M03-TMDL-01A

UPPER AND NORTH FORK BIG HOLE RIVER PLANNING AREA TMDLS AND FRAMEWORK WATER QUALITY RESTORATION APPROACH

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Montana Department of
ENVIRONMENTAL QUALITY

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ERRATA SHEET FOR THE "UPPER AND NORTH FORK BIG HOLE RIVER PLANNING AREA TMDLS AND FRAMEWORK WATER QUALITY RESTORATION APPROACH"

This TMDL was approved by EPA on June 30, 2009. Several copies were printed and spiral bound for distribution, or sent electronically on compact disks. The original version has a minor change that is explained and corrected on this errata sheet. If you have a bound copy, please note the correction listed below or simply print out the errata sheet and insert it in your copy of the TMDL. If you have a compact disk please add this errata sheet to your disk or download the updated version from our website.

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

The following table contains corrections to the TMDL. The first column cites the page and paragraph where there is a text error. The second column contains the original text that was in error. The third column contains the new text that has been corrected for the "Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach" document. The text in error and the correct text are underlined.

Location in the TMDL	**Original Text**	**Corrected Text**
Page 21, Section1.1, last paragraph	A total of 25 TMDLs are provided in this document.	A total of 24 TMDLs are provided in this document.

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ACRONYMS

Acronym	Meaning
ABWA	Absarokee-Beartooth Wilderness Area
ACE	Acclimated Chronic Exposure
AFO	Animal Feeding Operations
AGWT	American Ground Water Trust
AML	Abandoned Mine Lands
ARM	Administrative Rules of Montana
ATV	All Terrain Vehicle
AWRA	American Water Resources Association
Ave.	Average
BAER	Burned Area Emergency Rehab
BBCTU	Big Blackfoot Chapter of Trout Unlimited
BDNF	Beaverhead-Deerlodge National Forest
BEHI	Bank Erodibility Hazard Index
BER	Board of Environmental Review
BLM	Bureau of Land Management, United States
BMP	Best Management Practice
BNF	Bitterroot National Forest
BOD	Biochemical Oxygen Demand
BOR	Bureau of Reclamation
BP	Before Present
BUD	Beneficial Use Determination
CAFO	Concentrated Animal Feeding Operation
CALA	Controlled Allocation of Liability Act
CARRD	DNRC Conservation and Resource Development Division
CBM	Coal bed methane
CCAA	candidate conservation agreements with assurances
CCAC	Climate Change Advisory Group
CD	Conservation District
CECRA	Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CH4	Methane
Chl-a	Chlorophyll A
Cl	chloride
CMB	Chemical Mass Balance
CMZ	Channel Migration Zone
CNMP	Comprehensive Nutrient Management Plans
CO2	Carbon Dioxide
CPUE	catch-per-unit-efforts
CREP	Conservation Reserve Enhancement Program
CRP	Color Removal Plant or Conservation Reserve Program
CTM	Critical Thermal Maxima (CTM)

CV	Coefficient of variation
CWA	Clean Water Act
DEM	Digital Elevation Models
DEQ	Department of Environmental Quality, Montana
DEQ-7	Circular DEQ-7, Montana Water Quality Standards
DHES	Department of Health and Environmental Sciences
DMR	Discharge Monitoring Report
DNRC	Department of Natural Resources and Conservation
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DPHHS	Department of Public Health and Human Services
E&O	Education and Outreach
EC	Electrical Conductance
ECA	Equivalent Clear-Cut Area
EE/CA	Engineering Evaluation/Cost Analysis
EIS	Environmental Impact Statement
EMAP	Environmental Monitoring and Assessment Program
EPT	Ephmeroptera, Plecoptera, Trichoptera
EQIP	Environmental Quality Initiatives Program
ESA	Endangered Species Act
FAR	Functioning at Acceptable Risk
FAS	Federation of American Scientists
FSA	Farm Service Agency
FUR	Functioning at Unacceptable Risk
FWP	Fish Wildlife and Parks, Montana Department of
FWS	Fish and Wildlife Service
GAP	USGS GAP Analysis Program
GHG	Greenhouse Gases
GIS	Geographic Information Systems
GPS	Global Positioning Systems
GWIC	Montana Groundwater Information Center
HBI	Hilsenhoff Biotic Index
HCFC	Halogenated Fluorocarbons
HCP	Habitat Conservation Program
HFC	Hydrofluorocarbons
HRUs	Hydrologic Response Units
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
ILT	Incipient Lethal Temperatures
INFS	Inland Native Fish Strategy
INFISH	Inland Native Fish Strategy
IPCC	Intergovernmental Panel on Climate Change
IR	Integrated Report
ITEEM	Integrated Transportation and Ecosystem Enhancements for Montana
ITL	instantaneous temperature load
IWM	Irrigation Water Management

JCU	Jackson Candle Units
LA	Load Allocation
LC	Loading Capacity
LEED	Leadership in Energy and Environmental Design
LEP	Let Everyone Participate
LID	Low Impact Development
LNF	Lolo National Forest
LTA	Land Type Associations
LTAP	Local Technical Assistance Program
LWD	Large Woody Debris
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MCL	maximum contaminant level
MDEQ	Montana Department of Environmental Quality
MDFWP	Montana Department of Fish, Wildlife and Parks
MDOT	Montana Department of Transportation
MDSL	Montana Department of State Lands
MDT	Montana Department of Transportation
MFISH	Montana Fisheries Information System
mg/L	Micrograms Per Liter
mg/L	Milligrams Per Liter
mg/m2	milligram per meter squared
MGD	Million Gallons per Day
MGWPCS	Montana Ground Water Pollution Control System
MLR	Meander Length Ratio
MMI	Multi-Metric Index
MOS	Margin of Safety
MOU	Memorandum of Understanding
MPDES	Montana Pollutant Discharge Elimination System
mS/cm	Microsiemens Per Liter
MSCA	Montana Salinity Control Association
MSEO	Montana State Engineer.s Office
MSU	Montana State University
MTNHP	Montana Natural Heritage Program
MVFP	Montana Valley and Foothill Prairie
MWCB	Mine Wast Clean Up Bureau
MWCC	Montana Watershed Coordination Council
N2O	nitrous oxide
N	Nitrogen
Na	sodium
NDOC	Nondissolved Organic Carbon
NEPA	National Environmental Policy Act
NF	National Forest
NFHCP	Native Fish Habitat Conservation Plan
NFHCP	Native Fish Habitat Conservation Plan
NHD	National Hydrography Dataset

NO3+NO2	Nitrate + Nitrite as Nitrogen
NOx	Nitrogen Oxides
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NPS	Nonpoint Source Pollution
NRCS	Natural Resource Conservation Service
NRIS	Natural Resource Information Services
NSF	National Science Foundation
NTU	Nephelometric Turbidity Units
NWIS	National Water Information System
O3	ozone
O/C	Observed/Expected
ODEQ	Oregon Department of Environmental Quality
O/E	Observed/Expected
OHV	Off Highway Vehicle
P	Phosphorus
PCB	Polychlorinated Biphenyls
PCS	Permit Compliance System
PCTC	Plum Creek Timber Company
PEL	Probable Effect Levels
PFC	Proper Functioning Condition (Riparian)
PFI	Peak Flow Increases
PIBO	PACFIS/INFISH Biological Opinion
POC	Particulate Organic Carbon
POTW	Publicly Owned Treatment Works
PWS	Public Water Supply
QA/QC	Quality Assurance and Quality Control
RBP	Rapid Bioassessment Protocol
RIVPACS	River Invertebrate Prediction and Classification System
RMO	Riparian Management Objectives
ROS	Rain-on-Snow
RSI	Rifle Stability Index
SABS	Suspended and Bedded Sediments
SAP	Sampling and Analysis Plans
SAR	Sodium Adsorption Ratio
SC	Specific Conductance
SCD	Sufficient Credible Data
SCD/BUD	Sufficient and Credible Data/Beneficial Use Determination
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SDWIS	Safe Drinking Water Information System
SD	Secci Depth
SDDENR	South Dakota Department of Environment and Natural Resources
SEL	Severe Effects Level
SEV	Severity of ill Effects
SMCRA	Surface Mining Control and Reclamation Act

SMZ	Streamside Management Zones
SNTEMP	Stream Network Temperature
SNOTEL	Snowpack Telemetry
SO4	sulfate
SRF	State Revolving Fund
SRP	Soluble Reactive Phosphorus
SS	Suspended Sediment
SSTEMP	Stream Segment Temperature
STATSGO	State Soil Geographic Database
STORET	EPA's Storage/Retrieval Database
SSURGO	Soil Survey Geographic Database
SWCS	Soil and Water Conservation Society
SWMP	Storm Water Management Program
TAG	Technical Advisory Group
TDS	Total dissolved solids
TEL	Threshold Effect Levels
TET	Toxic Effect Threshold
TFAB	Technical and Financial Assistance Bureau
TIN	Total Inorganic Nitrogen
TIP	Total Inorganic Phosphorus
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads
TMI	Total Metals Index
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TPN	Total Persulfate Nitrogen
TR	Total Recoverable
TRWG	Teton River Watershed Group
TRWU	Tongue River Water Users
TSCA	Toxic Substances Control Act
TSI	Trophic State Index
TSS	Total Suspended Solids
UAA	Use Attainability Assessment
UET	Upper Effect Threshold
UNESCO	United Nations Educational, Scientific and Cultural Organization
USCOE	United States Army Corp of Engineers
USDA	United State Department of Agriculture
USDI	United States Department of Interior
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGBC	United States Green Building Council
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
VCRA	Voluntary Cleanup and Redevelopment Act

VFS	Vegetated Filter Strips
VNRP	Voluntary Nutrient Reduction Program
VNRS	Voluntary Nutrient Reduction Strategy
W/D Ratio	Width to Depth Ratio
WEPP	Water Erosion Prediction Project
WQA	Water Quality Act
WLA	Waste Load Allocation
WQMWG	Water Quality Monitoring Work Group
WQPB	Water Quality Planning Bureau
WQRP	Water Quality Restoration Plan
WQS	Water Quality Standards
WRCC	Western Regional Climate Center
WRP	Watershed Restoration Plans
WTI	Western Transportation Institute
WWTP	Waste Water Treatment Plant
YBP	Yellowstone Business Partnerships
YOY	Young of Year
µg/g	microgram per gram

EXECUTIVE SUMMARY

This document presents Total Maximum Daily Loads (TMDLs) and framework water quality improvement plans for the Upper and North Fork Big Hole River and 18 impaired tributaries (**Appendix K**, **Map 1**). This plan was developed by the Montana Department of Environmental Quality (DEQ) and submitted to the US Environmental Protection Agency (EPA) for approval, in accordance with the Montana Water Quality Act. The Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a water body can receive and still meet water quality standards. The goal of TMDLs is to eventually attain and maintain water quality standards in all of Montana's streams and lakes, and to improve water quality to levels that support all state-designated beneficial water uses.

The Upper and North Fork Big Hole TMDL Planning Areas (TPAs) are located in Beaverhead County and include the Big Hole River and its tributaries from headwaters to the confluence with Doolittle Creek. The tributaries originate in the Pintler, Pioneer and Beaverhead Mountains. The watershed drainage area encompasses about 730,800 acres, with land ownership consisting of federal, state, and private lands.

DEQ has performed assessments determining that the Big Hole River above Doolittle Creek and its 18 tributaries do not meet the applicable water quality standards. The scope of the TMDLs in this document address sediment, temperature and nutrient related problems (See **Table E-1**). Metals were assessed in a number of watersheds but no metals TMDL is provided in the document. Additional TMDLs in this TPA may be required in the future and a number of these circumstances are noted within the document.

<u>Sediment</u> – Sediment TMDLs were developed for the Big Hole River, North Fork Big Hole River, Doolittle, Fox, Francis, Governor, Johnson, Joseph, McVey, Miner, Mussigbrod, Pine, Rock, Ruby, Steel, Swamp, Tie, and Trail Creeks. Sediment is impacting beneficial water uses in these streams by smothering aquatic insect habitat, reducing fish spawning success, or filling pools which reduces fish populations. Water quality restoration endpoints for sediment in these stream segments were established for fine sediment levels in trout spawning areas, fine sediment in riffles where many aquatic insects reside, number of pools within a reach of stream, riparian vegetation health and the stability of streambanks. Attainment of these endpoints is believed to be capable of restoring all water uses presently impacted by sediment.

Sediment loads were quantified for naturally occurring conditions and impacted conditions for the following sources: bank erosion, hillslope erosion, and roads. The most significant sources included natural sediment loads, agricultural related loads from riparian vegetation impacts that influence bank erosion, and unpaved roads. The sediment TMDLs completed in the Upper and North Fork Big Hole TPAs indicate that reductions in sediment loads ranging from 10% to 46% will result in meeting the water quality restoration endpoints depending upon the watershed.

<u>Nutrients</u> – Francis and Steel Creeks were identified for nutrient TMDL formation. Nutrient targets include total nitrogen, total phosphorus, algae related measures and dissolved oxygen. Nutrient TMDLs are based upon target concentrations and stream flow. Nutrient allocations are

based upon water quality modeling results of specific restoration scenarios. Rock, McVey, Swamp, Fox, Pine and Warm Spring Creek watersheds may need nutrient TMDLs in the future. Many of these streams were added to Montana's list of impaired waters as nutrient limited during this TMDL development project. Other nutrient limited watersheds contained complex irrigation systems which imported and exported nutrients into and out of the watershed. Nutrient TMDLs could not be completed in these heavily influenced watersheds given current knowledge.

Metals – Various metals were assessed in Steel, Governor, Mussigbrod, and Joseph Creeks. No metals TMDLs are provided in this document because of varying reasons within each of these watersheds. Either human sources were not present when metals were found or metals were not found above targets during recent sampling if mining sources were present.

Water Temperature – A temperature TMDL is provided for the Upper Big Hole River above Doolittle Creek Confluence. The recommended strategies for achieving the pollutant reduction goals of the Upper and North Fork Watershed TMDLs are also presented in this plan. The most significant pollutant reductions will come from restoration of natural shrubby riparian buffers in the Upper Big Hole Valley. Healthy riparian zones will filter sediment and nutrients from runoff and update nutrients from groundwater before it enters streams. Promoting healthy riparian vegetation will also slow bank erosion and increase shade over streams. Many riparian areas will benefit from passive restoration approaches but some will need active riparian restoration. Creating more healthy riparian vegetation can be provided in the Upper Big Hole Valley by grazing management techniques and moving hay production away from immediate streamside areas.

Other recommended approaches, which will reduce pollutants, are unpaved road management, timber harvest practices that do not increase erosion to stream networks, road sanding BMPs, and the use of other land, soil and water conservation practices *capable of improving condition of stream channels and associated riparian vegetation.*

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

It is recognized that a flexible and adaptive approach to most TMDL implementation activities may become necessary as more knowledge is gained through implementation and future monitoring. The plan includes an effectiveness monitoring strategy that is designed to track future progress towards meeting TMDL objectives and goals, and to help refine the plan during its implementation.

Table E-1: List of Water Bodies, Impairment Causes, and Impaired Uses in the Upper and North Fork Big Hole TPAs for Which TMDLs Were Completed

Water Body & Location Description	Impairment Cause	TMDL Pollutant Category Completed
Big Hole River, above Pintlar Creek	Temperature	Temperature
North Fork Big Hole River, headwaters to mouth (Big Hole River)	Sediment/siltation	Sediment
Johnson Creek, headwaters to mouth (North Fork Big Hole River)	Sediment/siltation	Sediment
Tie Creek, headwaters to mouth (North Fork Big Hole River)	Sediment/siltation	Sediment
Trail Creek, Headwaters to Joseph Creek	Sediment/siltation	Sediment
Trail Creek, Joseph Creek to mouth (North Fork Big Hole River)	Sediment/siltation	Sediment
Joseph Creek, headwaters to mouth (Trail Creek-North Fork Big Hole River)	Sediment/siltation	Sediment
Ruby Creek, headwaters to mouth (North Fork Big Hole River)	Sediment/siltation	Sediment
Swamp Creek, headwaters to mouth (Big Hole River)	Sediment/siltation	Sediment
Rock Creek, headwaters to mouth (Big Hole River)	Sediment/siltation	Sediment
Miner Creek, headwaters to mouth (Big Hole River)	Sediment/siltation	Sediment
Steel Creek, headwaters to mouth (Big Hole River)	Phosphorus	Nutrients
Francis Creek, headwaters to mouth (Steel Creek) T3S R15W	Phosphorus Nitrogen Sediment/siltation	Nutrients Sediment
McVey Creek, headwaters to mouth (Big Hole River) T1S R15W	Sediment/siltation	Sediment
Doolittle Creek, tributary to the Big Hole River T1S, R14W	Sediment/siltation	Sediment

New data collected during this project indicated the need for sediment TMDLs in six other watersheds in addition to the TMDLs identified as needed by Montana's impaired waters list. The additional TMDLs completed within this document address aquatic life and cold water fishery impacts of siltation in the Upper Big Hole River, Fox, Governor, Mussigbrod, Pine and Steel creeks. Also, a nitrogen TMDL has been provided for Steel Creek.

SECTION 1.0
INTRODUCTION

1.1 Background

This document, the Upper Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach, describes the Montana Department of Environmental Quality's present understanding of sediment, nutrient and temperature water quality problems in rivers and streams of the Upper and North Fork Big Hole River TPAs and presents a general framework for resolving them. **Appendix K, Map 1** identifies the water bodies discussed within this document.

Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act, in 1972. The goal of this act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Clean Water Act requires each state to set water quality standards to protect designated beneficial water uses and to monitor the attainment of those uses. Fish and aquatic life, wildlife, recreation, agriculture, industrial, and drinking water are all types of beneficial uses designated in Montana. Streams and lakes (also referred to as water bodies) not meeting the established standards are called *impaired waters*, and those not expected to meet the standards are called *threatened waters*.

The water bodies with their associated impairment and threatened causes are identified within a biennial integrated water quality report developed by DEQ (**Table 1-1** identifies impaired waters for the Upper and North Fork Big Hole River TPAs). Impairment causes fall within two main categories: pollutant and pollution. Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal Clean Water Act require the development of total maximum daily loads (TMDLs) for impaired and threatened waters where a measurable pollutant (for example, sediment, nutrients, metals or temperature) is the cause of the impairment. The water body segments with pollutant impairment causes in need of TMDL development are contained within the 303(d) List portion of the State's integrated water quality report. The integrated report identifies impaired waters by a Montana water body segment identification, which is indexed to the National Hydrography Dataset.

A TMDL refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. The development of TMDLs and water quality improvement strategies in Montana includes several steps that must be completed for each impaired or threatened water body and for each contributing pollutant (or "pollutant/water body combination"). These steps include:

- Characterizing the existing water body conditions and comparing these conditions to water quality standards. During this step, measurable target values are set to help evaluate the stream's condition in relation to the applicable standards.
- Quantifying the magnitude of pollutant contribution from the pollutant sources
- Determining the TMDL for each pollutant, based on the allowable loading limits (or loading capacity) for each pollutant/water body combination.
- Allocating the total allowable load (TMDL) into individual loads for each source (referred to as the load allocations or waste load allocations).

In Montana, restoration strategies and recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation.

The above four TMDL steps are further defined in Section 4.0 of this document. Basically, TMDL development for an impaired water body is a problem solving exercise. The problem is excess pollutant loading negatively impacting a designated beneficial use. The solution is developed by identifying the total acceptable pollutant load to the water body (the TMDL), characterizing all the significant sources contributing to the total pollutant loading, and then identifying where pollutant loading reductions should be applied to one or more sources to achieve the acceptable load.

Table 1-1: 2006 Impaired Water Bodies, Impairment Causes, and Impaired Beneficial Uses in the Upper and North Fork Big Hole River TPAs.

Water body & Location Description	Water body ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Big Hole River, above Pintlar Creek	MT41D001-030	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Temperature	**Temperature***	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
North Fork Big Hole River, headwaters to mouth (Big Hole River)	MT41D004-010	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
Mussigbrod Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-020	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Lead	Metals	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
Johnson Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-030	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Total Kjehldahl Nitrogen (TKN)	Nutrients	Aquatic Life, Cold Water Fishery
Schultz Creek, headwaters to mouth (Johnson Creek)	MT41D004-040	Sedimentation/ Siltation	Sediment	Aquatic Life, Cold Water Fishery

Table 1-1: 2006 Impaired Water Bodies, Impairment Causes, and Impaired Beneficial Uses in the Upper and North Fork Big Hole River TPAs.

Water body & Location Description	Water body ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Tie Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-060	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Nitrogen	Nutrients	Aquatic Life, Cold Water Fishery
Trail Creek, headwaters to Joseph Creek	MT41D004-070	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
Trail Creek, Joseph Creek to mouth (North Fork Big Hole River)	MT41D004-080	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
Joseph Creek, headwaters to mouth (Trail Creek-North Fork Big Hole River)	MT41D004-090	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Lead	Metals	Aquatic Life, Cold Water Fishery, Drinking Water
		Copper	Metals	Aquatic Life, Cold Water Fishery
Ruby Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-100	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
Swamp Creek, headwaters to mouth (Big Hole River)	MT41D004-110	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Nitrogen	Nutrients	Aquatic Life, Cold Water Fishery
		Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery

Table 1-1: 2006 Impaired Water Bodies, Impairment Causes, and Impaired Beneficial Uses in the Upper and North Fork Big Hole River TPAs.

Water body & Location Description	Water body ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Rock Creek, headwaters to mouth (Big Hole River)	MT41D004-120	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Nitrogen	Nutrients	Aquatic Life, Cold Water Fishery
		Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery
Miner Creek, headwaters to mouth (Big Hole River)	MT41D004-140	Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
Governor Creek, headwaters to mouth (Big Hole River-South of Jackson)	MT41D004-150	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Copper	Metals	Aquatic Life, Cold Water Fishery
Pine Creek, headwaters to mouth (Andrus Creek-Governor Creek)	MT41D004-160	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery
Fox Creek, headwaters to mouth (Governor Creek)	MT41D004-170	Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery
Warm Springs Creek, headwaters to mouth (Big Hole River-Near Jackson)	MT41D004-180	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	Sediment	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Total Kjehldahl Nitrogen (TKN)	Nutrients	Aquatic Life, Cold Water Fishery
		Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery
Steel Creek, headwaters to mouth (Big Hole River)	MT41D004-190	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
		Copper	Metals	Aquatic Life, Cold Water Fishery
		Cadmium	Metals	Aquatic Life, Cold Water Fishery
		Phosphorus	**Nutrients**	Aquatic Life, Cold Water Fishery

Table 1-1: 2006 Impaired Water Bodies, Impairment Causes, and Impaired Beneficial Uses in the Upper and North Fork Big Hole River TPAs.

Water body & Location Description	Water body ID	Impairment Cause	TMDL Pollutant Category	Impaired Uses
Francis Creek, headwaters to mouth (Steel Creek) T3S R15W	MT41D004-200	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Nitrogen	**Nutrients**	Aquatic Life, Cold Water Fishery
		Phosphorus	**Nutrients**	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
McVey Creek, headwaters to mouth (Big Hole River) T1S R15W	MT41D004-210	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Nitrogen	Nutrients	Aquatic Life, Cold Water Fishery
		Phosphorus	Nutrients	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
Doolittle Creek, tributary to the Big Hole River T1S, R14W	MT41D004-220	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Sedimentation/ Siltation	**Sediment**	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation
Pintlar Creek, headwaters to mouth (Big Hole River)	MT41D003-170	Habitat Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery
		Temperature	Temperature	Aquatic Life, Cold Water Fishery
		Low Flow Alterations	Not a Pollutant	Aquatic Life, Cold Water Fishery, Recreation

*Bold text in the pollutant category column indicates a TMDL is included for the pollutant in this document.

This document only provides TMDLs for pollutants identified by bold text in **Table 1-1**. The TMDLs address the associated impairment causes. New data collected during this project indicated the need for sediment TMDLs in six other watersheds in addition to the TMDLs identified as needed by Montana's impaired waters list. The additional TMDLs completed within this document address aquatic life and cold water fishery impacts of siltation/sedimentation in the upper Big Hole River, Fox, Governor, Mussigbrod, Pine, and Steel creeks. Also a nitrogen TMDL was completed for Steel Creek which Montana's impaired waters list did not identify. A total of 24 TMDLs are provided in this document. Other impairment causes in **Table 1-1** will be addressed in the future.

1.2 Water Quality Impairments and TMDLs Addressed Within This Plan

Water quality impairments affecting the Upper Big Hole River and its tributaries, which are addressed by this plan, include sediment, nutrients, metals, and elevated water temperatures. These pollutants have been shown to impair some designated uses of these streams, including aquatic life and cold water fisheries, and drinking water (See **Table 1-1**). Because TMDLs are completed for each pollutant/water body combination, this framework water quality improvement plan, contains several TMDLs.

The DEQ recognizes there are some pollutant listings for this TPA that are not addressed with TMDLs at this time, however, some pollutants may not have been on Montana's list of impaired waters at the time this TMDL project was initiated. Other TMDLs may not have been addressed at this time because there may have been unacceptable levels of uncertainty with current knowledge or because there were indications in newly collected data that a number of the TMDLs were not necessary even though pollutants were identified as potentially influencing a use on Montana's impaired waters list.

Impairment can be due to a group of causes defined as "pollution". TMDLs are not required for pollution, although in many situations the solution to one or more pollutant problems will be consistent with or equivalent to the solution for one or more pollutant problems. The link between pollutant TMDLs in this document and pollution impairment causes usually resides in the source assessment of pollutants and the restorataion strategy to reduce pollutant loads. For instance, most sediment sources within the watershed relate to riparian vegetation conditions that hold soils in the streambanks together and provide sediment filtering near streams. Riparian habitat alterations are a source of sediment in many areas of this watershed and are addressed by sediment TMDLs in the restoration approach for reducing sediment load to the stream network. Similarly, the temperature TMDL for the Big Hole River addresses reduced flows as a source of heating in the source assessment. Flow alteration is not a pollutant, yet it influences stream temperature. Restoration approaches for the temperature TMDL identify stream flow as an important approach to reducing temperature.

