to be higher than maximums otherwise identified in the Public Review Draft. The maximum temperature vs. discharge graph shows that in 2003, the temperature criteria as described in Table 47 were almost always met for rainbow and brown trout at a discharge near or exceeding our recommended absolute minimum in-stream flow for this portion of the Sun River. As a result of that, we recommend that the in-stream flows are adopted as targets within the temperature section of the TMDL document. We also made a quick examination of maximum water temperatures at different sites monitored in 2003. Results showed that temperatures exceeded 77F at both the Highway 287 and Lowery bridges. We can make these data available to you at your convenience.

> **RESPONSE:** The graph provided has been incorporated into the final document because it supports the link between temperature and discharge for a critical range of in-stream discharges.

9) COMMENT: The current temperature data displays in the draft TMDL inadequately break out the temperature data for flows in the range of 40 cfs to 150 cfs and up to 300 cfs for both the lower and upper Sun River. Clearly, more analysis and collection of specific temperature data are needed to identify positive correlations between an increase in river flows and a decrease in maximum temperatures. In particular, data collection that tests the relationship between temperature and flows below and at the drought-year minimum of 100 and 130 cfs, and up to the normal and near-normal year minimum of 220 cfs is required prior to the final TMDL. Analysis of the relationship between temperature and these minimum flow recommendations during the hot, low-flow months typical of July, August, and September are particularly important. With this emphasis in mind, TU supports the proposed Temperature Monitoring Plan set out in Section 11.7, and believes that such a plan is necessary to a successful thermal pollutant TMDL target.

RESPONSE: See response to Comments 6 and 7.

10) COMMENT: MT FWP submitted the following changes to this table.

Table 5. 2000 Montana Department of Fish, Wildlife and Parks electrofishing results from the Upper Sun River – Provisional Data.

Section Location	Section Length (miles)	Year	No. of Trout Per Mile > 8 inches	80% Confidence Intervals
Just downstream from Highway 287 Bridge	2.6	1997	63	36-90
		2000	157	124-190
		2002	130	106-154
		2003	91	65-117
Between Lowrey Bridge and Simms	5.0	1997	58	36-80
		2000	49	33-65
		2003	37	15-59
Just downstream from Town of Sun River	5.3	1997	-	-
		2000	81	41-121
		2003	48	15-81

RESPONSE: The final document has been revised to reflect the comment. The changes are reflected in Table 2-5.

11) COMMENT: We (MT FWP) have enclosed fish population estimates for three sections on the Sun River below Gibson Dam (see attachment). Although we would also prefer that fish biomass monitoring in the Sun River be utilized as targets in the TMDL plan, it is more realistic at this point to provide fish numbers and plan to set refined fish biomass targets in the future. At this time fish populations in the Sun River are depressed to the point where quantitative data is often difficult to obtain. We believe fish population density in the two unimpacted forks of the Sun River upstream from Gibson Reservoir provide a good reference for the potential in the mainstem Sun River. Based on long term average trout populations in the two forks above the reservoir, we feel trout densities of around 600 per mile should be achievable in the Main "Upper Sun River" downstream of Gibson Dam. We would anticipate that in a typical watershed, the density of trout would likely be higher below the confluence of the North and South Forks than in either tributary. Optimal condition targets could be 600 per mile, but realistically values similar to the long-term average of trout populations in the Deep Creek Section of the Smith River (420 per mile) may be more achievable and would probably produce an acceptable fishery. Thus, a value of 66% (400/mile) of the population levels in the N & S Forks Sun could be an acceptable target that may be reviewed at a later date.

> **RESPONSE:** Fish populations are affected by overall water quality and habitat conditions. Therefore, fishery population numbers are provided as a supplemental indicator to all pollutant TMDLs for the upper Sun River. Fish population is not provided as TMDL targets for any specific pollutant because many factors affect a fishery's population. In the case of the upper Sun River, it is readily apparent that the fishery is not meeting it's potential and therefore fishery supplemental indicators of impairment are appropriate for use. The indicator is presented in the temperature TMDL section of the upper Sun River, but relates to all TMDLs for the upper Sun River.

12) COMMENT: It makes sense that the expression of very high nutrient loads from Muddy Creek is not expressed in the form of excessive filamentous algal growth in either Muddy Creek or the lower Sun River because of high turbidity which results in inadequate light penetration for aquatic plant growth and silty substrates, which prevent attachment of aquatic plants. We believe the effects of excessive nutrient loads from Muddy Creek are eventually fully expressed in the form of noxious algal growth during the summer months in the Missouri River from Morony Dam to the headwaters of Fort Peck Reservoir. It is likely that the 5 Great Falls reservoirs allow turbidity to settle to the point where water clarity and gravelly substrates in the lower river provide excellent conditions for filamentous algal growth. Each summer, this river reach experiences a dense and steady stream of clumps of floating algae (Cladophora?) that clog irrigation pumps and make it almost impossible to fish during July through September due to continual fouling of fishing lines and gear. Since this problem does not exist to a significant degree upstream from Great Falls, we can only conclude it is a result of excessive nutrient inputs from Muddy Creek. Reduction of Muddy Creek nutrient loads would probably have substantial benefits to downstream irrigators and recreationists by reducing these growths of noxious algae.