1.3 Stakeholder and Public Participation

A technical advisory approach was used during the TMDL process. During the initial phases of TMDL development technical advisors and local stakeholders were provided the opportunity to supply information about known pollutant sources in the watershed and give comment on monitoring and modeling approaches for TMDL development. The Big Hole Watershed Committee and Big Hole River Foundation provided support for TMDL monitoring in a number of ways. Both groups supplied labor resources for TMDL monitoring crews. The Big Hole Watershed Committee provided landowner outreach during this timeframe to educate landowners about the TMDL process while securing land access for monitoring. These groups also provided in-kind local effort and secured state funding match to provide the State of Montana an avenue for use of federal funding for this project. The United States Forest Service also assisted in sediment, riparian habitat, temperature, metals and nutrient monitoring. Montana MDT completed a road sanding study for Lost Trail Pass for use in the TMDL effort.

Stakeholder and public comment processes considerations are reviewed in more detail in **Section 12.0** of this document.

1.4 Document Layout

The main body of the document provides a summary of the TMDL components. Additional technical details of these components are contained in the appendices of this report. In addition to this introductory section which includes the background, identification of TMDLs developed, and a description of stakeholder involvement during TMDL development, this document has been organized into the following sections:

- **Section 2.0 –**Watershed Description: a description of the physical and social characteristics of the watershed.
- **Section 3.0 –** Montana Water Quality Standards: discusses the water quality standards that apply to the watershed.
- **Section 4.0 –** Description of water quality target conditions and influencing factors.
- **Section 5.0 –** Comparison of existing conditions for each stream of interest and how they compare to the water quality targets and influencing factors.
- **Section 6.0 –** Description of TMDL necessary components.
- **Sections 7.0-9.0 –** Sediment, Nutrient, and Temperature TMDL Components, sequentially: each section summarizes identified sources of the respective pollutant and the determined TMDL for the respective pollutant / water body combinations addressed by this plan.
- **Section 10.0 –** Restoration Objectives and Implementation Plan: discusses water quality restoration objectives and presents a framework implementation strategy for meeting the identified objectives and TMDLs.
- **Section 11.0 –** Monitoring for Effectiveness: describes a water quality monitoring plan for addressing uncertainty in assessments and evaluation the long term conditions within the watershed
- **Section 12.0 –** A review of technical, stakeholder and public involvement activities during this TMDL process.
- **Section 13.0 –** Literature Reference

SECTION 2.0
WATERSHED CHARACTERIZATION

The Upper Big Hole River Watershed lies in the southwest corner of Montana, about 50 miles west of Dillon, Montana (**Appendix K**, **Map 1**). The Upper Big Hole River TMDL planning area (TPA) is approximately 1,200 square miles (770,761 acres) and encompasses all the area upstream from the confluence of the Big Hole River with Pintlar Creek. This section provides a description of the physical, ecological, and socioeconomic character of the Upper Big Hole River TPA. Additionally, this chapter includes discussion of the relations between watershed characteristics to TMDLs and associated conservation issues in the basin.

2.1 Geological Setting

The Upper Big Hole River Valley is one of the widest and highest elevation valleys in southwest Montana. The valley area is approximately 32 x 52 miles and the valley floor elevation exceeds 6,000 feet throughout. Much of the valley bottom consists of Quaternary alluvial and glacial deposits, often overlying Tertiary aged sedimentary rocks of the Bozeman Formation (**Map 2**). The Beaverhead Mountains along the western edge of the watershed consist mostly of Proterozoic age quartzite, argillite, limestone, and shale. The Pioneer Mountains, which consist dominantly of Cretaceous granitic intrusive rocks, comprise the eastern boundary of the watershed. The northern boundary, defined by the Anaconda Range, consists mostly of Tertiary granitic intrusive rocks. Oil exploration in the 1980s revealed thick accumulations of Tertiary sediments filling the Upper Big Hole Valley. These basin fill deposits, which approach 14,000 feet in depth, are thicker than any other in the region (Alt and Hyndman 1986).

2.2 Soils

Detailed soils data is currently unavailable for the Upper Big Hole River TPA. However, the Natural Resource Conservation Service (NRCS) is currently conducting a detailed Soil Survey Geographic Database (SSURGO) soils survey and those data should be available for future efforts. Evaluation of the SSURGO soils database for Madison County indicates that soils contributed from the Bozeman Formation typically have low available water capacity, low clay content, and high permeability. This suggests that these soils have insufficient capacity to hold adequate water to support substantial plant growth. The nature of soils has implications for water management and TMDL planning in the basin.

2.3 Climate

The climate of the basin is an important consideration in support of sensitive beneficial uses. Long, cold winters and short, moderately hot and dry summers characterize the climate of the Upper Big Hole River Watershed. Average monthly minimum temperatures and maximum temperatures range from 1.8-78.1°F in January and July, respectively. The valley portions of the watershed are semiarid with average annual precipitation of 11.82 inches/year at Wisdom. Headwater portions of the watershed receive considerably more precipitation, reaching an average 53 inches/year in the headwaters of Berry Creek, located in the southwest portion of the watershed. The growing season is short, with an average of 45 frost-free days/year. Maximum daily temperatures are below freezing for an average of 75 days/year. A precipitation map can be found in **Appendix A**.

2.4 Hydrology

The hydrology of the Upper Big Hole River and its tributaries reflect significant alteration of natural flows due to water use practices. Because dewatering and associated thermal impairments figure largely in many of the 303(d) Listed streams, a detailed description of groundwater and surface water hydrology provides useful information to support TMDL planning. This section describes hydrologic conditions in the Upper Big Hole River Watershed based on existing hydrologic studies and limited evaluation of more recent gage data.

2.4.1 Surface Water Hydrology

Readily available stream gage data document the magnitude, timing and patterns of stream flow in the Upper Big Hole River TPA. Mean daily stream flows measured at three USGS gaging stations (**Table 2-1**) provide the basis to describe the surface water hydrology of the mainstem Big Hole River. The stream gage located in the uppermost watershed area (Big Hole River near Jackson gage) lies near Van Houten Lake. This gage station was active from 1948-1953. The gage located at Wisdom has been active since 1988 and has mean daily flow data for the months of April through December. Located further downstream, the gage below Mudd Creek has been active since 1997, and has recorded mean daily stream flow values for the months of April through October. It is important to note that the relatively short, recent periods of record for each gage encompass only impacted hydrologic conditions. Therefore, it is impossible to use the gage data to quantify natural flows or to quantify long-term hydrologic trends. The following analyses provide a means to evaluate existing hydrographic features and draw inference regarding the effect of human activities on basin hydrology:

- Maximum mean daily flow
- Mean monthly stream flow
- Low flow duration analysis

Table 2-1: USGS gaging stations utilized in hydrologic characterization

Site Number	Site Name	Period of Record	Drainage Area (sq mi)	Months Recorded
06023500	Big Hole River near Jackson	Apr 1948-Oct 1953	44	Jan-Dec
06024450	Big Hole River below Big Lake Cr at Wisdom	May 1988-Sept 2002	575	Apr-Dec
06024540	Big Hole River below Mudd Cr nr Wisdom	Oct 1997- Sept 2002	1267	Apr-Oct

- Recorded annual peak flows identify historic patterns of flooding in the watershed. At the Wisdom gage, measured annual peak flows between 1988 and 2002 ranged from less than 500 cfs to almost 4000 cfs (**Figure 2-1**). Individual periods with relatively low annual peak flows include 1988-1990, 1992-1994, and 2000-2002. Relatively high peak flows characterized the period from 1995-1999, with flows exceeding 1500 cfs at Wisdom each of those years. On June 7, 1991, flows at the Wisdom gage peaked at 3830 cfs, which is the flood of record at the gage. Since 2000, peak discharges at the Wisdom gage have been below 1300 cfs; measured peak discharges during 2000 and 2001 at the Wisdom gage were 649 cfs and 563 cfs, respectively. Peak flows downstream at the gage near Mudd Creek are typically 2 to 2.7 times larger than flows measured at Wisdom, reflecting the increased contributing drainage area at that location, including the North Fork Big Hole River.

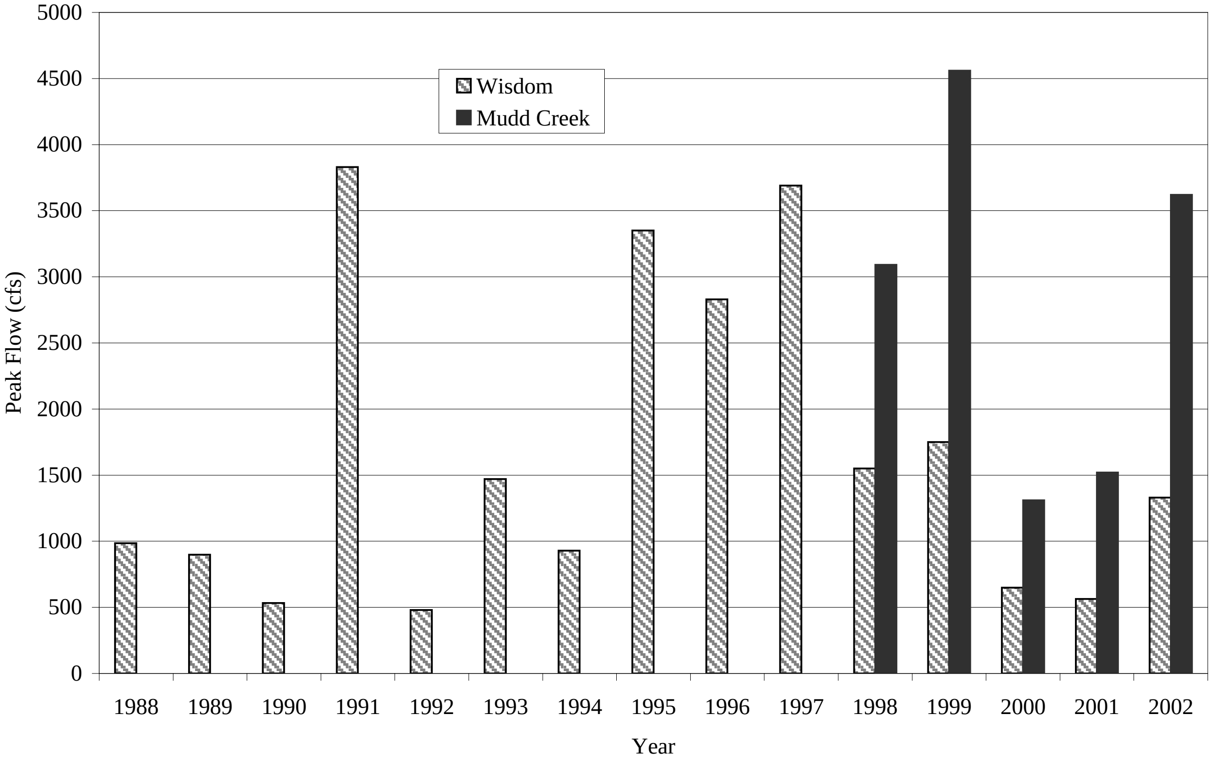

Figure 2-1: Annual peak discharges, Upper Big Hole River near Wisdom, and near Mudd Creek.

Recorded mean monthly discharge at the three gages indicate that annual peak water yields occur during the months of May and June on the mainstem Big Hole River, which is due to a combination of precipitation and snowmelt runoff during that time (**Figure 2-2**). Although the rising limb of the spring snowmelt hydrograph tends to be gradual through the months of April through June, flows tend to drop rapidly through late June and July, creating an asymmetric mean monthly hydrograph. This asymmetry increases in the downstream direction from Jackson to below Mudd Creek. The rapid drop in the recessional limb of the spring runoff hydrograph correlates to the onset of flood irrigation practices in the basin indicating the effect of this use on water quantity in the Big Hole River.

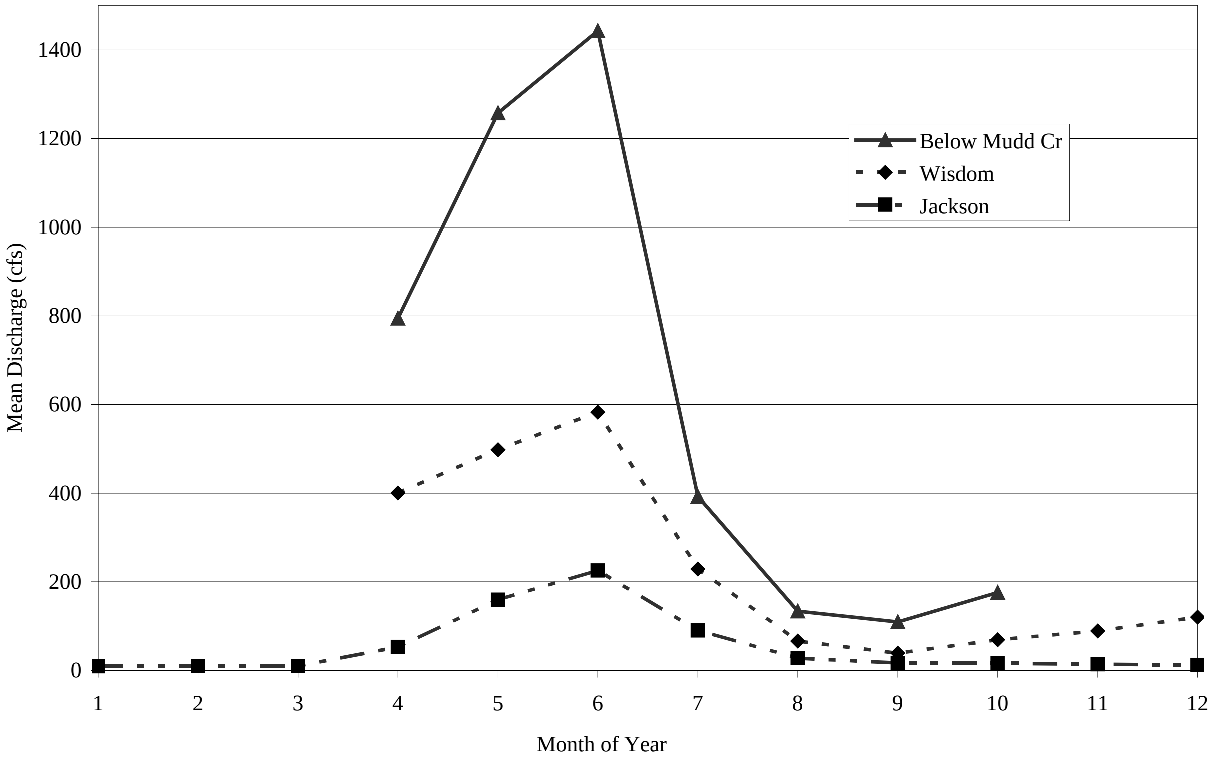

Figure 2-2: Mean monthly discharge for period of record on Upper Big Hole River USGS stream gages.

Analysis of mean daily stream flow data also describes the timing and magnitudes of minimum flows at a given location. One way to assess typical low flows is through an analysis of flow duration for a given stream gage record. Flow duration refers to the percent time that a given flow value is equaled or exceeded. A 100% duration flow reflects the flow equaled or exceeded 100% of the time, or the minimum flow value recorded at the gage. Flow duration curves for the three gaging stations illustrate effects of dewatering on the Big Hole River between the Jackson and Wisdom gaging stations, a reach providing critical habitat for Arctic grayling. Although the data from near Jackson and below Mudd Creek show 100% duration flows in excess of approximately 10 cfs, the Wisdom gage depicts a significant drop in flow magnitudes at about the 95% flow duration (**Figure 2-3**). Over the period of record at the Wisdom gage (April through December, 5/1988-9/2002), flows have been below 10 cfs approximately 5% of the time.

Seasonal dewatering of the Big Hole River is a leading cause of degraded fisheries habitat (Byorth and Magee 1996). At the Wisdom gage, a minimum discharge of 60 cfs is necessary to maintain the existing fishery, and a “minimum survival flow” of 20 cfs is required for short-term fisheries survival (DNRC 1995). At Wisdom, the proposed “minimum survival flow” of 20 cfs was unattained approximately 12% of the time over the period of record (**Figure 2-3**). The proposed fisheries maintenance discharge of 60 cfs was unattained approximately 39% of the time

In the uppermost reaches of the Big Hole River, from 1948 through 1953, which is the period of record at the gage near Jackson, flows exceeded a minimum of 9 cfs every day between April and October. Downstream at Wisdom, where the contributing drainage area is approximately 13 times larger, flows were less than 9 cfs for a total of 151 days, during the months of April through October, from 1988 to 2002 (5% of the time). This suggests that either natural runoff varied dramatically during the two periods of record, or that significant low flow dewatering occurs between the headwaters of the Big Hole River and Wisdom.

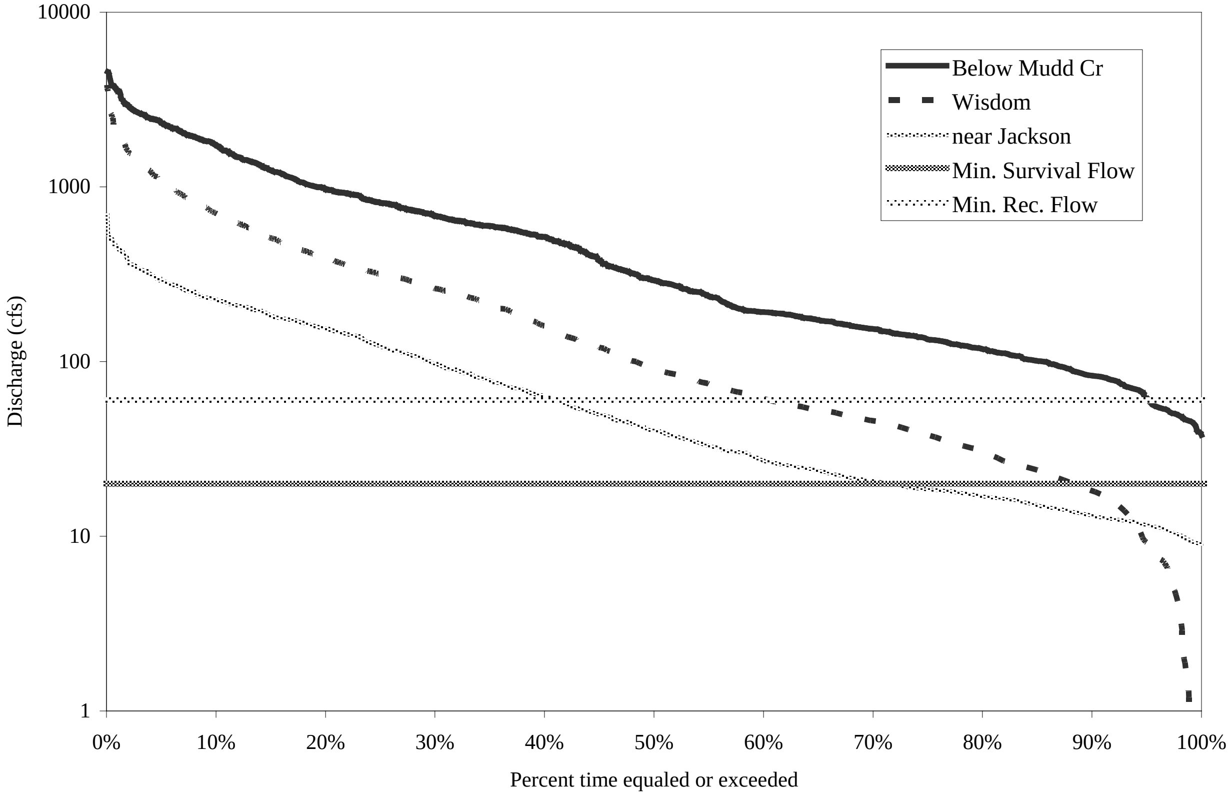

Figure 2-3: Mean daily flow duration curves for the Upper Big Hole River stream gage data, April though October.

Assessment of minimum-recorded, daily flows for the period of record clearly depicts the reduction of in stream flows in the Upper Big Hole River at Wisdom. Minimum flows tend to occur between early August and late September (**Figure 2-4**). Between late July and August, minimum flows were all less than 10 cfs. Minimum flows of less than 20 cfs have occurred in the months of June, July, August, September, and October.

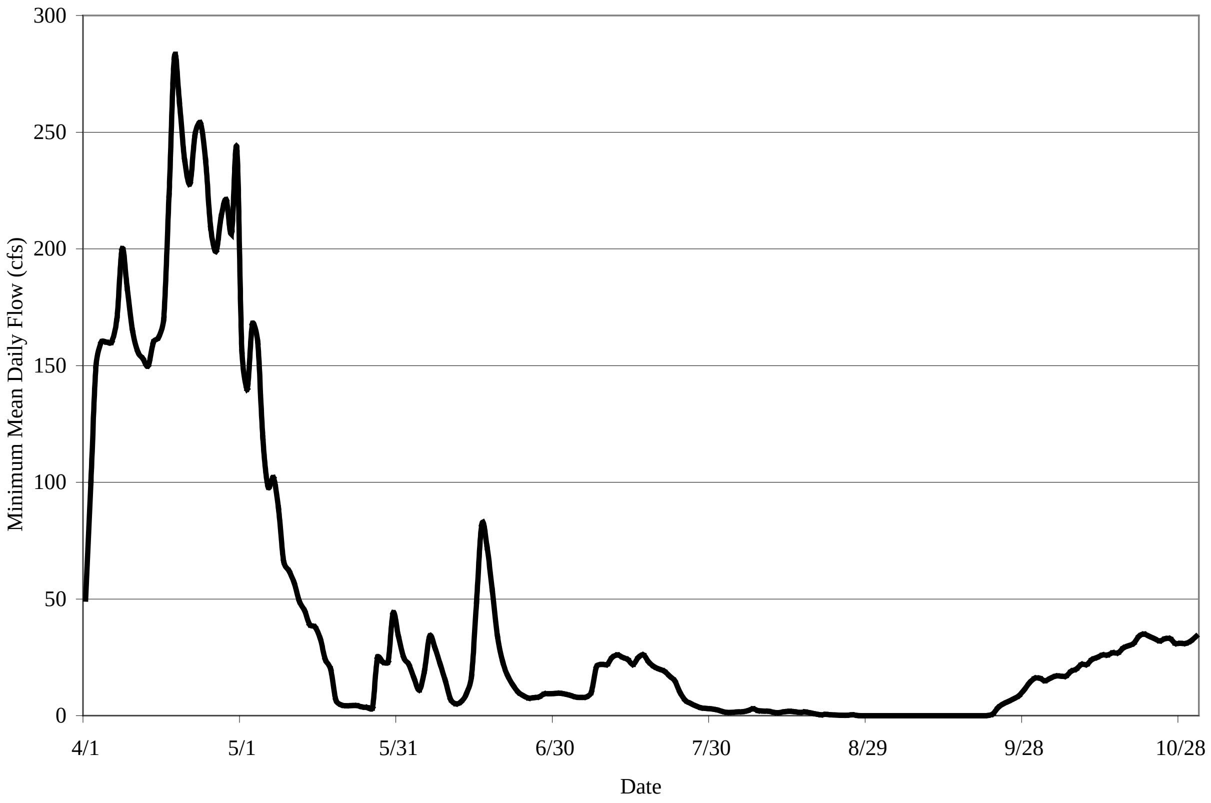

Figure 2-4: Minimum recorded mean daily discharge, 1988-2002, Big Hole River near Wisdom

A comparison of the stream flow contributed from individual major sub-watersheds identifies spatial trends in surface water withdrawals. Fundamentally, in a single basin, the relative contribution of flow from contributing sub-watersheds relates in part to the sub-watershed's drainage area. The contributing drainage area above the Wisdom gage (575 sq mi) is approximately 45% of that contributing to the gage below Mudd Creek. (1267 sq mi). The largest contributing sub-watershed between Wisdom and Mudd Creek is the North Fork Big Hole River. As the upper basin characteristics on the North Fork are physiographically similar to those of the Upper Big Hole River above Wisdom, it would follow that flows at Wisdom should be about 45% of those at Mudd Creek. Nevertheless, on average, mean daily summer flows at Wisdom are significantly less than 45% of those at Mudd Creek. In 1999, mid-summer flows at Wisdom were commonly less than 20% of those at Mudd Creek (**Figure 2-5**). By fall, relative flow contributions from the mainstem of the Upper Big Hole increased to 40% of the total flow below Mudd Creek. The relatively low surface water yield from the Upper Big Hole sub-watershed above Wisdom during summer months indicates that dewatering is a more significant impact in the sub-watershed area above Wisdom than the North Fork Big Hole River sub-watershed.

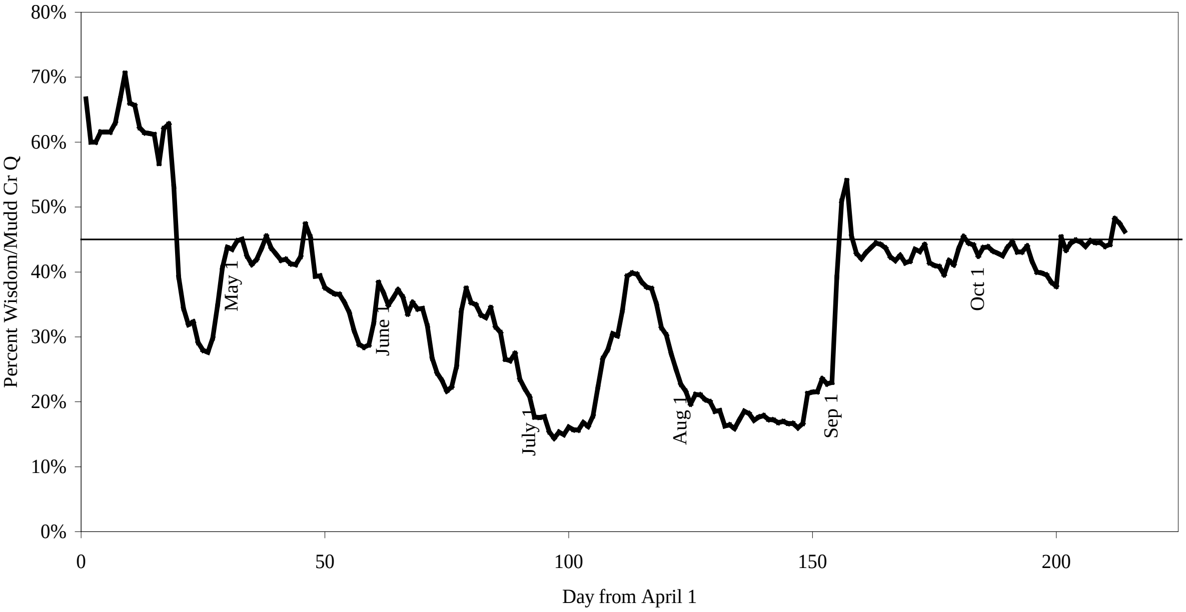

Figure 2-5: Ratio of mean daily flows on the Upper Big Hole River at Wisdom and near Mudd Creek.

The surface water hydrology of the Upper Big Hole River is typical of snowmelt driven watersheds. Peak discharges typically occur in the month of June, and the spring runoff event steeply recedes in July. The rate of flow recession following peak discharges tends to increase in the downstream direction from Jackson to below Mudd Creek. The flow duration and minimum flow assessments indicate that at the Wisdom gage instream flows were less than 20 cfs approximately 12% of the time. These minimum flows typically occurred during the months of June, July, August, and September. Analysis of relative contributions from sub-watersheds indicates the North Fork Big Hole River contributes more water relative to drainage size than the upper mainstem of the Big Hole River and its tributaries. This indicates that substantial dewatering occurs in the system upstream of Wisdom. As flood irrigation is widespread throughout the basin during late spring and summer, the reduction of instream flows during that period is systemic throughout the basin. However, the greatest relative impact of water use on the Big Hole River show surface flows evidently occur upstream of the North Fork confluence.

The Big Hole Drought Management Plan was adopted by the Big Hole Watershed Committee in partnership with Montana Department of Fish, Wildlife and Parks (FWP), Department of Natural Resources and Conservation (DNRC), and the U.S. Natural Resources Conservation Service (NRCS) in 1997. The plan has since been amended in 2000, 2002, 2004, 2005, and 2007. Its purpose is to mitigate the effects of low stream flows and lethal water temperatures for fisheries (particularly fluvial Arctic grayling) through a voluntary effort among agriculture, municipalities, business, conservation groups, anglers, and affected government agencies.

2.4.2 Ground Water/Surface Water Interactions

Interactions between ground water and surface water are an important component of the basin's hydrology. Connectivity between streams and the ground water table influences stream flow, especially at critical low flow periods. Understanding the dynamics between these waters is an essential element of water planning in the basin. This section describes the groundwater resource and its connectivity to surface waters.

Groundwater occurs in the permeable sands and gravels in the uppermost units within the Quaternary-age basin fill. Groundwater withdrawals in the basin are typically from this aquifer; the average well depth in the basin is 97 feet and average pumping level is 41 feet (DNRC 1995). Wells completed in the Tertiary and Quaternary sands and gravels typically produce about 5-20 gallons/minute (Marvin and Voeller 2000). Very shallow water table levels are common, especially during the maximum recharge period that extends from early spring to early summer.

Marvin and Voeller (2000) conducted a comprehensive investigation of ground water/surface water interactions in the Upper Big Hole River Basin during 1997 and 1998. These investigators integrated gaging station data, ground water elevations measured at 43 wells, climate data, and synoptic stream flow measurements from 20 tributaries. Using this data, the authors were able to assess several aspects of the groundwater resource and its influence on surface water. This includes seasonal and spatial patterns of groundwater storage, surface recharge dynamics, and losses to evapotranspiration.

Groundwater hydrographs for the basin depict a seasonal pattern influenced by snowmelt and irrigation practices (Marvin and Voeller 2000). Groundwater levels are lowest in winter and increase in March and April due to melting of the valley snowpack. Groundwater elevations continue to rise in May and June in response to contributions from the mountain snowpack and flood irrigation at lower elevations. Groundwater levels typically decline after mid-July following cessation of irrigation of hay meadows around July 4. Calculations based on average annual water changes suggest that groundwater storage in the basin is approximately 170,000 acre-feet

Groundwater hydrographs vary across the Upper Big Hole River Basin. The average annual water level change in the measured wells of the Upper Big Hole is about 5 ft. Still, marked variability occurs among wells. For example, in a well close to Governor Creek near Jackson, the 1996 peak water level occurred approximately one week after flood irrigation began in May, and, during those 6 days of irrigating, the water level rose 16.7 ft, or 2.8 ft/day. Active flood irrigation kept the water level relatively steady for the next 7 weeks. Irrigation ended on about July 9, 1996, and at that point the water levels dropped an average of 0.33 ft/day, until they stabilized in September at a level approximately 20 ft below the mid-summer peak.

Marvin and Voeller (2000) evaluated the extent of surface recharge from groundwater through several lines of evidence. First, a comparison of gaged total basin inflow to total outflow at the Mudd Creek gage indicated that during August 1998, inflows essentially balanced outflows (approximately 260 cfs). In September, however, outflows were approximately 32 cfs lower than inflows, indicating that groundwater contributions to surface flow failed to compensate fully for upstream surface-water losses related to evapotranspiration and seepage.

Next, the authors compared estimated basin water yield and measured surface water yield to draw inferences on the amount of water lost to evapotranspiration. With an average annual precipitation of 25.1 inches, the estimated total annual water yield delivered to the basin was 1.7 million acre-feet. Mean annual surface-water yield was approximately 456,000 acre-feet, which is approximately 27% of the total input. Mean annual evapotranspiration losses within the basin were therefore approximately 1.2 million acre-feet, or 18.3 inches (Marvin and Voeller 2000).

In addition to the general assessment of ground water/surface water interactions in the Upper Big Hole River Basin, Marvin and Voeller (2000) performed an intensive study within the Stanley, Sheep, and Francis Creek watersheds south of Wisdom (Francis Creek Unit). Data used in this evaluation included synoptic stream flow measurements on the streams and irrigation diversions and continuous flow measurements on the downstream end of Francis Creek, as well as on Huntley Ditch. These data were integrated with water levels measured in 23 wells within the unit.

Within the Francis Creek Unit, groundwater storage reductions in the fall and winter of 1997-1998 averaged 400 acre-feet/month. Between March and June 1998, total increase in storage was about 6,300 acre-feet. Natural melting of the valley snow pack contributed approximately 30% of this total, with the remainder (4200 acre-feet) attributable to recharge from irrigation in May and June. By September, storage dropped by approximately 4,500 acre-feet, of which an estimated 3,100 acre-feet was stored irrigation water. Marvin and Voeller attributed the reduction in water storage volume in July, August, and September to evapotranspiration processes, rather than surface or subsurface discharge.

Water balance results indicate that the 1998 evapotranspiration rates in the Francis Creek Unit were greatest during the month of July (4,800 acre-feet). For the entire 1998 growing season (May-September), evapotranspiration accounted for an estimated of 14,728 acre-feet of loss, which is approximately 57% of total input volume (Marvin and Voeller 2000). Assessment of irrigated acreage and associated evapotranspiration during the 1998 growing season corroborated these estimates. The evapotranspiration loss was 14,000 acre-feet, with grass hay consuming 64% of that value. Similarly, Levings (1986) estimated that approximately 73% of the total water delivered to the basin is lost to evapotranspiration.

In summary, the assessment of ground water storage trends, trends in surface water discharge, and evapotranspiration losses in the Francis Creek Unit indicate that although ground water storage increased by 4,200 acre-feet during the irrigation season (May and June), about that same amount was lost by subsequent evapotranspiration. This implies no correlation between the mid-to-late summer reduction in groundwater and surface water discharges. Thus, Marvin and Voeller (2000) concluded, “Irrigation returns appear to have a negligible effect on stream flow during the summer and early fall.” After the growing season, however, from October 1997 through February 1998, about 40% of the water released from groundwater storage was irrigation water. With relatively low evapotranspiration rates during that time of year, it is possible that irrigation water enhances surface water flows after the growing season ends.

2.5 Fluvial Geomorphology

Fluvial geomorphology refers to the study of the physical, morphological processes that operate within river systems and the landforms they create or have created. A number of factors influence fluvial geomorphology including basin geology, climate, vegetation, and hydrology. Because alterations in river geomorphology appear to be an issue with many 303(d) Listed streams in the Upper Big Hole River Basin, characterization of fluvial processes in the basin is an important component of watershed restoration planning. Integration of field observations, available documents, and interpretation of aerial photography provide the basis for the following geomorphic characterization of the Upper Big Hole Watershed.

2.5.1 General Setting

The Big Hole is the “highest and widest of the broad mountain valleys of western Montana” (Alt and Hyndman 1986). In the 1980s, wildcat oil well drilling revealed that the valley fill sediments are roughly 14,000 ft thick, which is far deeper than any other valley in the region. Erosion into this valley fill has resulted in the formation of terrace surfaces in the basin. The Tertiary-age Bozeman Formation underlies the highest surface. More recent alluvial deposits form additional terrace surfaces inset within the Bozeman Formation exposures. Glacial deposits, including outwash and moraines, are present on the basin margins.

2.5.2 Stream Morphology

As part of initial TMDL assessments, a basic Rosgen Level 1 stream classification of 303(d) Listed streams allowed segmentation of the channels into a series of reaches and broad categorization of the geomorphic character of each reach. This section provides a brief description of channel types identified in the classification effort (**Table 2-2**).

Observed channel types on the 303(d) Listed streams of the Upper Big Hole Basin range from steep, confined headwater channels to lower gradient channels in the valley bottoms. The geomorphic character of the individual stream segments is primarily a function of topography, geology, and land use. Proximal valley walls typically confine headwater channels, resulting in a lack of active floodplain area (A/B-type channels). In these areas, the valley walls are commonly steep timbered slopes with localized areas of timber harvest. The high elevation confined channels commonly transition into relatively broad glaciated valley bottoms that are relatively flat. Channels in these areas tend to be sinuous, stable stream segments that have willow dominated valley margins (E-type channels). As the streams enter the Upper Big Hole River Valley, the valley slope becomes more gradual. The streams in the basin tend to form sinuous threads that commonly occupy multiple active channels (DA-type channels). Commonly, reaches with multiple channel threads have a single, dominant C-type channel. In numerous areas, dense willows line the active channel margin, although the density of woody riparian vegetation is highly variable. Sediment storage in the form of bars is also variable; in most areas, little evidence of bar formation exists. In some reaches, however, such as those in which the channel abuts high terraces or where lateral migration rates are high, unvegetated point bars are common.

Table 2-2: Channel types (Rosgen 1996) identified on streams in the Upper Big Hole River Watershed in Level I classification activities.

Stream Type	Fundamental Characteristics
A	*A-Type Channels* are relatively steep channels that form in headwater areas as well as within bedrock canyons. These channels are entrenched and confined by steep valley margins such that little to no floodplain occurs on their border. As the boundaries of A-type channels are typically highly resistant to erosion, these stream types are generally quite resilient with respect to human impacts. The most common cause of geomorphic change within A-type channels is due to large scale sediment transport events, (landslides, debris flows, debris jam failure) that may result in blockage or deflection of channel flow.
B	*B-Type Channels* tend to form downstream of headwater channels, in areas of moderate slope where the watershed transitions from headwater environments to valley bottoms. Moderate slopes, moderate entrenchment, and stable channel boundaries characterize B-channels. Due to the relatively steep channel slopes and stable channel boundaries, B-channels are moderately resistant to human impacts, although, their reduced slopes relative to headwater areas can make them prone to sediment deposition and subsequent adjustment in the event of a large sediment transport event such as an upstream landslide, debris flow, or flood.
C	*C-Type Channels* are typically characterized by relatively low slopes, meandering plan forms, and pool/riffle sequences. The channels tend to occur in broad alluvial valleys, and they are typically associated with broad floodplain areas. C-channels tend to be relatively sinuous, as they follow a meandering course within a single channel thread. In stream systems in which the boundaries of C-type channels are composed of alluvial sediments, channels tend to dynamic in nature, and susceptible to rapid adjustment in response to disturbance.
D	*D-Type Channels* are braided channels that have open bar deposits between active channel threads. They tend to occur where sediment supply is abundant. They can commonly result from disturbances that increase sediment loads. D-channels are commonly aggradational, and are typically characterized by rapid rates of lateral adjustment.
DA	*DA-Type Channels* have multiple active channel threads that are relatively narrow and deep, separated by extensive, vegetated floodplains and wetlands. DA channels tend to form in areas of relatively low slope, with low bedload sediment volumes. Bank lines are typically very stable.
E	*E-Type Channels* are somewhat similar to C channels, as they form as single threads with defined, accessible floodplain areas. However, E channels are different in that they tend to have fine-grained channel margins, which provide cohesion and support dense bank line vegetation. The fine-grained, vegetation-reinforced bank lines allow for the development of steep banks, very sinuous plan forms, and relatively deep, U-shaped channel cross sections. E-type channels commonly form in low gradient areas with fine-grained source areas, mountain meadows, and in beaver-dominated environments. E-channels tend to have very stable plan forms, and efficient sediment transport capacities due to low width/depth ratios.

Table 2-2: Channel types (Rosgen 1996) identified on streams in the Upper Big Hole River Watershed in Level I classification activities.

Stream Type	Fundamental Characteristics
F	*F-Type Channels* typically have relatively low slopes (<2%), similar to C and E channel types. The primary difference between C/E channels and F channels is with respect to entrenchment. F channels are entrenched, which means that the floodplain is quite narrow relative to the channel width. The entrenchment of alluvial F-type channels typically is an indicator of an historic down cutting event. F-type channels may form in resistant boundary materials (e.g. U-shaped bedrock canyons), and relatively erodible alluvial materials (e.g. arroyos). When the boundary materials are erodible, the steep valley walls are prone to instability, and channel widening commonly occurs within the entrenched channel cross section.

Human influences on stream geomorphology are evident in the basin, especially along channels that occupy the valley bottoms. Numerous diversion structures are present along and within the channels, and the definition of the channels on aerial photographs is commonly reduced immediately downstream of major diversions. Riparian vegetation has been actively cleared from stream corridors, and locally stream segments have been straightened to accommodate infrastructure elements, such as highways and bridges.

2.5.3 Stream and Valley Geology Interaction

Reconnaissance-level field observations indicate that the primary types of sediment delivered to the river network include grus (granite-derived sand) and reworked alluvium consisting of gravels and coarse rounded cobbles/boulders. These particles tend to form an armor layer on the channel bed. The valley fill deposits exposed on terrace margins consist of relatively non-cohesive, poorly sorted, rounded alluvium. These deposits constitute a primary local sediment source for the Big Hole River and North Fork Big Hole River. As a result, the bed material is commonly bimodal, with a coarse, largely immobile lag substrate, and highly mobile sand. Gravel concentrations are higher where the channel directly accesses sediment from the terrace margins. Gravel concentrations appear to be relatively high in the Big Hole River upstream of Wisdom and on the North Fork Big Hole River.

2.5.4 Channel Evolution

A series of human activities over the last 200 years has affected the Upper Big Hole River system. In the 1800s, fur trappers described thousands of acres of riparian shrubs and beaver dams covering the valley. Beaver trapping in the intermountain west was dramatic, and the systemic reduction in beaver populations likely resulted in significant evolutionary changes in affected river channels. Some estimates suggest that 65 million beavers lived in North America 300 years ago (Wilkinson 2003). By the early 20th century, beaver populations had decreased to the point of being functionally extinct. The geomorphic implications of this extensive reduction in beaver populations are significant. Extensive beaver dams in river systems provide grade controls and result in the formation of complex channel networks with high water table levels that promote willow colonization. The consumption of willows by beavers promotes extensive suckering and active regeneration that increase bank stability. Beaver-dominated stream systems provide a complex in-channel habitat in the way of woody debris recruitment, pool formation, and trapping of fine sediment. Beaver dam-derived pools provide biological resilience to drought, and promote groundwater recharge (Wilkinson 2003). High flows result in periodic dam failure, which results in temporal shifts in primary channel dominance, sediment flushing, and habitat rejuvenation.

Documentation of the geomorphic effects of historic beaver removal in alluvial channels of the northern Rockies is limited; however, the topic is receiving increased attention due to ongoing watershed assessment efforts. In general, systems historically dominated by beavers show an evolution from marshy, wide, densely vegetated floodplain areas to less complex, entrenched channels and a narrower riparian corridor.

In the Upper Big Hole River Valley, descriptions of extensive beaver ponds, coupled with existing remnant stands of dense willows and associated multiple channel threads, suggest broad alluvial valley beaver ponding characterized the river system historically. The response to beaver removal was very likely simplification of the complex multi-channeled system. Entrenchment in the mainstem Big Hole River appears to have been limited due to the presence of very coarse substrate; however, this bed armoring resulted in localized channel widening as flow energy became concentrated in fewer active channels. Subsequent impacts of willow removal, intensive grazing, and flow diversions have further affected channel form and process. Results of the field reconnaissance and aerial assessment (Confluence et al. 2003) indicate that beaver removal, riparian corridor degradation, and instream flow diversion have resulted in reduced bank integrity, abandonment of side channels, reduced shading, and diminished small woody debris recruitment. The primary geomorphic response to these impacts have been increased flow conveyance within a primary channel thread, and increased width to depth ratio of the main channel and increased sheer stress on banks.

2.6 Vegetation

Plant community types within the Upper Big Hole River Watershed are typical of higher elevation areas of the Rocky Mountains ecoregion. The most detailed watershed wide assessment of vegetation types available for the Upper Big Hole Watershed is from the USGS GAP Analysis Program (GAP) vegetation project (Redmond et al. 1998). Vegetation types most abundant in the GAP analysis include lodgepole pine, mixed subalpine forest, and sagebrush (**Table 2-3**). Irrigated agricultural lands also comprise a significant portion of the watershed (9.3%). Coniferous forest dominates higher elevations; mid elevations have a combination of mixed forest, mesic shrubs, and sagebrush. Low elevation valleys typically possess a thin strip of riparian vegetation, the remaining area being almost entirely irrigated agricultural lands and low to moderate cover grasslands. Riparian vegetation comprises over 7% of the watershed, primarily in the form of shrub and understory riparian species. Overstory riparian vegetation is minimal unless conifers are present along streams in steeper gradient valleys in mountainous settings. Cottonwoods do not grow in this area because of natural limitations.

Table 2-3: Percent area of predominant vegetation types occurring in the Upper Big Hole Watershed TPA (Redmond et al. 1998).

Vegetation Cover Type	Percent Area
Lodgepole pine	21.7
Mixed subalpine forest	16.3
Sagebrush	13.9
Agricultural lands – irrigated	9.3
Low/moderate cover grasslands	8.5
Douglas fir	4.4
Mixed whitebark pine forest	3.8
Douglas fir/lodgepole pine	3.5
Montane parklands and subalpine meadows	3.5
Mixed mesic shrubs	2.5
Riparian shrubs	2.7
Rock	1.9
Riparian forbs and graminoids	1.8
Mixed riparian	1.1
Riparian conifer	1.0

2.7 Fisheries and Aquatic Life

The Upper Big Hole River Watershed supports prized fisheries in terms of both biodiversity and recreation. This includes a diverse mix of native and introduced species (**Table 2-4**). Species native to the drainage include fluvial Arctic grayling, westslope cutthroat trout, several species of sucker, burbot, mountain whitefish, and longnose dace. Recently, geneticists confirmed that a population of lake trout in Twin Lakes is an endemic population isolated from other lake trout populations by glaciers during the last ice age. Currently, this population is under review as a potential species of special concern due to its highly limited distribution, a condition that may increase its vulnerability to extinction (Montana Natural Heritage Program, personal communication). Introduced species include popular game species such as rainbow trout, brown trout, and brook trout. Common carp, a Eurasian species, is also present in the Upper Big Hole River.

Of particular interest is the fluvial Arctic grayling present in the mainstem of the Big Hole River and many of its major tributaries. This population is the last river dwelling population of Arctic grayling in the lower 48 states. Fluvial Arctic grayling were once widespread in the upper Missouri River drainage from its headwaters to Great Falls (Vincent 1962). Although lacustrine (lake dwelling) and adfluvial (migrating from lakes to streams) populations persist throughout this drainage, the fluvial form exists in only 4% of its historical range (Kaya 1992). Grayling are most abundant in the Big Hole River upstream of its confluence with the North Fork Big Hole River (Liknes and Gould 1987).

Grayling numbers in the Big Hole River Watershed have declined markedly from the early 1980s to the present causing considerable concern for the future of this population. Landowners, agencies, and conservation groups are actively pursuing solutions to reverse the decline and enhance recovery efforts for Arctic grayling. Reasons for the decline of fluvial Arctic grayling include habitat degradation, introduction of non-native salmonids, climatic change, and exploitation by anglers (Vincent 1962). Drought conditions during the late 1990s and early 2000s increased threats to the persistence of this population over the short term. Sampling efforts in 2002 found that catch-per-unit-efforts (CPUE) were the lowest since surveys began in 1978 (Magee and Lamothe 2003). Furthermore, biologists recently captured too few grayling to estimate population densities in key reaches of the Big Hole River (Magee and Lamothe 2003).

The westslope cutthroat trout is another species of special concern in the Upper Big Hole River Watershed. Westslope cutthroat trout have also experienced dramatic declines and are now present in 19-27% of their historic range in Montana (Van Eimeren 1996). In the Big Hole River Watershed, westslope cutthroat trout are presumably present in about 100 streams; however, they rate as abundant or common in only 26 of those streams (MFISH database, Natural Resources Information Service). Westslope cutthroat trout are present primarily in tributaries of the Big Hole River and are rarely present in the mainstem. Causes for the decline of westslope cutthroat trout include cumulative impacts of a number of factors. Similar to fluvial Arctic grayling, habitat degradation, introduced species, and dewatering have contributed to the decline of this species. In addition, hybridization with rainbow trout, and in some cases ,Yellowstone cutthroat trout, has greatly compromised the genetic integrity of westslope cutthroat trout throughout its range.

Table 2-4: Species of fish present in the Upper Big Hole River TMDL TPA and conservation status. Native species are presented in bold.

Family/species	**Scientific Name**	**Status***
Salmonidae		
Brook trout	*Salvelinus fontinalis*	
Westslope cutthroat trout	*Oncorhynchus clarki lewisii*	Species of special concern
Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Species of special concern
Rainbow trout	*Oncorhynchus mykiss*	
Brown trout	*Salmo trutta*	
Mountain whitefish	*Prosopium williamsoni*	
Arctic grayling	*Thymallus arcticus*	Candidate for ESA
Westslope cutthroat trout × Yellowstone cutthroat trout	*O. clarki lewisii* × O. clarki bouvieri	
Rainbow trout × westslope cutthroat trout	*O. mykiss* × *O. clarki lewisii*	
Golden trout	*O. aguabonita*	
Lake trout	*Salvelinus namaycush*	Species under review
Cyprinidae		
Longnose dace	*Rhinichthys cataractae*	
Common carp	*Cyprinus carpio*	
Redside shiner	*Richardsonius balteatus*	
Catostomidae		
White sucker	*Catostomus commersoni*	
Longnose sucker	*Catostomus catostomus*	
Mountain sucker	*Catostomus platyrhynchus*	
Gadidae		
Burbot (ling)	*Lota lota*	
Cottidae		
Mottled sculpin	*Cottus bairdi*	

***Montana Natural Heritage Program and Montana Fish**

The Big Hole River Watershed also supports burbot (also known as ling) the only freshwater member of the cod family. Burbot occur in both the mainstem of the Big Hole River and in numerous tributaries, often at relatively high elevations. Although burbot are a native game species, little is known about their life history and status in Montana streams (personal communication, Dr. Christopher Guy, fisheries biologist, Montana State University). However, the presence of several age classes of burbot in Big Hole River Watershed streams suggests this population may be relatively secure. Fisheries researchers at Montana State University have recently begun a review of the status of this species, which may shed more light on the status of the Big Hole River Watershed population.

In addition to providing significant habitat for sensitive, native species, the Upper Big Hole River Watershed provides high quality fishing opportunities for non-native salmonids. Brook trout are the most abundant introduced species in the basin followed by brown trout. Rainbow trout are also present in many streams in the watershed, however, at relatively low numbers. These species draw anglers from throughout Montana and the US making the Upper Big Hole River one of the most popular streams in the state. In fact, the Upper Big Hole River frequently ranks within the top 20 streams in the state and the top 10 streams in the region based on angler pressure statistics (MFISH database). The popularity of this fishery contributes significantly to the local economy. In 1997, angling contributed over $8 million in revenue to the Big Hole River Watershed.

Amphibians are among the other taxa that rely on surface waters for at least part of their life cycles. According to Maxwell et al. (2003), the Upper Big Hole River Watershed supports several species of amphibian including the Rocky Mountain tailed frog (*Ascaphus montanus*), Columbia spotted frog (*Rana luteiventris*) and boreal toad (*Bufo boreas boreas*). Rocky Mountain tailed frogs occur primarily in forested, headwater reaches of streams in the watershed, although observers noted numerous specimens in McVey Creek at relatively low elevations during 2004 field investigations. The Columbia spotted frog is abundant throughout the valley portions of streams, a habitat where it is typically uncommon in Montana (Reichel and Flath 1995). Presumably, flood irrigation practices in the basin are favorable to this species by providing ample marshy areas lacking predators during their breeding season. The boreal toad is a subspecies of the western toad and is a species of special concern due to risks associated with very limited and potentially declining numbers, extent, and habitat making it vulnerable to global extinction or extirpation in the state (MNHP and MFWP 2002).