> **RESPONSE:** This document identifies nutrient loads in both Muddy Creek and the Sun River in the vicinity of Vaughn that can be used as a source assessment for downstream TMDLs. As you indicate in the comment, the algal proliferation below Great Falls may be a combination of many factors. A TMDL will be written for the Missouri River in the future. At that time, the Sun River will be compared to other sources.

13) COMMENT: Freezeout Lake. The draft document provided an excellent summary of salinity and selenium problems at Freezeout, and the causes. We agree the best approach to reducing these problem lies in changing agricultural practices on the approximate 3500 acres of irrigated glacial lacustrine soils in the Freezeout watershed that produce approximately 70-90+ percent of salinity and selenium inputs to Freezeout. We question whether or not it is reasonable to totally dismiss cessation of irrigation on at least some of this acreage as "economically infeasible". While the draft document detailed the economic costs to local agriculture of ceasing irrigation, it did not provide an estimate of the costs of the downstream impacts of impaired water quality as a result of irrigation of these lands. These impairments affect wildlife in the Freezeout area and, ultimately can affect water quality and other uses including irrigated crops and fisheries in the Teton River watershed. These costs should be estimated and compared to the costs of reduction of irrigation in the Freezeout watershed before the economic feasibility can be accurately assessed. In addition, the economic analysis assumed all irrigation of these lands would cease, which is highly unlikely. More realistic options involving changes in water use practices, possibly coupled with elimination of irrigation in the most sensitive areas, should be entertained. It makes sense that water potentially conserved by changing irrigation practices in the Freezeout watershed should be used to address the salinity/selenium problems there. However, it is not certain that all conserved water would be needed to meet water quality targets at Freezeout. For instance, more compatible agricultural practices on these sensitive lands might substantially reduce loading, thereby reducing the need for "dilution". The door should be left open to return any "surplus" conserved water on these lands to the Sun River itself after (and if) water quality targets in Freezeout Lake are met.

RESPONSE: The final document has been revised to reflect portions of the comment.

14) COMMENT: This section provides a useful "roadmap" towards achieving the TMDL targets for the Sun River Water Quality Plan, and it makes the Plan a stronger document than it would have been without this section. Missing from the "roadmap" section, however, is any specific mention of an intent to dedicate water conserved through investments in irrigation efficiencies to improving flows on the Sun River. At a minimum, water conserved through irrigation efficiencies should be dedicated to instream flows in proportion to the public funds that are expended on the efficiencies project: public funds should translate into public benefit. Without such measures, the temperature, sediment, and other water quality targets of the Sun River Water Quality Plan will be very difficult to meet.

RESPONSE: The final document has been revised to reflect the comment in Section 11.0.

15) COMMENT: It could be further clarified that any irrigation water savings on the glacial lacustrine soils in the Freezeout watershed needed to balance pollutant loads to Freezeout Lake should be dedicated for that purpose. Some or all water conserved by improved irrigation efficiency on GID project lands outside the Freezeout watershed should be dedicated to instream use in the Sun River to reduce water quality impairments caused by sediment, temperature, and other parameters. In the section on the "Upper Sun River", there is mention of a water budget but there is no specific language (as there is in the Freezeout section) that at least a portion of water salvaged from future irrigation efficiency improvements should be left instream to meet temperature, sediment, and other water quality targets.

RESPONSE: The Freezeout Lake comment is addressed in Section 6.1.4 and 7.1.4. Section (10.2.5.1) addresses the comment about the Sun River

16) COMMENT: Based on our conversations with the Bureau of Reclamation and GID, it appears the average annual runoff into Gibson may be substantially greater than 319,800 AF as reported in 2.8.1 They suggested a runoff of 450,000 AF from April – July and 575,000 AF year-round.

RESPONSE: The final document has been revised to reflect the comment.

17) COMMENT: We could not find a listing in "References" for the Watson et al. (1996) study on Muddy Creek cited on page 147. The only "Watson" listing in References referred to a study on the Clark Fork River. Perhaps the latter contains the information on Muddy Creek.

RESPONSE: The final document has been revised to reflect the comment.

18) COMMENT: The numbers on sediment loads in Table 40 are a little confusing. The text does state some of them may not be accurate. The magnitude of difference is so enormous, more clarification or explanation may be required to qualify the comparison.

RESPONSE: The final document has been revised to reflect the comment. The load that was thought to be inaccurate was detracted from the document. The data is now depicted in Table 9-10.

19) COMMENT: The draft discusses the effects of thermal conditions on trout growth and survival. One aspect not mentioned is that stress caused by high water temperatures can dramatically increase trout susceptibility to disease.

RESPONSE: The final document has been revised to reflect the comment. The comment is addressed in Section 10.2.1.1.

20) COMMENT: A number of editorial comments were provided.

RESPONSE: Thank you for your comments. Many of the editorial comments were incorporated into the final document. MDEQ also made a significant effort to reorganize the document into a more practical format.