2.8 Land Use

Despite the challenging climate, the dominant land use in the Upper Big Hole River TPA is agriculture. Ranchers pasture their livestock on National Forest ranges in the summer and grow irrigated hay for winter feed in the valley bottom, or they summer pasture in the valley bottom and move their livestock out of the basin in the winter. Flood irrigation is used to grow hay throughout the valley bottom with the irrigation season being from early May through mid-July (USFS unpublished data).

Hay production has long been a hallmark of the Big Hole River Valley. The combined practices of hay production and winter-feeding allowed ranchers in the Big Hole River Valley to weather the especially harsh winter of 1886-1887 when ranchers in other parts of the state lost an average of 55% of their herds (Munday 2001). The Big Hole River Valley became renowned as the "land of 10,000 haystacks," a reputation facilitated by the local invention of the beaver slide hay-stacker (Munday 2001).

While hay production is still a principal land use in the Upper Big Hole River, there has been a declining trend over the past 20 years. Hay meadows have been converted to irrigated pastures, and cows and calves are often transported to lower elevations to overwinter. This change in land use has resulted in changes in water use in the basin. While irrigation of hay meadows typically ceased after the first cutting sometime in the early summer, irrigation of pastures for forage production occurs throughout the entire summer. Removal of water from the Big Hole River during the hottest part of the summer has implications for stream temperatures and Arctic grayling. Moreover, these practices have implications for forage production, favoring less nutritious sedges and other wetland species in uplands.

Logging and associated activities such as road construction occur in forested portions of the watershed. Spatial data describing extent and timing of timber harvest activities were unavailable for this phase of TMDL development. Still, restoration priority information provided by the US Forest Service (USFS) indicates that several tributaries receive increased sediment loads from roads. Based on information provided by the USFS, it appears that silvicultural practices in the Upper Big Hole River TPA have improved since the mid-1980s.

Relatively little historic mining and prospecting activity has occurred in the planning area. The Montana Bureau of Mines and Geology abandoned mines database lists 59 mines and prospects in this area. Of these, seven are located in the Steel Creek Watershed, which is listed as impaired for metals. Of these seven, one is under consideration for remediation.

Urban or residential development comprises very little of the Upper Big Hole River TPA. Jackson and Wisdom are the only towns and each has populations of about 100 people (2000 census data). Otherwise, residents of the Upper Big Hole River Valley live on widely spaced ranches. Overall, the Upper Big Hole River Watershed has escaped much of the development pressures facing other small, Montana communities. Harsh, long winters and hoards of mosquitoes in the summer are commonly identified constraints to subdivisions and recreational property development.

SECTION 3.0
TMDL REGULATORY FRAMEWORK

3.1 TMDL Development Requirements

Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify water bodies within its boundaries that do not meet water quality standards. States track these impaired or threatened water bodies with a 303(d) List. Recently the name for the 303(d) List has changed to Montana's Water Quality Integrated Report. State law identifies that a methodology for determining the impairment status of each water body is used for consistency and the actual methodology is identified in **Appendix A** of Montana's Water Quality Integrated Report.

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which Sufficient Credible Data (SCD) show that the water body or stream segment is failing to achieve compliance with applicable water quality standards (Montana Water Quality Act; Section 75-5-103(11)). A "threatened water body" is defined as a water body or stream segment for which SCD and calculated increases in loads show that the water body or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana Water Quality Act; Section 75-5-103(31)). State Law and Section 303 of the CWA require states to develop TMDLs for impaired or threatened water bodies.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable water quality standards to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and need to incorporate a margin of safety and consider seasonality. In Montana, TMDL development is often accomplished in the context of an overall water quality plan. The water quality plan includes not only the actual TMDL, but also includes information that can be used to effectively restore beneficial water uses that have only been affected by pollution, such as habitat degradation or flow modification, that are not covered by the TMDL program.

To satisfy the Federal Clean Water Act and Montana State Law, TMDLs are developed for each water body-pollutant combination identified on the state's list of impaired or threatened waters and are often presented within the context of a water quality restoration or protection plan. State Law (Administrative Rules of Montana 75-5-703(8)) also directs DEQ to "…support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for water bodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations. Montana TMDL laws provide a 5-year review process to allow for an adaptive management approach to update the TMDL and Water Quality Restoration Plan (WQRP).

3.2 Water Bodies and Pollutants of Concern

Category five of the Montana's Integrated Water Quality Report drives the scope of each TMDL project. Some streams within this TMDL planning area do not have sufficient information for 303d assessment or have been deemed as fully supporting all uses and meeting water quality standards and therefore may not be mentioned in this report. See Montana's Integrated Water Quality Report to determine the status of 303d assessment for streams not addressed within this document (http://www.deq.state.mt.us/wqinfo/303_d/what_is_303d.asp and http://cwaic.mt.gov/).

Most pollutant/stream combinations identified on the 2006 list are addressed; however, a few are not addressed at this time due to project and time constraints. These listings will be identified in a follow up monitoring strategy and addressed within a timeframe identified in Montana's law (*Montana Code Annotated 75-5-703*). However, TMDLs were not prepared for impairments where additional information suggests that the initial listings were inaccurate or where conditions had improved sufficiently since the listing to an extent that the pollutant no longer impairs a beneficial use. Where a pollutant is recommended for removal from the list, good cause justification is provided in the sections that follow. **Tables 3-1 and 3-2** provide a summary of water body information for the 2006 303(d) List for the Upper and North Fork Big Hole River TPAs. The integrated report identifies impaired waters by a Montana water body segment ID, which is indexed to the National Hydrography Dataset.

Table 3-1: Water Bodies on Montana's 303(d) List of Impaired Waters and Their Associated Level of Beneficial Use Support.

Water Body & Stream Description	Water Body #	Use Class	Aquatic Life	Fisheries - Cold	Drinking Water	Swimmable (Recreation)	Agriculture	Industry
Big Hole River, above Pintlar Creek	MT41D001-030	A-1	P	P	F	P	F	F
North Fork Big Hole River, headwaters to mouth (Big Hole River)	MT41D004-010	A-1	P	P	X	P	X	X
Mussigbrod Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-020	A-1	N	N	N	P	F	F
Johnson Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-030	A-1	P	P	F	P	F	F
Schultz Creek, headwaters to mouth (Johnson Creek)	MT41D004-040	A-1	P	P	F	F	F	F

Table 3-1: Water Bodies on Montana's 303(d) List of Impaired Waters and Their Associated Level of Beneficial Use Support.

Water Body & Stream Description	Water Body #	Use Class	Aquatic Life	Fisheries - Cold	Drinking Water	Swimmable (Recreation)	Agriculture	Industry
Tie Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-060	A-1	P	P	F	F	F	F
Trail Creek, Headwaters to Joseph Creek	MT41D004-070	A-1	P	P	F	F	F	F
Trail Creek, Joseph Creek to mouth (North Fork Big Hole River)	MT41D004-080	A-1	P	P	F	F	F	F
Joseph Creek, headwaters to mouth (Trail Creek-North Fork Big Hole River)	MT41D004-090	A-1	P	P	N	F	F	F
Ruby Creek, headwaters to mouth (North Fork Big Hole River)	MT41D004-100	A-1	P	P	F	P	F	F
Swamp Creek, headwaters to mouth (Big Hole River)	MT41D004-110	A-1	P	P	F	N	F	P
Rock Creek, headwaters to mouth (Big Hole River)	MT41D004-120	A-1	P	P	F	F	F	F
Miner Creek, headwaters to mouth (Big Hole River)	MT41D004-140	A-1	P	P	X	F	X	F
Governor Creek, headwaters to mouth (Big Hole River-South of Jackson)	MT41D004-150	A-1	N	N	F	P	F	F
Pine Creek, headwaters to mouth (Andrus Creek-Governor Creek)	MT41D004-160	A-1	P	P	F	P	F	F
Fox Creek, headwaters to mouth (Governor Creek)	MT41D004-170	A-1	P	P	F	F	F	F
Warm Springs Creek, headwaters to mouth (Big Hole River-Near Jackson)	MT41D004-180	A-1	P	P	F	P	F	P
Steel Creek, headwaters to mouth (Big Hole River)	MT41D004-190	A-1	N	N	N	P	F	F
Francis Creek, headwaters to mouth (Steel Creek) T3S R15W	MT41D004-200	A-1	P	P	F	F	F	F
McVey Creek, headwaters to mouth (Big Hole River) T1S R15W	MT41D004-210	A-1	P	P	F	F	F	F
Doolittle Creek, tributary to the Big Hole River T1S, R14W	MT41D004-220	A-1	P	P	F	P	F	P

Table 3-1: Water Bodies on Montana's 303(d) List of Impaired Waters and Their Associated Level of Beneficial Use Support.

Water Body & Stream Description	**Water Body #**	**Use Class**	**Aquatic Life**	**Fisheries - Cold**	**Drinking Water**	**Swimmable (Recreation)**	**Agriculture**	**Industry**
Pintlar Creek, headwaters to mouth (Big Hole River)	MT41D003-170	A-1	P	P	F	P	F	F
Little Lake Creek, headwaters to mouth (Big Hole River)	MT41D004-130	A-1	F	F	F	F	F	F

Legend - **F**= Full Support; **P**= Partial Support; **N**= Not Supported; **T**= Threatened; **X**= Not Assessed (Insufficient Credible Data)

Table 3-2 lists the water bodies on the 2006 303(d) List of impaired waters. Probable causes of impairment, as identified on the 2006 list, includes sediment-related listings (siltation, suspended solids, turbidity, bank erosion), metals (cadmium, copper, lead, mercury, and zinc), thermal modification, nutrients, riparian and fish habitat degradation, habitat alteration, habitat modification, channel incisement, and flow alteration (dewatering). Metals, temperature, nutrients, and sediment TMDLs are needed for specific water bodies in this TPA. Habitat and flow related listings are pollution related and will likely be addressed as sources of pollutants in this document.

Table 3-2: Probable Cause(s) and Source(s) for Impaired Waters.

Water Body	**2006 Causes**	**2006 Sources**
Big Hole River, above Pintlar Creek	Alteration in stream-side or littoral vegetative covers Low flow alterations Temperature	Highways, roads, bridges, infrastructure (New Construction) Loss of riparian habitat Rangeland grazing Agriculture Irrigated crop production
North Fork Big Hole River, headwaters to mouth (Big Hole River)	Alteration in stream-side or littoral vegetative covers Low flow alterations Sedimentation/Siltation	Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Silviculture Activities Irrigated Crop Production Highway/Road/Bridge Runoff (Non-construction Related)

Table 3-2: Probable Cause(s) and Source(s) for Impaired Waters.

Water Body	2006 Causes	2006 Sources
Mussigbrod Creek, headwaters to mouth (North Fork Big Hole River)	Lead Alteration in stream-side or littoral vegetative covers Low flow alterations Other anthropogenic substrate alterations Physical substrate habitat alterations	Acid Mine Drainage Impacts from Abandoned Mine Lands (Inactive) Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Rangeland Grazing Agriculture Impacts from Hydrostructure Flow Regulation/modification Irrigated Crop Production Natural Sources
Johnson Creek, headwaters to mouth (North Fork Big Hole River)	Alteration in stream-side or littoral vegetative covers Low flow alterations Sedimentation/Siltation Total Kjehldahl Nitrogen (TKN)	Grazing in Riparian or Shoreline Zones Irrigated Crop Production Silviculture Harvesting
Schultz Creek, headwaters to mouth (North Fork Big Hole River)	Sedimentation/Siltation	Forest Roads (Road Construction and Use) Grazing in Riparian or Shoreline Zones Silviculture Harvesting
Tie Creek, headwaters to mouth (North Fork Big Hole River)	Physical substrate habitat alterations Sedimentation/Siltation Nitrogen (Total)	Rangeland Grazing Silviculture Activities Unspecified Unpaved Road or Trail
Trail Creek, Joseph Creek to mouth (North Fork Big Hole River)	Physical substrate habitat alterations Sedimentation/Siltation	Grazing in Riparian or Shoreline Zones Impacts from Abandoned Mine Lands (Inactive) Streambank Modifications/Destabilization Silviculture Activities Unspecified Unpaved Road or Trail
Trail Creek, headwaters to confluence with Joseph Creek	Physical substrate habitat alterations* Sedimentation/Siltation*	Grazing in Riparian or Shoreline Zones Impacts from Abandoned Mine Lands (Inactive) Streambank Modifications/Destabilization Silviculture Activities Unspecified Unpaved Road or Trail
Joseph Creek, headwaters to mouth (Trail Creek-North Fork Big Hole River)	Lead Copper Physical Substrate habitat alterations Sedimentation/Siltation	Impacts from Abandoned Mine Lands (Inactive) Channelization Highways, Roads, Bridges, Infrastructure (New Construction) Silviculture Harvesting

Table 3-2: Probable Cause(s) and Source(s) for Impaired Waters.

Water Body	2006 Causes	2006 Sources
Ruby Creek, headwaters to mouth (North Fork Big Hole River)	Alteration in stream-side or littoral vegetative covers Low flow alterations Physical substrate habitat alterations Sedimentation/Siltation	Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Rangeland Grazing Silviculture Activities Impacts from Hydrostructure Flow Regulation/Modification Irrigated Crop Production Dredge Mining Forest Roads (Road Construction and Use) Unspecified Unpaved Road or Trail
Swamp Creek, headwaters to mouth (Big Hole River)	Alteration in stream-side or littoral vegetative covers Low flow alterations Sedimentation/Siltation Nitrogen (Total) Phosphorus (Total)	Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Irrigated Crop Production
Rock Creek, headwaters to mouth (Big Hole River)	Alteration in stream-side or littoral vegetative covers Low flow alterations Physical substrate habitat alterations Sedimentation/Siltation Nitrogen (Total) Phosphorus (Total)	Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Agriculture Impacts from Hydrostructure Flow Regulation/modification Irrigated Crop Production
Miner Creek, headwaters to mouth (Big Hole River)	Sedimentation/Siltation	Forest Roads (Road Construction and Use) Grazing in Riparian or Shoreline Zones
Governor Creek, headwaters to mouth (Big Hole River-South of Jackson)	Alteration in stream-side or littoral vegetative covers Copper Low flow alterations Other anthropogenic substrate alterations Physical substrate habitat alterations	Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Agriculture Impacts fro Hydrostructure Flow Regulation/modification Irrigated Crop Production Habitat Modification-other than Hydromodification
Pine Creek, headwaters to mouth (Andrus Creek-Governor Creek)	Alteration in stream-side or littoral vegetative covers Phosphorus (Total)	Rangeland Grazing

Table 3-2: Probable Cause(s) and Source(s) for Impaired Waters.

Water Body	**2006 Causes**	**2006 Sources**
Fox Creek, headwaters to mouth (Governor Creek)	Phosphorus (Total)	Grazing in Riparian or Shoreline Zones
Warm Springs Creek, headwaters to mouth (Big Hole River-Near Jackson)	Alteration in stream-side or littoral vegetative covers Low flow alterations Sedimentation/Siltation Total Kjehldahl Nitrogen (TKN) Phosphorus (Total)	Grazing in Riparian or Shoreline Zones Loss of Riparian Irrigated Crop Production
Steel Creek, headwaters to mouth (Big Hole River)	Cadmium Alteration in stream-side or littoral vegetative covers Copper Low flow alterations Other anthropogenic substrate alterations Physical substrate habitat alterations Phosphorus (Total)	Acid Mine Drainage Impacts from Abandoned Mine Lands (Inactive) Grazing in Riparian or Shoreline Zones Loss of Riparian Habitat Rangeland Grazing Agriculture Impacts from Hydrostructure Flow Regulation/modification Irrigated Crop Production Habitat Modification-other than Hydromodification
Francis Creek, headwaters to mouth (Steel Creek) T3S R15W	Alteration in stream-side or littoral vegetative covers Sedimentation/siltation Nitrogen (Total) Phosphorus(Total)	Grazing in Riparian or Shoreline Zones
McVey Creek, headwaters to mouth (Big Hole River) T1S R15W	Alteration in stream-side or littoral vegetative covers Sedimentation/siltation Nitrogen (Total) Phosphorus (Total)	Grazing in riparian or shoreline zones
Doolittle Creek, tributary to the Big Hole River T1s R14W	Alteration in stream-side or littoral vegetative covers Low flow alterations Sedimentation/siltation	Highways, Roads, Bridges, Infrastructure (New Construction) Agriculture Irrigated crop production

Table 3-2: Probable Cause(s) and Source(s) for Impaired Waters.

Water Body	2006 Causes	2006 Sources
Pintlar Creek	Other flow regime alterations Low flow alterations Physical substrate habitat alterations Temperature	Impacts from hydrostructure Flow regulation/modification Irrigated crop production Impacts from abandoned mine lands (Inactive) Grazing in riparian or Shoreline zones

* Impairment causes will be identified in the 2008 impaired waters list.

Impairment status and impairment list reviews will also be provided for each water body in **Section 5.0** of this document in text form.

3.3 Applicable Water Quality Standards

Water quality standards include the uses designated for a water body, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a water body. The ultimate goal of these TMDLs and framework 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 **Section 3.3**. Pollutants addressed in this plan include nutrients, sediment, metals, and thermal modification. This section provides a summary of the applicable water quality standards for each of these pollutants.

3.3.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a water body based on the potential of the water body 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 include 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 include 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 water body must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or nonpoint source discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or 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 U.S. 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 3-3**. All water bodies within the Upper Big Hole TPA are classified as A-1.

Table 3-3: Montana Surface Water Classifications and Designated Beneficial Uses Applicable to the Upper Big Hole Watershed.

Classification	Designated Uses
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. Water quality must 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.

3.3.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy.

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular WQB-7 (DEQ, January 2004). 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) exposure by water consumption, as well as through direct contact, such as swimming.

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

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must either 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 water body.

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 water body. 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 Upper Big Hole 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 3-4**. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a water body's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses (see definitions in **Table 3-4**).

Table 3-4: Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified A-1.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.637(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.

Table 3-4: Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
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 standards for water column metals in Montana include specific standards for the protection of both aquatic life and human health. Acute and chronic criteria have been established for the protection of aquatic life. The criteria for some metals vary according to the hardness of the water. The applicable numeric metals standards (guidelines for aquatic life), for the specific metals of concern in the Upper Big Hole TPA, are presented in **Table 3-5**. Actual standards for aquatic life at any given hardness are calculated using **Equation 3-1** and **Table 3-6**. The actual standards are used to determine standards exceedences in this document, not the guidance from **Table 3-5**. Existing data indicates that other metals are below water quality standards.

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

Table 3-5: Montana Numeric Surface Water Quality Standards Guide for Metals.

Parameter	**Aquatic Life (acute) (µL)**[a]	**Aquatic Life (chronic) (µL)**[b]	**Human Health (µL)**[a]
Cadmium	0.52 @ 25 mg/L hardness	0.97 @ 25 mg/L hardness	5
Copper	3.79 @ 25mg/L hardness	8.25 @ 25 mg/L hardness	1,300
Lead	13.98 @ 25 mg/L hardness	0.545 @ 25 mg/L hardness	15
Mercury (TR)	1.7	0.91	0.05
Zinc (TR)	37 @ 25 mg/L hardness[c]	37 @ 25 mg/L hardness[c]	2,000

[a] Maximum allowable concentration.

[b] No 4-day (96-hour) or longer period average concentration may exceed these values.

[c] Standard is dependent on the hardness of the water, measured as the concentration of $CaCO_3$ (mg/L) (see **Table 3-6** for the coefficients to calculate the standard).

Note: TR – total recoverable.

Hardness-based standards for aquatic criteria are calculated using the following equation and are used for determining impairment:

Equation 3-1:

Chronic = exp.{mc[ln(hardness)]+bc} where mc and bc are values from **Table 3-6**

Table 3-6: Coefficients for Calculating Metals Freshwater Aquatic Life Standards (DEQ 2002).

Parameter	ba (acute)	bc (chronic)
Cadmium	-3.924	-4.719
Copper	-1.700	-1.702
Lead	-1.46	-4.705
Zinc	0.884	0.884

Note: If hardness is <25 mg/L as CaCO3, the number 25 must be used in the calculation. If hardness is equal or greater than 400 mg/L as CaCO3, 400 mg/L must be used for the hardness value in the calculation.

Montana also has a narrative standard that pertains to metals in sediment. 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 (ARM 17.30.623(2)(f)). This narrative standard includes metals-laden sediment.

Temperature

Montana’s temperature standards address a maximum allowable increase above “naturally occurring” temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana’s temperature standards address the maximum allowable rate at which temperature changes (i.e., above or below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as A-1 or B-1, the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67ºF) is 1°F and the rate of change cannot exceed 2°F per hour. If the natural occurring temperature is greater than 67ºF, the maximum allowable increase is 0.5ºF (ARM 17.30.622(e), ARM 17.30.623(e)).

Nutrients

There are no statewide numeric Aquatic Life standards for nutrients. Numeric human health standards exist for nitrates. Human health standards for nitrogen are listed in **Table 3-7**.

Table 3-7: Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)*
Nitrate as Nitrogen (NO_3-N)	10,000
Nitrite as Nitrogen (NO_2-N)	1,000
Nitrate plus Nitrite as N	10,000

*Maximum Allowable Concentration

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 µg/L) and total phosphorus (20 µg/L upstream of the confluence with the Blackfoot River and 39 µg/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 that protect all uses 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.

3.3.3 Reference Approach for Narrative Standards

When possible, a reference site approach is used to determine the difference between an impacted area and a "natural" or least impacted water body. The reference site approach is the preferred method to determine naturally occurring conditions; but, when appropriate reference sites are not easily found, modeling, or regional reference literature values are used.

SECTION 4.0
WATER QUALITY TARGETS

The water quality targets presented in this section are based on the best available science and information available at the time this document was written. TMDL targets are not stagnant components of this plan. Targets will be assessed during future TMDL reviews for their validity when new information may be available.

Targets help identify conditions that protect beneficial uses. Targets also help evaluate compliance with standards and serve as goals by which to measure the progress of future restoration efforts. For pollutants with numeric standards, compliance with that standard is, by default, a numeric target. Nevertheless, most of the pollutants in the Upper and North Fork Big Hole TPAs have some type of associated narrative standards (**Section 3.0**). Because of the ambiguity associated with narrative standards and variability in field conditions that may affect application of narrative standards, DEQ will use multiple lines of evidence for metal, nutrient, thermal conditions, and sediment target setting within the Upper and North Fork Big Hole TPAs. Supplemental indicator levels are sometimes presented for measures that provide strong supporting evidence for determining if a TMDL will be pursued. Also, other supporting information may be provided for clarifying if a TMDL will be pursued.

A number of the targets and indicators presented in this document are based on internal reference conditions. The targets and indicators which contain a rationale using an internal reference condition for threshold settings are related to site condition in this case, and not watershed condition. These types of parameters include riparian vegetation condition and bank erosion. The term “reference” is used for reaches of stream that are considered to have current and historic reasonable land use conservation practices in place for the applicable land use at the site. In this document, the term “reference” does not imply a reference watershed where upstream land or water use practices are in a “reference” condition. The reference sites are not to be considered reference watersheds and do not relate well to all targets presented in this document, notably those that are more dependant upon watershed scale sources such as fine sediment, water chemistry, or stream flow measures. Other targets are based on regional or historical reference data, but when appropriate reference data are sparse or non-existent, secondary reference approaches can be applied. These secondary approaches include modeling, literature reviews, and professional judgment. In many situations, a combination of reference site and secondary reference approaches are used to establish reference conditions.

4.1 Thermal Targets

Thermal targets are provided for the Big Hole River and Pintlar Creek. Targets incorporate the use of Montana’s water quality temperature standard and the factors that influence water temperatures. Temperature modeling was used as a tool to determine if Montana’s water quality temperature standards are likely being met or exceeded in the Big Hole River above the North Fork Confluence. Targets also incorporate the relationship between channel geometry, riparian shading, and flow volumes in maintaining cool temperatures. The linkage between temperature conditions and fishery impacts is also investigated. Because any one approach to setting temperature targets has uncertainty, a number of targets will be used.

4.1.1 Temperature

4.1.1.1 Montana's Temperature Standard

Interpretation of Montana's narrative temperature standards can be difficult. The standards designate that only a specific derivation from the natural occurring temperature condition is tolerable (**Section 3.0**). Thermal modeling was used as a tool to indicate that Montana's water quality standards are likely exceeded in the Upper Big Hole River. The TMDL assessment used monitoring data from reference and non-reference reaches to model temperature conditions with varying stream flows and reference physical conditions on two short reaches of the Big Hole River (**Appendix B**). Although a high level of modeling certainty was desired, thermal modeling for the whole Upper Big Hole River was not feasible because of the complex nature of the natural stream channels and the irrigation network in this TPA. Continuous temperature monitoring, riparian shade, stream flow, and channel dimensions were monitored on the upper and lower section on two reaches of the Upper Big Hole River. This information was used to model temperature conditions with varying influencing factors to simulate the difference between existing conditions and reasonable land, soil, and water conservation practices. The difference in temperatures is used to indicate if Montana's water quality temperature standard is likely being met or exceeded.

Also, the targets will incorporate an "or" statement where Montana's temperature standards should be met or all the reference physical condition targets should be met in combination. In this approach, if all reasonable land, soil, and water conservation practices are installed, state standards are met. Yet, if the temperature standards are met, the use is supported, and not all areas need to have full installation of restoration practices to meet the standards.

4.1.1.2 Width-to-Depth Ratios

A numeric target for temperature is width-to-depth ratio, calculated by dividing the bankfull width by the average bankfull depth. Average bankfull depths were calculated by dividing the bankfull width by cross section area. Impacted reaches of the Big Hole River had substantially greater width-to-depth ratios than reference reaches. This relates to thermal loading because the high-surface-area-to-volume ratio in over widened reaches decreases thermal inertia allowing water to heat more readily. Also, a narrower channel receives increased shade from a constant sized riparian canopy when compared to a wider channel.

The target for width-to-depth ratios for the Big Hole River mainstem calls for the 75th percentile of any assessed reach's width-to-depth to approximate or be less than 43, which is the 75th percentile for the reference reaches (**Table 4-1**). Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is needed. The 75th percentile of the reference population is used as a comparative statistic because lower width-to-depth ratios are desirable for reducing water temperature. Comparing median reference and non-reference statistics may also indicate if there is a shift toward widened streams from reference conditions where reasonable land practices are occurring and may be considered. Applying this target to assessed reaches of the Big Hole River indicates all the reference reaches met these criteria; however, most impacted reaches exceeded the target substantially. For Pintlar Creek, width-to-depth ratios measured on valley reference tributaries provided the basis for targets (**Table 4-1**). Consequently, Pintlar Creek's target for width-to-depth ratio is for the 75th percentile to be less than or approximately 19.5, following the same rationale as the targets presented for the mainstem of the Big Hole River. Median statistics may also be used for assessing if width-to-depth ratios are over wide.

The width-to-depth ratios reported for the Upper Big Hole TMDL project are collected at set intervals along a reach of stream and may fall at any type of stream channel area. These width-to-depth ratios are representative of cumulative widths measures, but not comparable to with-to-depth ratios collected only at riffle cross sections.

Table 4-1: Select descriptive statistics for width-to-depth ratios measured on reference and impacted reaches of the Big Hole River and Pintlar Creek.

Reach Type/Name	N	Minimum	Maximum	25th percentile	Median	75th Percentile
Big Hole River						
Reference	15	8	43	21	22	26
Impacted	30	4	82	34	45	58
Pintlar Creek						
Pintlar Creek	9	4	15	11	11	14
Valley reference tributaries	39	4	30	10	14	20

4.1.1.3 Canopy Density

Measurement of riparian canopy density over the stream using a handheld spherical densitometer (Lemmon 1956) is used as a target. On the Big Hole River, canopy density on reference reaches was significantly greater than on impacted reaches. The target for canopy density at streambanks is that the 25th percentile canopy density must approximate or be more than 31.5 percent, which is the 25th percentile of reference reaches (**Table 4-2**). Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is necessary while those with greater exceedence will be weighed more heavily. Selection of the lower quartile relates to this measure usually showing a non-normal distribution, making the upper quartiles more variable. Comparing median reference and non-reference statistics may also indicate if there is a shift toward less riparian shading from reference conditions where reasonable land practices are occurring and may also be used to determine if a TMDL is needed. Comparisons of shading on assessed reaches indicated that most impacted reaches failed to meet the target. The canopy density target for Pintlar Creek is provided by applying the same rationale for the Big Hole mainstem target setting strategy to valley tributary reference sites (**Table 4-2**). This temperature target only applies to sites where shrubs are the predominant riparian growth potential. Riparian tree harvest was not found during aerial photo reviews or during field efforts on Pintlar Creek or the Big Hole River stream corridors.

Table 4-2: Select distribution statistics for overstory canopy density measured at streambanks on reference and impacted reaches of the Upper Big Hole River and Pintlar Creek.

Reach Type	**N**	**Minimum**	**Maximum**	**25th percentile**	**Median**	**75th Percentile**
Big Hole River						
Reference	15	2	100	15	43	52
Impacted	30	0.00	100	0	1	15
Pintlar Creek						
Pintlar Creek	5	0	92	45	56	72
Valley Reference Tributaries	40	0	100	36	64	81

4.1.1.4 Understory Shrub Cover along Green Line

Understory shrub cover along the green line (at bank full) is a measure of the proportion of 202 equidistant points along the streambanks that intercept shrubs from 0.5-3.0 meters in height. This method is a modification of the method developed by Winward (2000) with vegetation classes following EMAP methodologies developed by the EPA (Lazorchak et al. 1999). Shrub cover relates to thermal loading, as riparian shrubs are the primary cover type along the Big Hole River and Pintlar Creek below Pintlar Lake, with potential to provide substantial shading. Targets developed for this parameter are based on comparing the 25th percentile of the study stream to be greater than or approximate the 25th percentile of the reference conditions. Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is necessary while those with greater exceedence will be weighed more heavily. A higher canopy cover is desired; therefore, the 25th percentile is used for statistical comparison to reference condition. Comparison of median conditions may also be used to determine if a TMDL is necessary.

Several considerations played a role in the development of numeric targets from the reference reach data on the Big Hole River. First was the relatively low cover of understory shrubs in reference reach BH28. Field notes support the impacted status of riparian shrub cover in this reach was due to historic livestock grazing practices, which justified eliminating it from the statistical calculation of numeric targets for this parameter. In contrast, BH09 had exceptionally dense cover of riparian shrubs and no indication of livestock use. This relatively pristine state presents a potentially unfeasible scenario as ranchers often rely seasonally on riparian areas for thermal cover and high quality forage for livestock. Reference reach BH18 represented a scenario where BMPs were effectively utilized and, therefore, would meet the intent of Montana’s Clean Water Act (CWA). Therefore, shrub cover on BH18 is a suitable reference for other reaches of the Big Hole River supporting livestock grazing uses. Using this site, the target for understory shrub cover along the green line will be for the 25th percentile to approximate or be more than 35 percent. Understory shrubs measured along the green line on valley reference tributaries provide the target for Pintlar Creek (**Table 4-3**). Following the approach as the Big Hole River, the target for Pintlar Creek will be for the 25th percentile to approximate or be less than 30 percent.

Table 4-3: Distributional statistics for understory shrub cover along the green line on reference and impacted reaches of the Big Hole River.

Reach Type	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole River						
reference (BH18)	4	32%	72%	37%	49%	63%
Impacted	24	0%	42%	4%	10%	23%
Pintlar Creek						
Pintlar Creek	8	37%	84%	42%	63%	81%
Valley reference tributaries	28	10%	85%	30%	59%	72%

4.1.1.5 Stream Flow

Stream flow is another factor with pronounced influence on thermal regime and is a major limiting factor for Arctic grayling in the Big Hole River. Irrigation withdrawals on Pintlar Creek also have potential to alter thermal regime. Pintlar Creek is periodically dewatered over much of its length (MFISH database). Reduced flows have less thermal inertia and therefore a greater tendency toward higher daily maximum temperatures.

Maintaining minimum flows in the Big Hole River is currently the focus of conservation efforts by landowners and agencies. To maintain consistency among planning efforts in the basin, targets for stream flow will incorporate those prescribed in the Candidate Conservation Agreement with Assurances (CCAA) (MFWP and USFWS 2005), but presenting only these flows as a target is not consistent with requirements of Montana's WQ law. Montana Law indicates that State recognized water rights can not be divested, impaired, or diminished due to application of water quality law. Meeting the CCAA and FWP instream flow targets may not always be possible while considering Montana's water laws and varying weather conditions. An alternative approach to meeting instream flows will be to apply all reasonable irrigation water management practices in the watershed that will increase instream flows without divesting, impairing, or diminishing any State recognized water right. Significant increases in stream flow can be accomplished by local irrigation water savings efforts which employ water saving engineering and management practices along with water leasing. Much of this type of work has already occurred during the past few years, and stream gage data reflect the efforts. To fully understand which irrigation water management practices are feasible, a more thorough water balance study should occur. Efforts should continue to expand application of all reasonable irrigation water management practices in the watershed which increase stream flow.

An approach to meeting instream flows that will reduce water temperature will be to meet the instream flow numeric targets based on the Candidate Conservation Agreements with Assurances (CCAA) for the Big Hole River and Montana FWP instream flow reservations (Pintlar Creek) **OR** apply all reasonable irrigation water management practices in the watershed that will increase instream flows without divesting, impairing, or diminishing any State recognized water rights. A brief rationale for the CCAA and Montana FWP instream flow reservations are provided below (**Table 4-4**).

Flow targets in the CCAA are provided to protect arctic grayling and use a reach based approach for prescribing minimum flows (**Table 4-4**). Thermal modeling efforts indicate that applying these instream flow conditions will have substantial influence on minimizing both mean daily and maximum daily temperatures on the Big Hole River (**Appendix B**). Currently, the only data available to evaluate target attainment are from the USGS gage station at the Wisdom Bridge. Montana FWP has installed AquaRod flow measuring devices at the other bridges and these data will be available for future TMDL target use. It is unknown if flow targets provided in the CCAA will be feasible by implementing all reasonable land, soil, and water conservation practices.

The FWP instream flow reservation is based on a wetted perimeter study which indicates a critical flow where riffles will stay wetted. It is unknown if flow targets provided by the FWP instream flow reservation will be feasible by implementing all reasonable land, soil, and water conservation practices.

Because of the uncertainty between the numeric stream flow targets and reasonable land, soil, and water conservation practices, an alternative to meeting flow targets is provided. Another option to meet instream flow targets indicates they can alternatively be met by implementing all reasonable irrigation water management practices in the watershed.

Table 4-4: Minimum flow targets for reaches within the Upper Big Hole River TPA in the CCAA.

CCAA Management Segment	Monitoring Site	Summer/Fall Minimum Flow Target (cfs)
A	Miner Creek Bridge	20
B	Little Lake Creek Bridge	40
C	Wisdom Bridge	60
D	Mudd Creek Bridge	100

Because of complications in access and the presence of significant beaver activity, considerable uncertainty exists regarding the relative role of dewatering on temperature regime in Pintlar Creek. The alternative is to apply FWP’s reservation for instream flow as determined by the wetted perimeter method (Leathe and Nelson 1989). This calls for minimum flows of 10 cfs along the entire length of the stream below Pintlar Lake year round. An advantage to applying this target is constancy with existing fishery conservation recommendations for this stream. Nevertheless, the sufficiency of this flow volume to meet temperature WQS is unknown. Long-term monitoring and application of adaptive management will provide the means to evaluate the suitability of this target in supporting beneficial uses in Pintlar Creek. Pintlar Creek is identified by Montanan Fish, Wildlife, and Parks as periodically dewatered in the lowest 10 miles of the stream.

4.1.1.6 Linking Temperature to Fishery Impacts

Although Montana's temperature standards do not require a linkage of altered temperature conditions to an impacted use, this document will review the linkage. The potential for the Upper Big Hole River to support temperatures that are completely optimal for Arctic grayling (or the surrogate species, bull trout) is not fully known, but their presence suggests that the Upper Big Hole Valley historically supported conditions approximating Arctic grayling's optimal temperature needs. Although temperatures that are shown to support the fishery are not used specifically for targets because they don't directly relate to Montana's water quality temperature standards, they are useful for determining if the fishery is likely impacted by temperature conditions. These temperatures are also a consideration, along with other factors, for estimating naturally occurring conditions since native fish populations have survived in the watershed.

The thresholds used to determine if the fishery may be impacted are a maximum temperature of 64.4ºF (or 18ºC) because this temperature has the potential to physiologically impact grayling in a short timeframe. This temperature level is presented to protect against extreme physiological stress or lethal conditions. Optimal temperatures for bull trout, and potentially Arctic grayling, are between 10-12°C (50-54°F) with temperatures exceeding 59°F (15°C) resulting in sufficient physiological stress to inhibit growth (Fraley and Shepard 1989). Therefore, to promote a thermal regime favorable to growth of Arctic grayling, the sliding 7-day average of daily maximum temperatures is compared to a sublethal temperature stress target of 59°F (15°C). This document will use these fishery support temperature thresholds to indicate potential impacts to Arctic grayling, but will not use these thresholds as temperature targets because they do not relate to Montana's temperature standards.

4.1.1.7 Summary of Targets to Address Temperature in the Big Hole River

Targets developed to address temperature as a pollutant in the Big Hole River and Pintlar Creek consist of multiple lines of evidence (**Tables 4-5 and 4-6**). These include Montana's temperature standard, width-to-depth ratio, stream flow, and riparian vegetation shading characteristics. Combined, these measures provide a robust indication of the thermal setting and status of features that influence thermal loading.

Table 4-5: Numeric targets to address temperature loading in the Big Hole River.

Status	**Target**	**Rationale**	
Temperature monitoring and associated modeling indicates the standard is likely exceeded.	The maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67ºF) is 1°F and the rate of change cannot exceed 2°F per hour. If the natural occurring temperature is greater than 67ºF, the maximum allowable increase is 0.5ºF (ARM 17.30.622(e), ARM 17.30.623(e)).	Developed to protect all water uses, most notably, the fishery.	
Meet both temperature targets above OR meet all of the surrogate targets below.			
Width-to-depth ratio	75th percentile ≤26 Median ≤22	Decreased surface area to volume ratio is less vulnerable to heating.	7 of 9 reaches not meeting target
Canopy Density Measured Over the Stream	25th percentile ≥15% Median ≥43%	Shading from streamside vegetation is important functional attribute in maintaining cooler water temperatures.	3 of 9 reaches not meeting target
Understory Shrub Cover along Green Line	25th percentile ≥37% Median ≥49%	Shading from streamside vegetation is important functional attribute in maintaining cooler water temperatures. Transpoevaporation also cools the stream corridor during heating periods.	2 of 9 reaches not meeting target
Instream Flow	>60 cfs at Wisdom gage *OR* apply all reasonable irrigation water management practices in the watershed that will increase instream flows without divesting, impairing or diminishing any State recognized water right.	Minimum summer survival flow prescribed in other grayling conservation efforts. More water in the stream provides thermal buffering capacity.	Flows not maintained

Table 4-5: Numeric targets to address temperature loading in the Big Hole River.

Status	Target	Rationale	
Irrigation Return Flows	Where irrigation return flows are occurring such that they are contributing to a measurable increase in temperature, the thermal loading will be reduced consistent with the irrigation water management BMPs that will be necessary to meet in-stream flow targets.	Reduce thermal loading.	Irrigation water return flows are present and likely vary in temperature. These were difficult to assess because they are transient in space and time.

Table 4-6: Numeric targets to address temperature loading in Pintlar Creek.

Parameter	Target	Rationale	Status (2004)
Water Quality Standard	The maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 67ºF) is 1°F and the rate of change cannot exceed 2°F per hour. If the natural occurring temperature is greater than 67ºF, the maximum allowable increase is 0.5ºF (ARM 17.30.622(e), ARM 17.30.623(e)).	Developed to protect all water uses, most notably, the fishery.	Unknown
Meet both temperature targets above OR meet all of the surrogate targets below.			
Width-to-depth ratio	75th percentile ≤20 Median ≤14	Decreased surface area to volume ratio is less vulnerable to heating.	Assessed reach met target Aerial photo interpretation of entire reach indicates high likelihood of meeting the target.
Canopy Density Measured Over the Stream	25th Percentile ≥36% Median ≥64%	Shading from streamside vegetation is important functional attribute in maintaining cooler water temperatures.	Assessed reach met target. Aerial photo interpretation indicates high likelihood of meeting the target.

Table 4-6: Numeric targets to address temperature loading in Pintlar Creek.

Parameter	Target	Rationale	Status (2004)
Understory Shrub Cover along Green Line	25th percentile ≥30% Median ≥59%	Shading from streamside vegetation is important functional attribute in maintaining cooler water temperatures. Transpoevaporation also cools the stream corridor during heating periods.	Target met in assessed reach. Based on aerial photo interpretation, most reaches below Pintlar Lake are likely to approximate this target.
Instream Flow	≥10 cfs along entire stream below Pintlar Lake ***OR*** apply all reasonable irrigation water management practices in the watershed that will increase instream flows without divesting, impairing or diminishing any State recognized water right.	Minimum summer survival flow prescribed in other grayling conservation efforts. More water in the stream provides thermal buffering capacity.	Little to no stream guage data is available. A number of significant diversions are present.
Irrigation Return Flows	Where irrigation return flows are occurring such that they are contributing to a measurable increase in temperature, the thermal loading will be reduced consistent with the irrigation water management BMPs that will be necessary to meet in-stream flow targets.	Reduce thermal loading.	Irrigation water return flows are present and likely vary in temperature. These were difficult to assess because they are transient in space and time.

4.2 Sediment

Numeric targets and supplemental indicators for sediment are measures of instream siltation, factors that contribute to loading, storage and transport of sediment, or biological response to increased sediment. Other considerations in developing these targets include the natural variation in sediment storage along the river continuum. Specifically, some reaches will have a natural tendency for storage of sediment and others will be more efficient at sediment transport. Therefore, targets follow stratifications employed in data analysis. Stratification categories include the mainstem Big Hole River, North Fork Big Hole River, valley tributaries, and montane tributaries. Topographic breaks between the montane zone and foothills provided the basis for distinctions between montane and valley reaches. When appropriate, reaches on the North Fork Big Hole River were included with other tributary streams to increase statistical power. For parameters such as width-to-depth ratio, this was inappropriate, as the North Fork Big Hole River appeared to differ in potential channel geometry.

4.2.1 Sediment Targets

4.2.1.1 Width-to-depth Ratios

In addition to serving as a numeric target for temperature, width-to-depth ratio is also a suitable target for sediment TMDLs. Stream energy dynamics are shifted when stream channels are overly wide. Shifts in stream energy cause changes in sediment transport capacity, benthic sediment sorting, and pool formation. In addition, it relates directly to habitat quality as deeper, narrower channels provide superior fish habitat compared to wide, shallow streams. Moreover, a wide unstable channel is often a direct result of unstable banks that produce sediment. These links between width-to-depth ratio and sediment delivery and transport justify its inclusion as a numeric target. Evaluation of this method of quantifying width-to-depth ratio further suggests it is a reliable predictor of human disturbance (Kauffman et al. 1999). These factors decrease uncertainty in the use of this metric, an important consideration in its use as a numeric target. However, this target being exceeded alone, without other sediment target exceedences, does not constitute a need for a TMDL.

Valley gradient, valley confinement, riparian vegetation types, and watershed areas are natural factors that affect stream channel width and depth (**Table 4-7**). For example, using the Rosgen channel classification system (Rosgen 1996), A, DA, and E channels have relatively low width-to-depth ratios of 12 or less. Conversely, C channels tend to have greater width-to-depth ratios (>12). To adjust for these tendencies, streams were stratified into four classifications: Mainstem Big Hole River, valley tributaries, montane tributaries, and North Fork Big Hole River. This stratification takes into account valley slope and width, stream size, and riparian vegetation type that are the most significant factors affecting stream channel characteristics. Montane reaches tended to break out among three channel types with B channels occupying steeper valley types, and E and C channels occurring in lower gradient montane valley reaches. Because B channels tend to be resistant to lateral and vertical instability in the Upper Big Hole TPA, montane B channels were eliminated from this analysis and width-to-depth ratio target development.

Table 4-7: Channel types (Rosgen 1996) identified on streams in the Upper Big Hole River Watershed in Level I classification activities and verified with field investigations.

Stream Type (w:d ratios)	Fundamental Characteristics
A (<12)	A-Type Channels are relatively steep channels that form in headwater areas as well as within bedrock canyons. These channels are entrenched and confined by steep valley margins such that little to no floodplain occurs on their border. As the boundaries of A-type channels are typically highly resistant to erosion, these stream types are generally quite resilient with respect to human impacts. The most common cause of geomorphic change within A-type channels is due to large scale sediment transport events, (landslides, debris flows, debris jam failure) that may result in blockage or deflection of channel flow.
B (>12)	B-Type Channels tend to form downstream of headwater channels, in areas of moderate slope where the watershed transitions from headwater environments to valley bottoms. Moderate slopes, moderate entrenchment, and stable channel boundaries characterize B-channels. Due to the relatively steep channel slopes and stable channel boundaries, B-channels are moderately resistant to human impacts, although, their reduced slopes relative to headwater areas can make them prone to sediment deposition and subsequent adjustment in the event of a large sediment transport event such as an upstream landslide, debris flow, or flood.
C (>12)	C-Type Channels are typically characterized by relatively low slopes, meandering plan forms, and pool/riffle sequences. The channels tend to occur in broad alluvial valleys, and they are typically associated with broad floodplain areas. C-channels tend to be relatively sinuous, as they follow a meandering course within a single channel thread. In stream systems in which the boundaries of C-type channels are composed of alluvial sediments, channels tend to dynamic in nature, and susceptible to rapid adjustment in response to disturbance.
DA (<40)	DA-Type Channels have multiple active channel threads that are relatively narrow and deep, separated by extensive, vegetated floodplains and wetlands. DA channels tend to form in areas of relatively low slope, with low bedload sediment volumes. Bank lines are typically very stable.
E (<12)	E-Type Channels are somewhat similar to C channels, as they form as single threads with defined, accessible floodplain areas. However, E channels are different in that they tend to have fine-grained channel margins, which provide cohesion and support dense bank line vegetation. The fine-grained, vegetation-reinforced bank lines allow for the development of steep banks, very sinuous plan forms, and relatively deep, U-shaped channel cross sections. E-type channels commonly form in low gradient areas with fine-grained source areas, mountain meadows, and in beaver-dominated environments. E-channels tend to have very stable plan forms, and efficient sediment transport capacities due to low width/depth ratios.
F (>12)	F-Type Channels typically have relatively low slopes (<2%), similar to C and E channel types. The primary difference between C/E channels and F channels is with respect to entrenchment. F channels are entrenched, which means that the floodplain is quite narrow relative to the channel width. The entrenchment of alluvial F-type channels typically is an indicator of an historic down cutting event. F-type channels may form in resistant boundary materials (e.g. U-shaped bedrock canyons), and relatively erodible alluvial materials (e.g. arroyos). When the boundary materials are erodible, the steep valley walls are prone to instability, and channel widening commonly occurs within the entrenched channel cross section.

A Rosgen level I channel classification followed by field verification allowed classification of channel types across the Upper Big Hole River TPA. On the Big Hole River, channel types varied among assessed reaches with a tendency for reference reaches to have braided channels, (Rosgen DA), interspersed with C channel types (**Table 4-8**). These DA channels are highly desirable in terms of having low width-to-depth ratios and providing superior habitat for Arctic grayling, a species preferring low gradient, braided rivers. With the exception of reach BH08, impacted reaches were typically C channels. The maintenance of the DA configuration to the lowermost reference reach suggested targets based on reference reaches with a tendency for braiding was appropriate for the entire length of Big Hole River in this TPA.

Table 4-8: Rosgen channel types of assessed reaches on the Big Hole River.

Reach Name	Reach Type	Stream Type
BH09	Reference	DA
BH18	Reference	C/DA
BH28	Reference	C/DA
BH08	Impacted	C/E
BH16	Impacted	C
BH22	Impacted	C
BH26	Impacted	C

Channel types on valley tributaries tended towards C and E channels with many reaches being transitional between these types (**Table 4-9**). Reference reaches had a greater tendency to be E channels, except for the reference reaches on the North Fork Big Hole River, which were C channels. The prevalence of C/E transitional channels in the smaller valley reference tributaries justifies the application of width-to-depth ratio targets from these reference areas. Therefore, targets for width-to-depth ratio will vary with an internal reference applied to the North Fork Big Hole River and other valley tributaries will follow distributional statistics from valley reference tributaries.

Table 4-9: Channel type classifications of assessed valley reaches in Upper Big Hole River TPA.

Stream Name	Reach Name	Stream Type	Reach Type
Doolittle	DC03	E/C	impacted
Fox	FC03	E	reference
Fox	FC02	E	impacted
Governor	GC04	C	impacted
Governor	GC06	C	impacted
Governor	GC11	C	impacted
Johnson	JC07	C	impacted
Little Lake	LL05	E	reference
McVey	MV03	E	impacted
Miner	MC05	E	reference
Mussigbrod	MC06	C/E	reference
Mussigbrod	MC07	E	impacted
North Fork	NF02	C	reference
North Fork	NF06	C	reference
North Fork	NF07	C	impacted
North Fork	NF11	C	impacted

Table 4-9: Channel type classifications of assessed valley reaches in Upper Big Hole River TPA.

Stream Name	Reach Name	Stream Type	Reach Type
Pine	PN03	C/E	impacted
Pintlar	PC04	C/E	reference
Pintlar	PC04R	C/E	reference
Rock	RO04	C	impacted
Rock	RO06	C	impacted
Ruby	RC07	E/C	impacted
Ruby	RC08	E/C	impacted
Steel	SC06	C/D	impacted
Steel	SC03	E	impacted
Swamp	SW03	E	impacted
Swamp	SW10	C	impacted
Warm Springs	WS11	C/E	impacted
Warm Springs	WS10	C/E	impacted

Channel types on montane reaches were variable with B, C, and E channel types being present (**Table 4-10**). Most reference reaches occupying low gradient, meadow sections were narrow, deep E channels. The B channels occurred in higher gradient reaches. The exception was the reference reach on Warm Springs Creek (WS07), which classified as a C channel. Field notes suggest that livestock grazing practices contributed to channel widening in this reach, making it marginal in terms of reference reach status. As a result, it was eliminated from the pool of reference reaches for segments occupying montane meadows.

Table 4-10: Channel type classifications of assessed montane tributary reaches in Upper Big Hole River TPA.

Stream Name	Reach Name	Stream Type	Reach Type
Frances	FR01	C	impacted
Johnson	JC03	B	reference
Johnson	JC02	B	impacted
Johnson	JC02R	B	impacted
Joseph	JO02	C	impacted
Ruby	RC04	E	impacted
Schultz	SH01	B	reference
Steel	SC02	E	reference
Tie	TI02	E	impacted
Trail	TC02	E	reference
Trail	TC07	E	reference
Trail	TC03	E	impacted
Trail	TC08	B	impacted
Warm Springs	WS07	C	impacted

The width-to-depth depth ratio targets for the mainstem of the Big Hole River for the sediment TMDL will be the same as those designated to address thermal alterations (**Section 1.1.1** and

Table 4-1). Reducing width-to-depth ratios to approximate those measured in reference reaches will improve sediment transport capabilities and may reduce accumulations of fine sediment on the streambed. Therefore, the width-to depth target to address sediment in the Big Hole River was for the 75th percentile to approximate or be less than 30 (**Table 4-11**). Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is necessary, while those with greater exceedence will be weighed more heavily. This target would account for a range of potential Rosgen channel types including C, DA, and E.

Using the same rationale as the Big Hole River for montane tributaries, valley tributaries, and the North Fork Big Hole River, the numeric target for width-to-depth ratios will be for the 75th percentile to approximate or be less than the 75th percentile of reference reaches for the appropriate stratification (**Table 4-11**). The target for montane reaches occupying higher gradient B channels will be for the 75th percentile to approximate or be less than 16. On montane reaches within low gradient, meadow environments, the 75th percentile will be to approximate or be less than 14. Because reference reaches on the North Fork Big Hole River were C channels, the width-to-depth ratio for this stream reflects morphology typical of stable C channels, but well below thresholds for “very high width-to-depth ratios” as ranked by Rosgen (1996) with the 75th percentile being to approximate or be less than 30. Finally, the target established for valley tributaries follows the same approach. Therefore, the target for valley tributaries calls for the 75th percentile to approximate or be less than 17.

The width-to-depth ratios reported for the Upper Big Hole TMDL project are collected at set intervals along a reach of stream and may fall at any type of stream channel area. These width-to-depth ratios are representative of cumulative widths measures, but not comparable to with-to-depth ratios collected only at riffle cross sections.

Table 4-11: Distributional statistics for cumulative width-to-depth ratios measured on reference reaches on montane tributaries, valley tributaries, the North Fork Big Hole River, and the mainstem Big Hole River.

Stream Classification	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Montane Tributaries (high gradient channels)	10	6	42	8	13	15
Montane Tributaries (low gradient channels)	10	4	16	8	10	13
Valley Tributaries	39	5	32	10	14	19
North Fork Big Hole River	10	10	30	17	24	28
Big Hole River	15	8	43	21	22	26

4.2.1.2 Percent Fines (Pebble Counts)

Pebble counts are a common method to quantify size class distribution of streambed particles in gravel bed streams (Wolman 1954) with applications to sediment transport, hydraulics, and streambed monitoring. Pebble counts in this effort used the 100-particle count in riffles, which is a standard method for surface particles (Bunte and Abt 2001).

Benthic measurements of fine sediment are a direct measurement of sediment conditions and relate directly to aquatic life and fisheries uses. Accumulations of fine substrate particles fill the interstices of coarser bed materials, reducing habitat space and its availability for benthic fish and macroinvertebrates (Platts et al. 1983; Hawkins et al., 1983; Rinne, 1988; Waters, 1995; Mebane, 2001, Zweig et al., 2001; Reylea et al., 2000). In addition, these fine particles impede circulation of oxygenated water into hyporheic habitats. Not meeting this target suggests fine sediment is likely impacting aquatic life and cold water fish.

Targets will be set by comparing median reference conditions to data from impacted areas (**Tables 4-12 and 4-13**). A minimum of 10 percent fines in riffles will be used for targets if the median reference condition falls below this level. Using a minimum of 10 percent is based upon the fact that studies show a marked impact to aquatic life begins to occur at specific levels of fine sediment in riffles and 10 percent falls below this threshold, yet it preserves the setting where low fine sediment is expected with reasonable watershed management (Rylea et al, 2000). Also, as broadcast spawning fish, grayling may rely on lower ends of riffles, as well as runs, for spawning activity and may warrant percent fines targets set in riffle areas that is more protective than for other species utilizing this habitat area.

Table 4-12: Distributional statistics of percent particles <6 mm in 100-particle pebble counts on reference reaches (not watersheds).

	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole River	0	11	0	0	5
North Fork Big Hole River	7	16	9	12	14
Valley Tributary	1	41	16	22	30
Montane Tributary	11	44	13	17	27

Table 4-13: Distributional statistics of percent particles <2 mm in 100-particle pebble counts on reference reaches (not watersheds).

	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole mainstem	0	8	0	0	4
North Fork	5	14	7	10	14
Valley tributaries	1	38	12	18	20
Montane	4	32	4	13	22

4.2.1.3 Percent Fines (Viewing Bucket)

Sampling surface fines with a 49-point grid is another common method of quantifying fine particles on streambed surfaces (Platts et al. 1987, Hankin and Reeves 1988, Overton et al. 1997). In field assessments of 2004, crews employed a 49-point grid on Plexiglas bottomed viewing buckets at four locations across each pool tail. This is a measure of the number of grid intersections underlain by at least one particle less than 6 mm in diameter and is expressed as a percentage for each pool tail. Pool tails were the selected channel unit type, as these are typically preferred spawning areas for most salmonids, excluding Arctic grayling. Applicability of this assessment technique to species such as Arctic grayling is uncertain. Cutthroat trout are likely the most sensitive species to siltation effects in this area. Westslope cutthroat trout are, or have been, present in most of the streams of the Upper Big Hole Valley and are likely the most siltation sensitive fish species present.

Percent fines in reference reaches varied with highest levels occurring in valley tributaries (**Table 4-14**). Median values will be used for target comparison. With the exception of valley tributaries, median reference values were less than 30 percent. In contrast, median values in valley tributary streams exceeded 80 percent fines. This suggests that high levels of fine sediment were somewhat natural in these low gradient streams or that sediment loading from the watershed above the reference reaches overwhelmed the ability of these reaches to transport sediment. The reference reaches do not represent a reference watershed condition, but do represent areas where the appropriate land management supports a stream channel with dimensions for efficient sediment transport and sorting. Because reference sites are used instead of reference watersheds, the median of the internal reference conditions is used as a target threshold, and any exceedence of the target is considered grounds for TMDL development. If the threshold is approached with other indicators of sediment condition departure, the stream may also be considered for TMDL development since most streams in this area are not considered to be near reference condition except for Miner and Little Lake Creek watersheds.

Table 4-14: Distributional statistics of percent particles <6 mm sampled using 49-point grids in reference reaches in the Upper Big Hole River TPA.

Classification	N (pool tail)	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole River	14	3	100	10	22	57
Montane (high gradient)	15	0	100	5	10	42
Montane (low gradient)	9	13	100	42	50	92
North Fork Big Hole River	3	11	38	11	11	24
Valley	36	10	100	27	80	95

4.2.1.4 Pool Frequency

Pool frequency is another parameter allowing inference on the influence of sediment in streams. Alterations in sediment loading or sediment transport efficiency may have deleterious effects on this important component of fish habitat, thereby decreasing the stream’s ability to support this beneficial use. Sediment may limit pool habitat by filling in pools with fines. Alternatively, aggradation of larger particles may exceed the stream’s capacity to scour pools, thereby reducing the prevalence of this critical habitat feature. Therefore, pool frequency is a measure that potentially responds to both fine and larger fractions of sediment delivered to the stream and addresses transport efficiencies related to alterations in flow and channel geometry.

Comparing expected pool frequency with existing pool frequency provides a means of evaluating sediment transport dynamics and habitat quality relating to sediment. Two ways allow prediction of expected pool frequency for a given reach. One rule of thumb is that in unaltered streams, pools occur on average at every 5-7 channel widths (Dunne and Leopold 1978, Rosgen 1996). Alternatively, reference reaches provide a means of predicting pool frequency based on the assumption that these reaches represent the potential pool frequency as pool forming features, such as woody debris and channel geometry are intact.

Several natural factors have potential to influence pool frequency, and these need to be included in interpretations. One factor is channel type as influenced by gradient, topography, and bed material. Streams occupying higher gradient, confined reaches with boulder or bedrock substrate have less potential to scour pools than more meandering valley reaches with finer bed materials. To control for these factors, B channels in montane portions of the watershed were eliminated from the suite of reference reaches used in the calculation or application of this target.

Analyses of reference reach data indicates these reaches had pool frequencies close to the expected for unaltered streams, namely, a pool occurred for every 5-7 channel widths (**Table 4-15**). To control for variability in channel widths, these values are expressed as a function of the average number of median bankfull widths between pools. These results suggest sediment loading and transport was in balance to support adult fish habitat requirements in reference reaches.

Table 4-15: Distributional statistics for bankfull width per pool measured on reference reaches in the Upper Big Hole River TPA.

Classification	**N**	**Minimum**	**Maximum**	**25th Percentile**	**Median**	**75th Percentile**
Big Hole River	3	3.0	5.6	3.9	4.7	5.1
Valley Tributaries + NF	7	4.7	21.8	5.2	7.3	8.4
Montane C and E channels	2	2.8	6.0	5.1	5.4	5.7

Unlike many of the parameters used as targets and supplemental indicators, only one result per assessed reach is possible for this parameter, yet many measures are incorporated into the result. The bankfull width to pool frequency target will be ≤ the designated 75th percentile of the reference data set. These values are consistent with the typical values for meandering streams and account for the potential for reaches occupying various locations in the watershed.

4.2.1.5 Understory Shrub Cover along the Green Line

The proportion of riparian shrubs along the bankfull margin or green line provides another target to address siltation in the Upper Big Hole River TPA. Shrubs promote structural stability of banks through their massive, deep root systems (Beschta 1991). During flooding events, shrubs form protective mats over banks, which dissipate flow velocities and permit the transported sediments to settle out, thereby building banks and providing fertile soils (Platts and Rinne 1985). During winter months, vegetative cover promotes bank stability by insulating banks and reducing ice formation in the soil, which reduces heaving and erosion (Bohn 1989). Together, the functional attributes of maintaining bank stability and filtering sediments result in reduced delivery of sediment to surface waters. Understory shrub cover along bank full margins can be applied for use in the sediment target weight of evidence approach with relatively high certainty. As described above, this parameter has direct relevance to near stream sediment production.

Percent shrub cover along the green line showed considerable similarity among reference reaches on the Big Hole River, North Fork Big Hole River, and valley tributaries (**Table 4-16**). Shrub cover was less on montane tributaries, because conifer trees were a more significant component along some of the forested reaches. However, most reaches assessed in forested environments had potential for riparian shrub community with a few exceptions. This target will not be applied to the exceptions where conifers were dominant in riparian zones. The target is for the 25th percentile of percent shrub cover to approximate or be more than the 25th percentile of the reference reaches. Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is necessary, while those with greater exceedence will be weighed more heavily. The 25th percentile of the reference population is used as a comparative statistic because a higher amount of understory along the bank of streams is desired. Although the 25th percentile will be used as a target, the overall quartiles may be used to assess stream conditions along with an aerial photo review of the entire stream corridor. Median conditions may also be used to determine if a TMDL is necessary when considered in a multiple line of sediment impact approach with other targets.

Table 4-16: Distributional statistics for percent understory shrub cover on streambanks measured on reference reaches on montane tributaries, valley tributaries, and the North Fork Big Hole River.

Stream Classification	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole River	12	10	86	31	50	73
North Fork	8	24	62	35	41	51
Valley Tributaries	28	10	84	32	58	72
Montane Tributaries (C and E Channels)	12	26	80	36	41	73

4.2.2 Supplemental Indicators for Sediment

4.2.2.1 Eroding Banks

Extent and severity of bank erosion presents an indicator to address siltation in streams in the Upper Big Hole River TPA. Eroding banks are often a significant source of sediment to streams. Although bank erosion is a natural process along streams, land use practices that reduce riparian vegetation and result in mechanical damage to banks can accelerate this natural process and directly contribute sediment to the stream system.

Field assessments in 2004 included a survey of visually eroding banks within each 1000-foot study site. Evaluations included measurements of the length and height of eroding banks and completion of a questionnaire geared at evaluating severity of erosion per bank. Note that only one value of this measure occurs per assessment reach, unlike some of the other measures used for targets and indicators.

Visually eroding banks were a relatively rare feature on reference reaches in the Upper Big Hole River TPA (**Table 4-17**). Median area of eroding bank ranged from 47-148 ft^2 on reference reaches depending on stream classifications based for target setting. Bank erosion composed less than 10 percent of the streambank length on most reference reaches. The target for bank erosion on the Big Hole River mainstem calls for the 75^{th} percentile of any assessed reach's bank erosion to approximate or be less than the 75^{th} percentile for the reference reaches. Minor exceedences of the target value, or exceedences that are within statistical expectations, will result in little, if any, weighing toward determining if a TMDL is necessary, while those with greater exceedence will be weighed more heavily. The 75^{th} percentile of the reference population is used as a comparative statistic because accelerated bank erosion rates are undesirable. Median conditions may also be assessed to help compare reference condition to the stream of concern.

Table 4-17: Distributional statistics for area of eroding banks (ft^2) measured on reference reaches in the Upper Big Hole River TPA.

Classification	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Big Hole River	2	148	493	0	320	406
Montane Streams	4	36	243	0	53	113
Valley Streams*	6	31	297	0	118	212

* Valley streams include North Fork Big Hole River, as reference values were similar to other reference valley reference reaches.

4.2.2.2 Macroinvertebrate Bioassessment Score

Siltation exerts a direct influence on benthic macroinvertebrates assemblages through several mechanisms. These include limiting preferred habitat for some taxa by filling in interstices or spaces between gravel. In other cases, fine sediment limits attachment sites for taxa that affix to substrate particles. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site, and are used by the DEQ to evaluate impairment condition and beneficial use support during the 303(d) Listing process (the assessment in this document is not the 303(d) Listing process). The advantage to these bioindicators is that they provide a measure of support of associated aquatic life, an established beneficial use of Montana's waters.

In 2006, Montana DEQ adopted impairment thresholds for bioassessment scores based on two separate methodologies. The **Multi-Metric Index (MMI)** method assesses biologic integrity of a sample based on a battery of individual biometrics. The **River Invertebrate Prediction and Classification System (RIVPACS)** method utilizes a probabilistic model based on the taxa assemblage that would be expected at a similar reference site. Based on these tools, the DEQ adopted bioassessment thresholds that were reflective of conditions that supported a diverse and biologically unimpaired macroinvertebrate assemblage, and therefore a direct indication of beneficial use support for aquatic life.

The MMI is organized based on the different ecoregions within Montana. Three MMIs are used to represent the various Montana ecoregions: Mountain, Low Valley, and Plains. Each region has specific bioassessment threshold criteria that represent full support of macroinvertebrate aquatic life uses. The Big Hole Watershed falls within both Mountain and Low Valley MMI regions. The MMI score is based upon the average of a variety of individual metric scores. The metric scores measure predictable attributes of benthic macroinvertebrate communities to make inferences regarding aquatic life condition when pollution or pollutants affect stream systems and instream biota.

The RIVPACS model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled. The RIVPACS model provides a single dimensionless ratio to infer the health of the macroinvertebrate community. This ratio is referred to as the Observed/Expected (O/E) value. Used in combination, the results suggest strong evidence that a waterbody is either supporting or non-supporting its aquatic life uses for aquatic invertebrates.

Basis for Target Values

For the Multi-Metric Index, individual metric scores are averaged to obtain the final MMI score. The score will range between 0 and 100. **The impairment thresholds are 63 and 48 for the mountain and low valley indices, respectively.** The impairment threshold (10th percentile of the reference dataset) represents the point where DEQ technical staff believed macroinvertebrates are affected by some kind of impairment (e.g. loss of sensitive taxa).

The RIVPACS impairment threshold for all Montana streams is any O/E value <0.8. However, the RIVPACS model has a bidirectional response to nutrient impairment. Some stressors cause macroinvertebrate populations to decrease right away (e.g. metals contamination) which causes the score to decrease below the impairment threshold of 0.8. Nutrient enrichment may actually increase the macroinvertebrate population diversity before eventually decreasing below 0.8. An upper limit was set to flag these situations. The 90th percentile of the reference dataset was selected (1.2) to account for these situations, and any value above this score is defined as impaired unless specific circumstances can justify otherwise. However, RIVPACS scores >1.0 are considered unimpaired for all other stressor types.

Most scores significantly below the RIVPACS and MMI impairment thresholds are impaired. Some model scores may be close to the threshold. These sites may be considered unimpaired in some situations. For example, a site classified in the Mountain ecoregion may have a mountain MMI score of 83, well above the mountain MMI threshold (63), and a RIVPACS score of 0.76, close to the RIVPACS impairment threshold (0.8). The assessor may determine that the macroinvertebrate community at the site is unimpaired. Ultimately, the assessor will determine the degree of impairment (i.e. moderate or severe) using best professional judgment and guidance found in the State's bioassessment process (DEQ, 2006). These values will also be used for targets in this document, but do not necessarily indicate that sediment is the cause of the impacted macro invertebrate community. These metrics need to be considered along with physical sediment and stream channel data.

4.2.3 Sediment Target and Supplemental Indicator Summary

The following **Tables 4-18 through 4-22** summarize sediment targets and supplemental indicators for each of the distinctly different stream categories found in the Upper Big Hole Watershed. The categories include the mainstem of the Big Hole River, the North Fork of the Big Hole River, valley bottom tributaries, and montane tributaries.

Table 4-18: Targets and supplemental indicators to address sediment in the upper Big Hole River (above Doolittle Creek).

Parameter	**Target**	**Rationale**
Targets		
Width-to-depth ratio	75th Percentile ≤26 Median ≤ 22	Streams with the appropriate width-to-depth ratio transport and sort sediment more efficiently.
Understory Shrub Cover along Green Line	25th Percentile ≥35%	Shrubs function to maintain bank stability, reduce in channel sediment sources and filter sediments.
Pool Frequency (# of Bankfull Widths between pools)	≤5.55	Indicates if fine or larger sized sediment transport dynamics or supply is excessive and indicates if fish habitat is impacted by pool filling.
Percent Fines < 6 mm (Viewing Bucket)	Median ≤22%	Indicates if fine sediment supply is impacting salmonid fish spawning success.
Percent Fines < 2 or 6mm (Pebble Counts)	Median ≤10%	Indicates if fine sediment supply is likely impacting macroinvertebrates or broadcast fish spawning success.
Supplemental Indicators		
Human Caused Sources	Significant human caused sources have to be present.	If no significant human caused sediment yield or transport changes are present in a watershed, restoration practices can not reduce sediment loads. A TMDL is not necessary for naturally occurring sources.
Macroinvertebrate Bioassessment	Mountain MMI >63 Valley MMI >48 1.2>RIVPACS>0.80	Macroinvertebrates are a direct measure of beneficial use.
Eroding Banks	75th Percentile ≤493	Eroding banks are a significant source of sediment

Table 4-19: Targets and supplemental indicators to address sediment pollution in the North Fork Big Hole River

Parameter	Target	Rationale
	Targets	
Width-to-depth ratio	75th Percentile ≤28 Median ≤ 24	Streams with the appropriate width-to-depth ratio transport and sort sediment more efficiently.
Understory Shrub Cover along Green Line	25th Percentile ≥35%	Shrubs function to maintain bank stability, reduce in channel sediment sources and filter sediments.
Pool Frequency (# of Bankfull Widths between pools)	≤7.93	Indicates if fine or larger sized sediment transport dynamics or supply is excessive and indicates if fish habitat is impacted by pool filling.
Percent Fines < 6 mm (Viewing Bucket)	Median ≤11%	Indicates if fine sediment supply is impacting salmonid fish spawning success.
Percent Fines < 2mm (Pebble Counts)	Median ≤10%	Indicates if fine sediment supply is likely impacting macroinvertebrates or broadcast fish spawning success.
	Supplemental Indicators	
Human Caused Sources	Significant human caused sources have to be present.	If no significant human caused sediment yield or transport changes are present in a watershed, restoration practices can not reduce sediment loads. A TMDL is not necessary for naturally occurring sources.
Macroinvertebrate Bioassessment	Mountain MMI >63 Valley MMI >48 1.2>RIVPACS>0.80	Macroinvertebrates are a direct measure of beneficial use.
Eroding Banks	75th Percentile ≤176	Eroding banks are a significant source of sediment

Table 4-20: Targets and supplemental indicators to address sediment in the valley tributaries in the Upper Big Hole River TPA.

Parameter	Threshold	Rationale
Targets		
Width-to-depth ratio	75th Percentile ≤19 Median ≤14	Streams with the appropriate width-to-depth ratio transport and sort sediment more efficiently.
Understory Shrub Cover along Green Line	25th Percentile ≥30%	Shrubs function to maintain bank stability, reduce in channel sediment sources and filter sediments.
Pool Frequency (# of Bankfull Widths between pools)	≤7.93	Indicates if fine or larger sized sediment transport dynamics or supply is excessive and indicates if fish habitat is impacted by pool filling.
Percent Fines < 6 mm (Viewing Bucket)	Median ≤80%	Indicates if fine sediment supply is impacting salmonid fish spawning success.
Percent Fines < 2mm (Pebble Counts)	Median ≤18%	Indicates if fine sediment supply is likely impacting macroinvertebrates or broadcast fish spawning success.
Supplemental Indicators		
Human Caused Sources	Significant human caused sediment production or transport impacts are present.	If no significant human caused sediment yield or transport changes are present in a watershed, restoration practices can not reduce sediment loads. A TMDL is not necessary for naturally occurring sources.
Macroinvertebrate Bioassessment	Mountain MMI >63 Valley MMI >48 1.2>RIVPACS>0.80	Macroinvertebrates are a direct measure of beneficial use.
Eroding Banks	75th Percentile ≤176	Eroding banks are a significant source of sediment

Table 4-21: Targets and supplemental indicators to address sediment in the montane tributaries in the Upper Big Hole River TPA.

Parameter	Threshold	Rationale
Targets		
Width-to-depth ratio	75th Percentile ≤15 Median ≤13 in high gradient channels 75th Percentile ≤13 Median ≤10 in low gradient channels	Streams with the appropriate width-to-depth ratio transport and sort sediment more efficiently.
Understory Shrub Cover along Green Line	25th Percentile ≥30%	Shrubs function to maintain bank stability, reduce in channel sediment sources and filter sediments.
Pool Frequency	≤6.61 in C and E channels	Indicates if fine or larger sized sediment transport dynamics or supply is excessive and indicates if fish habitat is impacted by pool filling.
Percent Fines < 6 mm (Viewing Bucket)	High gradient - Median ≤10% Low gradient Median ≤50%	Indicates if fine sediment supply is impacting salmonid fish spawning success.
Percent Fines < 2mm (Pebble Counts)	Median ≤13%	Indicates if fine sediment supply is likely impacting macroinvertebrates or broadcast fish spawning success.
Supplemental Indicators		
Human Caused Sources	Significant human caused sediment production or transport impacts are present.	If no significant human caused sediment yield or transport changes are present in a watershed, restoration practices can not reduce sediment loads. A TMDL is not necessary for naturally occurring sources.
Macroinvertebrate Bioassessment	Mountain MMI >63 Valley MMI >48 1.2>RIVPACS>0.80	Macroinvertebrates are a direct measure of beneficial use but these metrics don’t directly relate to sediment so they must be used along side sediment data.
Eroding Banks	75th Percentile ≤200	Eroding banks are a significant source of sediment

4.3 Nutrients

Targets and supplemental indicators for nutrients are based upon interpretation of Montana’s narrative water quality standards. Montana’s water quality standards for nutrients are addressed via the narrative criteria identified in **Section 3.3.2.1**. These narrative criteria do not allow for “*substances attributable municipal, industrial, agricultural practices or other discharges that will...(e) create conditions which will produce undesirable aquatic life*”, ARM 17.30.637.

Nutrient targets include direct measures of nutrient concentrations in surface waters, measures of benthic chlorophyll *a* concentrations, and the role of riparian vegetation in mitigating nutrient loading through uptake and filtering. Dissolved oxygen levels may indicate a nutrient impairment condition that may limit fish and aquatic life growth and may be used as supplemental information if available. In addition, biological assemblages may provide several indicators of nutrient enrichment.

Framework Nutrient TMDLs

It is acknowledged that existing nutrient data for the Upper – North Fork Big Hole TPA is limited and targets are based on a numeric translation of Montana's narrative nutrient standards. As a result, the level of certainty associated with the nutrient targets and existing condition review may be low depending upon water body, and upon potential adoption of numeric nutrient standards in the future, may need to be revised. The nutrient targets are considered interim values that may need to be revised in the future and compliance with the targets is currently considered voluntary. An adaptive management strategy to facilitate revision of the nutrient targets, TMDLs, and allocations is presented in **Section 9.0**.

4.3.1 Nutrient Concentrations and Chlorophyll a

The Big Hole River and its tributaries are mostly located in the Middle Rockies ecoregion. The most sensitive uses are those associated with fisheries and aquatic life uses. If these uses are protected, drinking water and agriculture uses will also be protected. The standard relative to fisheries and aquatic life prohibit "conditions which produce undesirable aquatic life" (ARM 17.30.637). The narrative standard does not define what undesirable aquatic life is, nor does it provide nutrient concentrations appropriate to control it. In response to EPA's directive to states to develop numeric nutrient criteria, Montana submitted a nutrient plan to EPA in 2002 detailing how they will determine which beneficial uses are impacted, how undesirable aquatic life will be defined, and how numeric nutrient criteria will be developed. Since 2002, Montana has conducted a number of technical studies and is pursuing development of numeric criteria for nutrients.

In the interim, to facilitate a measurable comparison of ambient water quality data with the narrative standards and to establish end-point nutrient goals for the TMDLs, indicators of nutrient impairment and threshold values have been selected based on the results of the work that Montana has completed to date in an effort to ultimately develop numeric nutrient criteria (Suplee *et. al*., 2007; Suplee, 2006; Suplee, 2005). These nutrient investigations are used for setting nutrient and chlorophyll *a* interim targets along with riparian vegetation studies within the Big Hole Watershed that are used for justifying supplemental indicators for nutrients. The interim targets and associated indicator values provided in this document are not water quality standards. Rather, they are considered interim values subject to modification in the future following the adaptive management strategy presented in **Section 9.0.**

The selected interim targets for Upper – North Fork TPA include total phosphorus (TP), total nitrogen (TN), and benthic chlorophyll-*a*. Interim threshold values for the nutrient parameters are presented in **Table 4-22**. These are growing season, or summer, values applied from July 1st through September 30th.

Table 4-22: Interim Nutrient Targets

Parameter	**Concentration**
Total Phosphorus	0.049 mg/l
Total Nitrogen	0.320 mg/l
Maximum Benthic Chlorophyll-*a*	150 mg/m2

When evaluating compliance with these goals it is important to consider that high levels of phosphorous or nitrogen loading to a stream might not show up as elevated concentrations in the water column, particularly during growing season. This is because nutrient uptake by growing algae could occur to the extent that nutrient concentrations in the water column are significantly reduced within a given length of stream. Therefore, it is important to measure algae concentrations, represented by benthic chlorophyll a, at the same time that nutrient concentrations are being measured to provide an adequate characterization of water quality conditions. When subsequently evaluating compliance with the above endpoint goals, it is important to first evaluate compliance with the chlorophyll a values before drawing conclusions regarding compliance with either the total phosphorous or total nitrogen concentration values. Furthermore, the interim total phosphorous and total nitrogen targets are not to be applied as absolutely no exeedence values should occur since occasional minor exeedences of these values do not equate to conditions necessary to cause nuisance algae growth.

4.3.2 Supplemental Indicators for Nutrients

4.3.2.1 Biological Indicators

Both macroinvertebrate and diatom associations may provide supplemental indications of nutrient conditions. Biological community metrics may be presented in the impairment status section as supporting information for streams that have borderline nutrient and chlorophyll *a* concentrations but generally will not carry much weight in the decision process.

4.3.2.2 Riparian Vegetation

Field assessments conducted during 2004 field measured several conditions that are provided for supplemental indicators to address nutrient enrichment in streams in the Upper Big Hole River TPA. Understory shrub cover along green line and line transect, and corresponding measures of percent bare ground relate to nutrient conditions in the streams. These follow the thresholds prescribed to address siltation (cross reference).

Measures of riparian vegetative cover classes relate to nutrient loading in several ways. First is the role of streamside vegetation in mitigating nutrient inputs, which occurs through several mechanisms. Vegetation filters and takes up nutrients contributed from overland flow and accumulations of livestock wastes near the stream. These functions are especially important in agricultural watersheds (Lowrance et al. 1984). In addition, woody species such as willows are phreatophytes, which are deep-rooted plants that obtain water from the water table. These plants have the potential to mitigate nutrients contributed from subsurface irrigation return flows that leach nutrients from soil. Another assumption in applying these measures as supplemental indicators is that an intact, functioning riparian area suggests that livestock management practices limit accumulations of manure adjacent to the stream channel. This limits the extent to which manure is a direct source of nutrients to surface waters. The greenline and cross sectional transect riparian vegetation measures are outlined further in the sediment target section above (**Section 4.2.1**). The same threshold values for sediment will be applied for nutrient supplemental indicators.

Bare ground is typically an undesirable feature in riparian areas and often an indicator of disturbance. Livestock grazing practices have the potential to increase bare ground through vegetation removal and trampling. This has implications for nutrients as increased cover of bare ground suggests that near channel sources of sediment and nutrients are elevated due to a lack of bank protection afforded by vegetation. Moreover, high proportions of bare ground limit the filtering capacity of riparian areas that limit introduction of fine sediment and associated nutrients through surface run off. Reference reach summary statistics, which will be considered for bare ground comparisons, are provided in **Table 4-23**.

Table 4-23: Percent bare ground measured along the green line on reference reaches.

Classification	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Valley Tributaries	28	0	29	0	4	13
Low Gradient Montane Tributaries	24	0	58	2	6	19
High Gradient Montane Tributaries	Not Applicable					

4.3.2.3 Percent Shrub Cover along Line Transects

Understory shrub cover measured along line transects, established perpendicular to stream flow, provided additional information on status of riparian shrubs on assessed reaches. Line transects measure the proportion of a measuring tape intercepted by various classes of vegetative cover across the flood prone area. This differs from green line counts, which enumerates the proportion of 202 equidistant points intercepting vegetative classes at the bank line. Maintaining shrub cover along the width of the flood prone area reduces the risks for nutrient production and delivery to streams by decreasing soil erosion and increasing filtering from overland flow. Thresholds based on reference sites are provided in **Table 4-24**.

Table 4-24: Percent shrub cover measured along line transects on reference reaches.

Classification	N	Minimum	Maximum	25th Percentile	Median	75th Percentile
Valley Tributaries	35	25	95	47	64	77
Low Gradient Montane Tributaries	35	4	90	20	49	76
High Gradient Montane Tributaries	Not Applicable					

4.3.2.4 Dissolved Oxygen

Low Dissolved Oxygen (DO) often occurs in rivers, lakes and reservoirs in response to excessive nutrient loading and therefore, is an indirect indicator of potential nutrient impairment. In addition, Montana has numeric standards for dissolved oxygen associated with the aquatic life use. The Montana Water Quality Standards (17.30.623 (2)(b) require that no person may violate the numeric freshwater aquatic life dissolved oxygen standards presented in **Table 4-25** (DEQ, 2006). A table of fish spawning times and schedule for the presence of early life stages of fish that are likely to occur may be found at http://www.deq.state.mt.us/wqinfo/Standards/SpawningTimesFWP.pdf. The Montana dissolved oxygen standard is 5.0 mg/L as a 7-day minimum concentration and is proposed as an interim indicator to assess the nutrient impacts and also used directly to assess compliance with Montana's DO standards. Little to no dissolved oxygen data exist during nighttime periods, therefore this indicator will not be assessed at this time, but may be assessed during a future TMDL review.

Table 4-25: Minimum Aquatic Life Standards (Class B-1) for Dissolved Oxygen (mg/L)

Time Period	Early Life Stages	Other Life Stages
30-day average	NA	6.5
7-day average	9.5 (6.5)	NA
7-day average minimum	NA	5
1-day minimum	8.0 (5.0)	4

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.

4.3.2.5 Summary of Targets and Supplemental Indicators for Nutrients

Targets and supplemental indicators for nutrient enrichment involves use of multiple lines of evidence (**Table 4-26**). These include water chemistry and vegetative cover. Combined, these parameters will provide a robust understanding of the trophic status of streams in the Upper Big Hole River TPA. These targets and indicators are used collectively to determine if Montana's water quality standards pertaining to nutrient impacts are likely exceeded.

Table 4-26: Numeric targets and supplemental indicators to address nutrient enrichment in streams in the Upper Big Hole River TPA.

Parameter	**Threshold**	**Applicable Timeframe**	**Rationale**
InterimTargets			
Total Nitrogen	<320 µg/L	July 1-Sept 30th	Nutrient contributing to eutrophication
Total Phosphorus	<49 µg/L	July 1-Sept 30th	Nutrient contributing to eutrophication
Chlorophyll a	<150 µg/L	Year Round but typical growth occurs between July 1-Sept 30th.	Measures primary productivity of benthic algae and allows inference on nutrient loading and proliferation of undesirable aquatic life
Supplemental Indicators			
Percent Shrubs along Green Line in non conifer dominated riparian zones	25th percentile and median ≥ reference reaches statistics	July 1-Sept 30th	Vegetation functions in the filtering and uptake of nutrients
Percent Shrubs along Line Transects in non conifer dominates riparian zones	25th percentile and median ≥ reference reaches statistics	July 1-Sept 30th	Vegetation functions in the filtering and uptake of nutrients
Percent Bare Ground in non conifer dominates riparian zones	25th percentile and median ≥ reference reaches statistics	July 1-Sept 30th	Increased bare ground along the stream channel suggests sources of sediment and nutrient are elevated and filtering functions of riparian vegetation are limited

Applicable dissolved oxygen standards outlined in table 4-24

4.4 Metals

Similar to other pollutants in the Upper Big Hole River TPA, targets and supplemental indicators for metals contamination use multiple lines of evidence. These include direct measures of metals in surface waters and benthic sediment, along with biological metrics shown to be sensitive to metals pollution. These targets and supplemental indicators, combined with identification of potential sources of metals contamination, are used as a direct interpretation of Montana’s numeric and narrative water quality standards.

4.4.1 Metals in Surface Waters

Because numeric standards exist for metals in surface waters, numeric targets are relatively straightforward. Targets for each metal will be set to protect human health and aquatic life. The most conservative of the available numeric standards will be used (**Table 4-27**), which will be either human health standards or chronic aquatic life standards, depending on water hardness and the metal of concern. Because the data set used for the Upper and North Fork Big Hole TPAs is somewhat limited, it is assumed that unless a sample was collected during a summer rainstorm event, the sample represents a 96 hour period and thus can be applied to any of these standards.

Table 4-27: Numeric standards for metals listed as probable causes of impairment in streams in the Upper Big Hole River TPA (Circular WQB-7 2002)

Pollutant	**Aquatic Life Standards**		**Human Health Standards**
	Acute (µg/L)	***Chronic (µg/L)***	***(µg/L)***
Cadmium	0.52 @ 25 mg/L hardness	0.97 @ 25 mg/L hardness	5
Copper	3.79 @ 25mg/L hardness	8.25 @ 25 mg/L hardness	1300
Mercury (TR)	1.7	0.91	0.05
Zinc (TR)	37 @ 25 mg/L hardness^{c}	37 @ 25 mg/L hardness^{c}	2,000
Lead	13.98 @ 25 mg/L hardness	0.545 @ 25 mg/L hardness	15

4.4.2 Metals in Benthic Sediments

Metals associated with benthic sediment provide another means to evaluate risks to aquatic life and coldwater fisheries. Due to their close association with the streambed, benthic organisms, including many fish species, periphyton, and macroinvertebrates, have increased potential to integrate metals from benthic sediments into their tissues. This may have a direct adverse effect on these beneficial uses and provide an avenue for accumulation of metals into the food web. Metals of concern in the Upper Big Hole River TPA (cadmium, copper, and lead) have a low to moderate bioaccumulation potential based on aquatic bioconcentration factors (EPA 1985a, EPA 1985b, EPA 1985c, cited in CDM 1994). Therefore, contamination of benthic sediments with these metals will have low to moderate effects on higher trophic levels.

Evaluation of metals concentrations in benthic sediments also has an advantage over water column measures. Metal concentrations in the water column can be highly variable with factors such as stream flow. For example, increased flows can either dilute or mobilize metals and may be difficult to sample. In contrast, metals associated with benthic sediments are less susceptible to variability in flow, although large events may scour and transport these constituents.

Unlike metals concentrations in surface water, numeric targets for metals in benthic sediments are lacking. A literature review conducted by Buchman, 1999 provides a reference for evaluating the potential effect of sediment metals by identifying concentrations with observed adverse effects on aquatic species. Targets follow a conservative approach through selection of concentrations observed at or below the threshold effect level (TEL) (**Table 4-28**). Exceeding a sediment metals target by itself may indicate that further water quality monitoring is needed. How this information is used is further discussed **Section 1.4.4**.

Table 4-28: Sediment metals targets for streams in the Upper Big Hole River TPA (modified from Buchman, 1999).

Parameter	Target
Cadmium	≤0.6 mg/kg
Copper	≤36 mg/kg
Mercury	≤0.174 mg/kg
Lead	≤35 mg/kg
Zinc	≤123 mg/kg

4.4.3 Biological Indicators of Metals Contamination

Several metrics calculated from macroinvertebrate and periphyton proportional counts are sensitive to metals loading and provide targets and indicators of the influence of metals on aquatic life (**Table 4-29**). In addition, there should be no toxic risk at any level of the food chain associated with the water body if metals originate from aquatic habitats. The DEQ has employed some of these for several years, and others are under development. The percent of abnormal cells metric is a measure of the proportion of diatom frustules showing abnormalities in their shape or striae (the distinctive lines of pores allowing identification of diatom taxa). Heavy metals contamination, especially in poorly buffered waters, can result in deformation of these features. Similarly, the metals tolerance index, a diatom metric under development, is similar to the metals tolerance index developed for macroinvertebrates. Dr. Loren Bahls of Hannaea is working on calibrating this metric for use in Montana streams, and it may be available in the near future.

A metals tolerance index was constructed to assess metal contamination impacts on the macroinvertebrate community in Silver Bow Creek. This metric is used along with other metrics to indicate a potential impact to macroinvertebrate communities. This indicator should only be used with other biological indicators of metal contamination because of its uncertainty.

Table 4-29: Numeric supplemental indicators.

Parameter	Target	Description	Citation
Percent abnormal cells (diatoms)	<3%	Proportion of frustules showing deformities, which are often an indicator of metals contamination	McFarland et al. 1997, Bahls 1993
Metals sources	If no human caused metals sources are present but metals are above standards, site specific metals standards may be pursued. Significant human caused sources need to be present for TMDL completion.		
Bioaccumulation	Bioaccumulation poses no risk at all levels of food chain.		

4.4.4 Summary of the Decision Process Used to Determine if Metals TMDL are Necessary

The existence of human caused metals sources will be used as a supplemental indicator. The process chart identified in **Figure 4-1** assumes that human caused sources have been identified. **Figure 4-1** identifies the decision process used to determine if metals are impacting uses in the Upper Big Hole TPA. If water quality data exceed water column metal standards, a TMDL for the specific metal will be written. Where limited water quality samples do not exceed standards, but a sediment metal concentration is above a guidance level, biological responses are considered. If there is a toxicological response in a biological community and a high sediment metal concentration, the Department will provide a follow up water column monitoring strategy that could lead to a TMDL. If the water column chemistry (both high and low flow conditions) and biological results (both periphyton and macroinvertebrate) are not over the threshold, then it can be concluded that it is not needed.

There are a few exceptions to the general decision process. The first is where sediment chemistry metals are greater than published guidance values and upstream human caused metals sources indicate the possibility of metals conditions exceeding targets further upstream in the watershed. Under this scenario, a follow up monitoring plan will be provided. The amount of additional sampling needed in this circumstance will be based on the individual situation.

The second exception is when the metal has low toxic effects on aquatic life, but a high bioconcentration factor that is likely to influence human health through fish consumption, as is the case with mercury. In this case, high concentrations of mercury found in sediment without a toxic effect is sufficient information to trigger TMDL formation, or at least further mercury monitoring actions. This is especially true if fish tissue analysis data is available and indicates bioconcentrating effects.

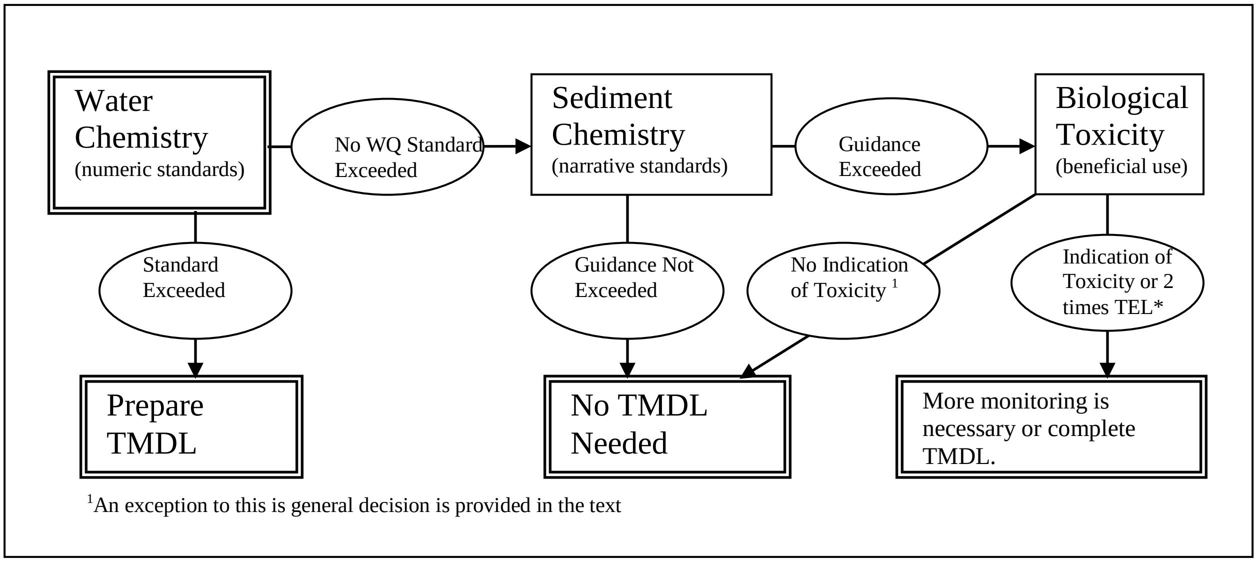

Figure 4-1: Decision Process to Determine if a Specific Metal is Impacting a Use for Upper/NF Big Hole TPAs.

*NOAA SQIRTS freshwater threshold effect level.

4.5 Miscellaneous Supplemental Indicators

Other data that pertains to beneficial uses, pollutant sources, or watershed conditions may be presented in the Existing Conditions and Data Summary section. Some of these data include differing measures of chemistry, biology, or physical measurements not specifically explained as targets and supplemental indicators. The information provided by the other measures will support overall decisions, but will not be used for TMDL targets.

Ongoing monitoring efforts in the Upper Big Hole River TPA will provide additional indicators useful in evaluating the biological, chemical, and physical integrity of streams and response to restoration activities. Fish population assessments conducted by FWP and USFS will provide valuable information on coldwater fisheries, a key beneficial use in the Upper Big Hole River TPA. Information from these efforts will be incorporated into future TMDL planning because targets are not static and may be updated based on more robust scientific understanding from future studies. MFWP and USFWS conservation goals for grayling restoration may be useful in future TMDL planning efforts and, through future implementation and study efforts, may have measurable change based on other parameters not mentioned in this document. Future TMDL reviews should consider other available, relevant, environmental measures along with the targets and supplemental indicators provided in this document.

SECTION 5.0
EXISTING CONDITIONS SUMMARY

The following sections provide a summary of available data and a comparison to water quality targets for streams identified on Montana's list of impaired waters. Although placement onto the 303(d) List indicates water quality is likely impaired, a comparison of water quality targets to existing data provides a more robust link of a specific pollutant to an impacted use and the need for TMDL development or follow-up monitoring. This review of data usually provides a more robust data set than those used for Montana's 2006 list of impaired waters. Target comparisons also establish a starting point from which to measure future water quality restoration success. This review does not take the place of the 303(d) List of sufficient and credible data reviews or beneficial use determinations.

5.1 Upper Big Hole River

This segment of Big Hole River originates south of Jackson, Montana in the Beaverhead Mountains and flows northward ending at its confluence with Pintlar Creek (**Appendix K**, **Map 1**). Tributaries flow from the Beaverhead, Pioneer and Pintler mountain ranges. The major tributaries include the North Fork Big Hole River, Warm Spring, Steel, Swamp, Governor, Big Lake, and Rock Creeks. Pine forests dominate upper elevations of the watershed. The Big Hole Valley is a broad, low gradient broad valley dominated by hay and cattle production.

Montana's 2006 integrated water quality report indicates that aquatic life, coldwater fishery, and contact recreation are partially supported in the upper segment of the Big Hole River. Potential causes of impairment are identified as alteration instream-side or littoral vegetative covers, low flow alterations and temperature. The major watershed sources identified during the TMDL source assessment are associated with transportation and agriculture.

5.1.1 Temperature

Thermal alterations on the mainstem of the Big Hole River, primarily in the form of elevated summer temperatures, present a significant constraint on the biological and physical integrity of this stream. The alteration in this thermal regime is of considerable importance due to the role of the Big Hole River in supporting the last fluvial population of Arctic grayling in the lower 48 states (Section 2). Evidence supporting this 303(d) listing, and therefore the need for a TMDL to address temperature, comes from a variety of sources and data types.

The water quality targets presented relate to riparian vegetation conditions that provide shading, stream channel conditions that promote instream thermal inertia, and thermal inputs such as irrigation return flow. Increasing instream flow by way of irrigation water saving management activities will provide thermal inertia to lessen daily temperature fluctuations. The combined suite of targets would meet Montana's water quality temperature standard if achieved. The water quality temperature standard is also provided as a target but can be difficult to assess. Temperature modeling scenarios are provided for each of the temperature influencing factors which are provided as targets. Results from the modeling scenarios provide a sensitivity analysis indicating the degree of influence each target can have on temperature conditions in the Big Hole River.

5.1.1.1 Canopy Density and Understory Shrub Cover along Streambanks

Canopy density over the stream due to riparian vegetation was measured on a number of reaches on the upper Big Hole River. This effort compared canopy density and understory shrub cover among least-impacted and impacted reaches. Statistically significant differences between reference and impacted reaches existed in the amount of overhanging riparian vegetation and shrub cover along the streambank. Impacted field assessed reaches consistently failed to meet numeric targets for canopy density, and shrub cover developed from the reference reaches (**Table 5-1**). Comparison of temperature modeling results using reference and impacted canopy density results also indicates that human influences to stream-side shade are influencing stream temperatures to a level that exceeds the temperature standard.

Only a portion of the upper Big Hole River could be assessed by field measures. Aerial photo reviews were used to extrapolate to areas that were not assessed in the field. Assessment of aerial imagery during TMDL development indicated that removal of riparian understory shrub cover has reduced stream shading over significant portions of the stream channel. Almost the entire upper Big Hole River has the potential for riparian shrubs. An aerial photo assessment indicates that approximately 25 percent of the mainstem had dense, 30 percent had moderate, and 45 percent had low density streamside shrub cover. Historic aerial photo comparisons and fence line contrasts indicate almost all of the areas of low density shrub cover are human influenced. A significant portion of the river has reduced riparian canopy cover.

5.1.1.2 Stream Channel Geometry

High width-to-depth ratios were found when comparing impacted reaches to reference reaches (**Table 5-1**). The monitoring results indicate that in most areas assessed by the aerial photo assessment with “low riparian shrub cover” have higher width-to-depth ratios. The over widened channels allow larger daily water temperature fluctuations and provide fewer deep coldwater refugia for aquatic species. A shallow and wide stream provides a large area for heat transfer during warm weather. Assuming consistent streamside canopy, a stream with a higher width-to depth ratio has reduced shading when compared to a narrower, deeper channel. Temperature modeling indicated that human caused influences to channel geometry increase maximum daily stream temperatures.

The TMDL project aerial photo analysis and subsequent field monitoring indicated that reference areas with higher riparian shrub cover were also more likely to have a low gradient, braided stream channel which promotes higher effective shade given the same vegetation height along streambanks. Many impacted areas of the upper Big Hole River are changing to a less stable Rosgen C type channel. A number of small channels have greater potential for shade from riparian vegetation than one larger channel.

5.1.1.3 Stream Flow

Stream flow is used as a supplemental indicator to be used in combination with other targets. Examination of hydrographic data showed depleted stream flows resulting from irrigation withdrawals in the basin. Reduced flow volume has less thermal inertia and is therefore more sensitive to solar inputs. Application of a supplemental indicator for flow provides additional evidence supporting the listing of the Big Hole River for temperature. Examination of stream flow at the Wisdom Bridge gage station for the past three years indicates stream flow frequently dropped below 60 cfs throughout the irrigation season (**Figure 5-1**). Stream flow was often below the fishery minimum survival flow of 20 cfs. Calculation of the frequency of flows below the target for the period of record at this gauging station indicates that these reduced stream flows occur during both dry and wet years and are not attributable solely to the recent drought conditions (**Figure 5-2**).

Meeting the CCAA and FWP instream flow targets may not always be possible while considering Montana's water laws and varying weather conditions. An alternative approach to meeting instream flows will be to apply all reasonable irrigation water management practices in the watershed that will increase instream flows without divesting, impairing or diminishing any State recognized water right. Significant increases instream flow can be accomplished by local irrigation water savings efforts which employ water saving engineering and management practices along with water leasing or donation for instream use. Some irrigation water management practices are being used in specific areas. The alternative to meeting the stream flow targets will be to apply **all** reasonable land, soil and water conservation practices that apply to the irrigation systems in the upper Big Hole watershed. This should include an irrigation water management study to determine where the irrigation systems should be upgraded to save water without severely affecting summer groundwater return flow to the stream network. All reasonable and appropriate irrigation water management activates should be utilized which will save water for instream use. These practices may include, but are not limited to:

- Irrigation scheduling between irrigators
- Ditch lining and maintenance
- Field leveling
- Gated pipe
- Knowing water needs of the crop and soil capacity to store water
- Soil moisture monitoring
- Controlling field runoff
- Drilling wells for stock instead of stock watering diversions
- Diverting water only when needed for intended use
- Irrigation structure upgrades (for more efficient water management) and maintenance
- Coordination between water users
- Other reasonable management practices

Another target relating to stream flow and irrigation water management will be to reduce warm water irrigation return flow to the upper Big Hole River and tributaries. Although no warm surface water returns were found during the TMDL assessment, it is likely that they exist. Many of these sources are transient and hard to assess in a scientific study. Irrigation water management activities that save water would also address this source.

A holistic water balance for the irrigation and stream network could not be assessed during the TMDL project because of the hydrologic complexity of this area. This effort should occur in the future and also consider water temperature of any irrigation returns that are found. The target pertaining to warm water irrigation returns will be a 65 percent reduction in overall inflow.

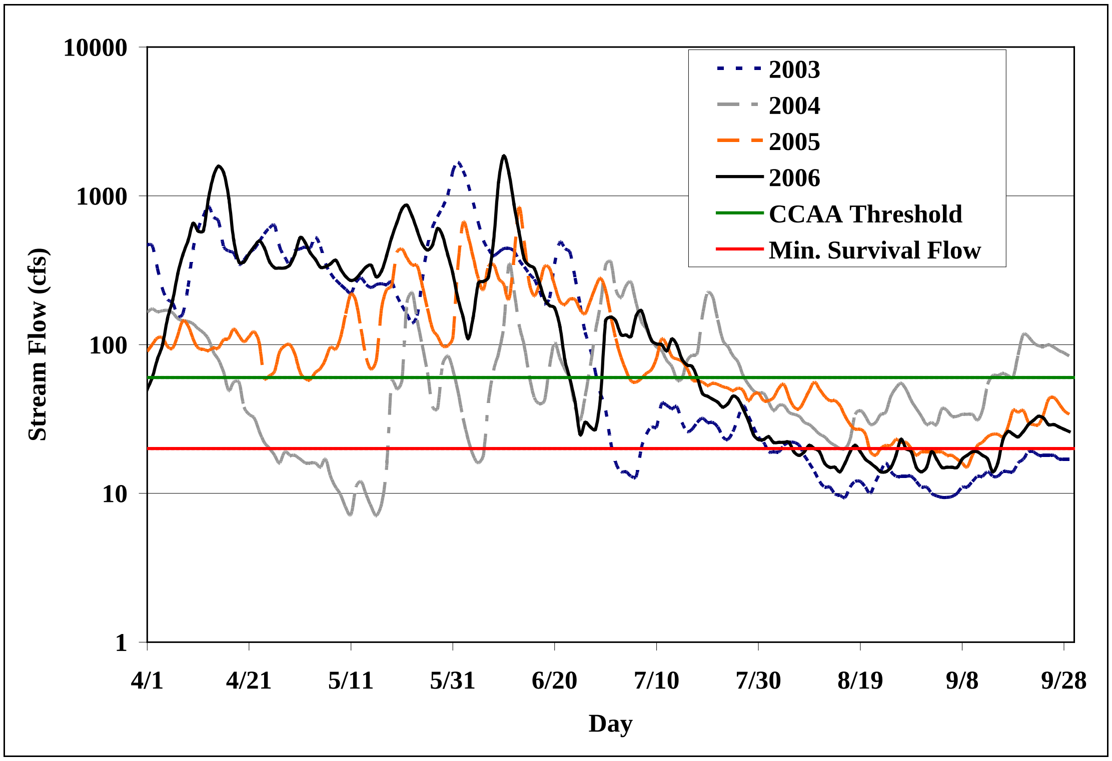

Figure 5-1: Stream flow measured on the Big Hole River at the Wisdom Bridge (USGS Gage 06024450)

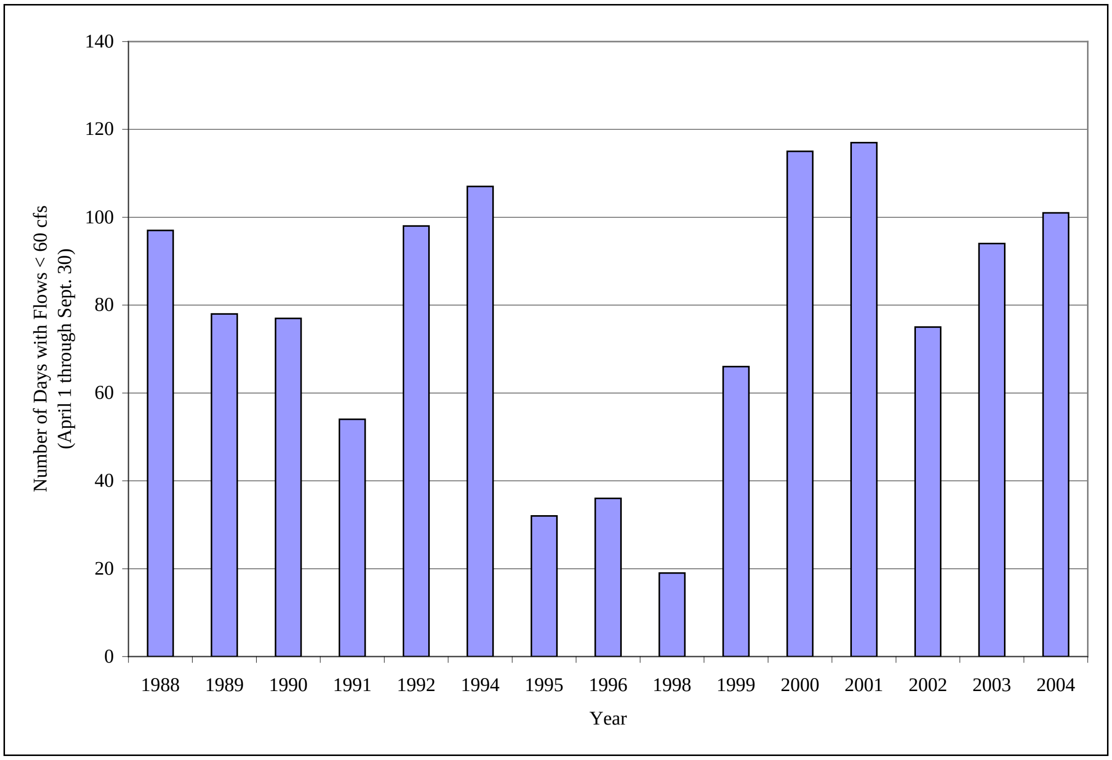

Figure 5-2: Number of days each year stream flow at Wisdom Bridge fell below 60 cfs

5.1.1.4. Temperature Data, Thermal Influences, and Link to an Impacted Use

An example is provided to link temperature conditions to shade, stream flow and stream channel conditions. A temperature monitoring site on reach BH26 represents one of the worst-case scenarios in terms of temperature due to the overly wide and shallow channel cross-section, low shrub cover, and the number of irrigation diversions upstream of this site. Maximum daily temperatures exceeded the 7-day sliding average of daily maximum temperatures known to limit fish in the same cold water class as arctic grayling (≤15 °C or 59 °F) throughout July and August. Moreover, these temperatures often approached the critical thermal maximum for Arctic grayling on several occasions. This temperature regime impacts cold stenotherms such as Arctic grayling.

Data from thermographs installed at the upper and lower ends reach BH26 indicate substantial thermal loading between the thermographs (**Figure 5-3**). The tendency for the downstream site to have markedly greater maximum daily temperatures accentuates the potential for these overly wide reaches with greatly reduced shrub cover to accrue heat during daylight hours. Additionally, the downstream site exhibits more rapid changes in temperature on both heating and cooling cycles, attributable to lower upstream canopy density, lower stream flows and higher width-to-depth ratios.

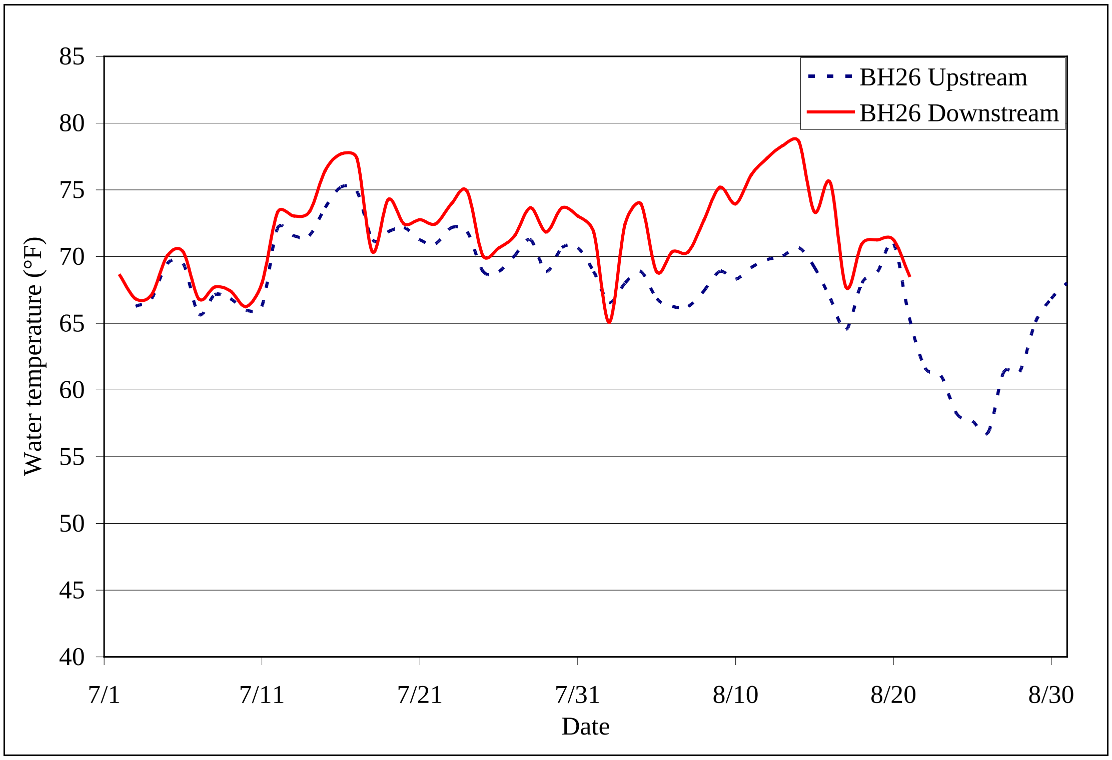

Figure 5-3: Temperatures measured using thermographs at the upstream and downstream boundaries of reach BH26 on the Big Hole River in 2004.

Examination of longitudinal trends in a sliding 7-day average maximum daily temperature target indicates temperatures exceeded a threshold likely to affect grayling over the entire length of the upper Big Hole River. Of the 13 thermographs installed in 2004, all registered temperatures in excess of 59 °F between June 30 and September 23, 2004. A tendency for the upstream stations to have fewer occurrences than downstream stations was apparent and may be due to groundwater influences along with human caused factors. Finally, an important consideration is climate during the period of record. The 2004 summer monitoring season was cooler and wetter than average, implying thermal conditions are warmer during hotter and drier years than 2004.

5.1.1.5 Temperature Modeling and Interpreting Montana’s Water Quality Temperature Standard

The SSTEMP (stream segment temperature model) was used for the upper Big Hole River to assess how stream temperature would fluctuate in response to increased stream shading, decreased channel width-to-depth ratio and an increase instream flow due to improved irrigation efficiency. Because of the complexity of the braided stream channel and the irrigation system network of the upper Big Hole Watershed, a full system assessment could not be completed. Alternatively, several segments with less complex hydrology were assessed with the SSTEMP model. Several reaches were modeled and compared to reference conditions during modeling scenarios.

Model results show that the increasing flow rate has minimal effect on lowering mean daily temperatures, but a significant effect on lowering daily maximum temperatures. Model runs simulating improved vegetation predict decreases in both mean and max outflow temperatures. Reducing stream channel width-to-depth ratios reduced maximum daily outflow temperatures but had little affect on the mean daily temperature. A more detailed description of the modeling is provided in Appendix B.

Land uses affecting stream side shade are also a significant factor influencing temperature. Modeling an increase instream shading to reference levels resulted in a simulated average daily decrease instream temperature from 0.5 to 1.5 ºF along one of the modeled segments depending on stream flow conditions, while another segment had a slightly smaller decrease. Modeling indicates that this source alone is likely impacting temperature to a level that exceeds Montana’s temperature standards. The modeling only assessed a few segments of the stream, but cumulative shade affects along the whole upper Big Hole River and its tributaries are a very significant influence on stream temperatures. An increase instream shading could be achieved through reasonable management changes and restoration projects designed to increase riparian vegetation.

Modeling scenarios that increased flows also contributed to reduced stream temperature. These scenarios simulate less irrigation water withdraw associated with reasonable irrigation water management. These scenarios estimated that daily maximum water temperatures drop from 0.5-1 ºF for every 10 cfs increase instream flow in the range of 10 to 80 cfs. Saving 10 cfs in the Upper Big Hole Watershed via irrigation water management activities is likely achievable with a local, voluntary effort that would not affect water rights if designed properly. This indicates reasonable irrigation water management activities could reduce stream temperatures significantly. Likely, water quality temperature standards are exceeded from this source alone. Until a basin wide, detailed irrigation system assessment is completed, irrigation water savings are only speculated by extrapolating results from other nearby studies.

Many areas of the upper Big Hole River are over widened due to lack of riparian species with deep binding root mass. Modeling scenarios indicated that the over widened stream channels contribute to increased heating and cooling rates. Widened channels produce more extreme high and low temperatures, but only slightly influence average daily temperatures. Modeling results indicate that over widened stream channels on the upper Big Hole River likely contribute to temperature standard exceedences during warm summer afternoons.

A modeling scenario combined increased shading, increased flow and narrower channels together. This scenario estimated stream temperature decrease of about 1.5-1.75 ºF along one segment of the stream, depending on flow conditions. This assumes that 10-15 cfs can be applied to instream flow from irrigation water management. The modeling only assessed a few segments of the stream, but cumulative affects from stream flow, shading and channel width along the whole upper Big Hole River and its tributaries are a very significant influence on stream temperatures. When considered together, changes to these three physical factors influence stream temperature to a degree that exceeds water quality temperature standards. Details of methods used for modeling and model results are included in Appendix B.

5.1.1.6 Summary of Temperature Conditions

Comparisons of available data to targets provide substantial evidence in that the upper segment of the Big Hole River is in need of a temperature TMDL (**Table 5-1**). All the targets are exceeded. Shrub density, shading, stream flow and channel geometry in impacted reaches deviated considerably from the targets. Modeling results suggest that these physical disturbances have a substantial effect on stream temperatures.

Table 5-1: Upper Big Hole River Temperature Targets and Existing Conditions

Criteria	**Rationale**	**Current Status**
Maximum allowable increase over naturally occurring temperature	Montana's standard: For waters classified as A-1 or B-1, a 1ºF maximum increase above naturally occurring water temperature is allowed within the range of 32ºF to 66ºF; within the naturally occurring range of 66ºF to 66.5ºF, no discharge is allowed which will cause the water temperature to exceed 67ºF; and where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF.	Modeling indicates that water temperature is increased by more than 0.5ºF when water temperatures are above 66.5ºF. Riparian vegetation reductions, over widened stream channels and irrigation inefficiencies contribute to heating.
Meet the Temperature Target Above or Meet All of the Surrogate Targets Below.		
Canopy Density Over the Big Hole River	The 25th percentile of all measures that represent the continuum of conditions along the segment ≥ 31% and the median ≥ 49%. No stream length greater than 1000 yards can fall below half of these values (25th percentile of 15% and median of 25%) because of localized heating concerns.	About half the assessed reaches fall below target values. Aerial photo assessment indicates significant stream lengths are likely below target values..
Canopy Density Over the Tributaries in the Valley	The 25th percentile of all measures that represent the continuum of conditions along the segment ≥ 36% and the median ≥ 64%. No stream length greater than 1000 yards can fall below half of these values (25th percentile of 18% and median of 32%) because of localized heating concerns.	Many tributaries are not meeting targets.
Irrigation Return Flows	Sixty five percent reduction in all irrigation return flow water that is warmer than stream water.	None were noted during TMDL monitoring, but are likely present. A thermal infrared assessment and water balance study would be useful for further assessing this target.
Point Sources	No permitted point sources.	
Supplemental Indicator (temperature dissipative capacity)		
Stream Flow	Apply irrigation water (IWM) savings from all reasonable irrigation efficiency projects to instream use during warmest months (July.-Sept).	Modeling indicates the daily maximum stream temperatures in August could be cooled by 0.5-1 ºF for every 10 cfs of instream applied IWM efficiency savings during low flow conditions. Reasonable IWM efficiency savings are unknown but expected to be at least 10 cfs based on other regional IWM study results.

5.1.2 Sediment

Sediment in the form of siltation was among listed probable causes of impairment on the 1996 303(d) List. Subsequent lists identified pollution such as riparian habitat alteration and flow alteration as causes of impairment. Nevertheless, associated forms of pollution such as “other habitat alterations” may influence delivery, in-stream sorting and transport of sediment in the Big Hole River. Therefore, this TMDL planning effort examined the information relating to sediment pollution, including physical measures that relate to sediment delivery, channel stability, sediment deposition and sediment transport.

Initial TMDL assessment of aerial photos described several indications that sediment delivery, channel stability, sediment deposition and sediment transport may be impacted in the upper Big Hole River. Information compiled in this process suggested that bank erosion associated with livestock grazing practices and willow removal was likely a significant in-channel source of sediment (OEA 1994). In addition, a reduction instreamside willows appeared to result in formation of an overly wide and shallow channel. This channel morphology can lead to accumulations of fine sediment on the streambed because of reduced sediment transport efficiencies and may produce a stream channel with fewer or less quality pools filled by larger sediment class sizes.

Comparisons among a time series of aerial photos indicate that land use practices adjacent to the stream were increasing the delivery of sediment from in channel sources. A reduction in shrub cover corresponded to significant lateral migration of streambanks. Between 1955 and 1996, an 81 percent reduction in riparian shrub cover occurred in areas with historic photos available. Associated with this vegetation removal was lateral bank migration of up to 94 feet on bend ways. Channel adjustments of this extent result in introduction of many tons of sediment into the system and increase channel width, which decreases the capacity of the channel to transport sediment.

Field surveys during 2004 provided several lines of evidence to evaluate the sources of sediment and the extent to which accumulations of sediment impact beneficial uses (**Appendix C**). These included a survey of eroding banks within assessed reaches, assessment of channel characteristics, riparian vegetation conditions, pebble counts, and percent fine grids measured with a viewing bucket.

Overall, pebble counts suggested relatively low proportions of fine sediment in riffles of the upper Big Hole River, all measures were less than 11 percent. Overall, fine sediment in riffles appears to be at levels that are below target levels. Sampling with the viewing bucket in pool tails indicated a tendency for two reference reaches to have low proportions of surface fines, while impacted reaches were more variable (**Table 5-2**). In light of the uncertainty associated with these data, a supportable conclusion is that the upper two reference reaches appear to have low proportions of surface fines in pool tails and in riffles, while accumulations of fine sediment may be a constraint on fish spawning habitat on lower reaches of the upper segment of the Big Hole River near Wisdom.

Pool frequency (number of bankfull widths between pools) is higher (a lower statistic) at most sites monitored in the upper half of the Big Hole River segment. Pool frequency is lower (higher statistic) in the lower half of the segment. This roughly corresponds with shifts in documented channel geometry due to past and current riparian vegetation conditions. Pools have been filled with course sized sediment originating from streambanks.

Width-to-depth ratios measured on reference and impacted reaches of the Big Hole River provide evidence that channel alterations may reduce sediment transport and sorting efficiency. Impacted reaches were overly wide and often exceeded width-to-depth ratio targets by a considerable extent (**Appendix C**). Also, over-wide stream channels usually have less pool habitat, which is a critical habitat for fish use. Wider channels were found in areas with less shrub cover along the streambanks.

The amount of bank erosion on the upper Big Hole River is quite variable and depends mainly upon how riparian vegetation has been managed along streambanks. A number of monitoring locations have large areas of eroding bank. Much of the bank erosion is also associated with changes instream channel type. Historically, the Big Hole River in the upper valley was mostly a braided stream system with smaller, deeper channels. In many areas where the stream is no longer a braided system it now exerts more energy on unstable banks causing large shifts in the channel where shrubs lacking on streambanks.

Shrubs hold together streambanks because of their extensive root systems. Historical (1940s) and recent aerial photo comparisons indicate significant reduction in riparian greenline shrub cover. Most sites that were monitored had low shrub growth on streambanks. During the initial phases of TMDL development, aerial photo assessments indicate that low shrub cover is common along the entire segment, although some areas do contain well managed riparian areas. An aerial photo review of 1996 to 2005 indicates that bank retreat rates are much higher in single channel areas with low riparian shrub growth when compared to areas having higher greenline shrub density within this segment of the Big Hole River.

5.1.2.1 Summary of Sediment Conditions

Targets and supplemental indicators associated with sediment loading and transport suggested increased sediment inputs from near channel sources combined with impacts to sediment transport because of stream channel change. Although results are less certain about the instream sediment measures, fine sediment measures indicate that coarse and fine sediment is impacting the fishery by depositing in pool and pool tail areas. It appears that fine sediment in riffles is not likely to affect aquatic insect food sources for the fishery. Pool frequency was very low in many of the impacted reaches suggesting sediment from eroding banks contributes to pool filling and over-widened stream channels. Pool filling by coarse and fine sediment likely impacts the fishery use by limiting adult use of pools for security and by impacting fish spawning areas.

5.1.3 Biological Indicators

A macroinvertebrate community assessment along the upper Big Hole River indicates areas with healthy communities and areas of impacted communities. The variability is likely due to the diverse conditions of riparian vegetation and channel conditions within this segment of river.

5.1.4 Big Hole River Existing Condition Conclusions

In conclusion, available data for the Big Hole River support pursuing a temperature TMDL. Irrigation withdrawals, channel widening, and a reduction in riparian shrub cover result in temperatures that negatively affect grayling and modeling indicates that Montana's temperature standards are exceeded during hot summer days. These temperatures are likely presenting sublethal and potentially lethal stress on Arctic grayling. Riparian vegetation alteration is clearly linked to excessive stream instability and associated excessive bank erosion. This leads to very high sediment loading and an associated loss of pools linked to the excess sediment within the stream (i.e. the sediment load is contributing to the "filling" of pool habitat). Pools are essential for secure fish holding cover and specific areas of pools are also essential for fish spawning habitat. The TMDL will address the considerable linkage between the sediment loading and riparian vegetation alteration along with other sources of sediment in the watershed.

Table 5-2: Summary of sediment targets and existing conditions for the Big Hole River.

Parameter	Target or SI	Reach/Site Name	Value	Threshold	Threshold Met?
Pebble Counts (≤6mm in riffles)	Target	BH09	0%	≤ 10	Y
		BH16	8%		Y
		BH18	0%		Y
		BH19	7%		Y
		BH22	9%		Y
		BH26	3%		Y
		BH26R	8%		Y
		BH28	**11%**		~
		BHO8	6%		Y
Pebble Counts (≤2mm in riffles)	Target	BH09	0%	≤ 10	Y
		BH16	1%		Y
		BH18	0%		Y
		BH19	2%		Y
		BH22	8%		Y
		BH26	0%		Y
		BH26R	3%		Y
		BH28	8%		Y
		BHO8	1%		Y

Table 5-2: Summary of sediment targets and existing conditions for the Big Hole River.

Parameter	**Target or SI**	**Reach/Site Name**	**Value**	**Threshold**	**Threshold Met?**
Fines Grid (≤6mm pool tailout)	Target	BH09	4	Median ≤ 22	Y
		BH18	11		Y
		BH28	**50**		**N**
		BH08	6		Y
		BH16	15		Y
		BH19	16		Y
		BH22	**57**		**N**
		BH26	12		Y
		BH26R	**100**		**N**
Width-to-depth ratio	Target	BH09	75th = 25 M = 22	75th percentile ≤ 26 Median ≤ 22	Y
		BH18	75th = **33** M = **27**		**N**
		BH28	75th = 21 M = 22		Y
		BH08	75th = **55** M = **51**		**N**
		BH16	75th = **34** M = **28**		**N**
		BH19	75th = **55** M = **44**		**N**
		BH22	75th = **35** M = **34**		**N**
		BH26	75th = **68** M = **59**		**N**
		BH26R	75th = **58** M = **56**		**N**
Understory shrub cover along the green line	Target	BH09	25th = 70 M =75	25th percentile ≥ 31 Median ≥ 50	Y
		BH18	25th = 36 M =50		Y
		BH28	25th = **19** M =**24**		**N**
		BH08	25th = **21** M =**27**		**N**
		BH16	25th = **35** M =**24**		**N**
		BH19	25th = **18** M =**14**		**N**
		BH22	25th = **8** M = **9**		**N**
		BH26	25th = **0** M = **0**		**N**
		BH26R	25th = **0** M = **2**		**N**

Table 5-2: Summary of sediment targets and existing conditions for the Big Hole River.

Parameter	**Target or SI**	**Reach/Site Name**	**Value**	**Threshold**	**Threshold Met?**
Pool Frequency (# of Bankfull Widths between pools)	Target	BH09	4.7	Median ≤ 4.7	Y
		BH08	3.7		**N**
		BH28	3.0		Y
		BH18	**5.6**		Y
		BH16	**28**		**N**
		BH19	**77**		**N**
		BH22	4.8		**N**
		BH26	**78.0**		**N**
		BH26R	**83**		**N**
Macroinvertebrates	SI	**Four out of seven samples indicate significant shift in aquatic insect community**			
Human Sources Present	SI	**Yes**			
Eroding banks (ft^2)	SI	BH09	**493**	≤ 406	**N**
		BH18	0		Y
		BH28	128		Y
		BH08	**942**		**N**
		BH16	249		Y
		BH19	**593**		**N**
		BH22	0		Y
		BH26	281		Y
		BH26R	**620**		**N**

5.2 Doolittle Creek

Doolittle Creek is a tributary of the Big Hole River which flows from the Pioneer Mountains northwest to the confluence with the Big Hole River (**Appendix K**, **Map 1**). Montana's 2006 Integrated Water Quality Report indicates that a number of beneficial uses are only partially supported in Doolittle Creek. Potential causes of impairment are identified as alteration instream-side or littoral vegetative covers, low flow alterations and sedimentation/siltation. The major watershed sources identified during the TMDL source assessment are associated with transportation and agriculture.

USFS information indicated numerous potential sources of sediment loading to surface waters from land use activities. Nevertheless, an important consideration in interpreting USFS reports is that the provided descriptions of conditions are prior to implementation of BMPs and major restoration activities in the drainage and are probably an unreliable indicator of current conditions. Assessments of aerial imagery by Confluence (2003) suggested that land use activities may be reducing willow cover in the lower portions of the stream and that irrigation withdrawals decreased stream power to the extent that channel definition was lost in these reaches. These initial analyses supported the 303(d) List status of Doolittle Creek.

The USFS provided updated reviews on the conditions and management activities instreams on their lands, including Doolittle Creek during the TMDL process (Wisdom Ranger District, USFS, unpublished reports). This narrative reiterated likely increases in sediment loading in the

Doolittle Creek watershed from a number of activities on USFS lands, including poorly designed roads, timber harvest, and livestock grazing through the 1990s. In response to the observed and modeled increases in sediment loading from land uses on the Forest Service lands, the USFS implemented BMPs and restoration activities to decrease production and delivery of sediment to streams. Grazing management changes included decreasing stocking rates and duration of grazing, improvements to off-channel watering systems, and implementation of grazing and riparian standards within the allotments.

5.2.1 Sediment

The USFS conducted an initial analysis of suspended sediment and discharge data collected from the mid-1980s through the early 1990s that suggested that livestock grazing practices contributed suspended sediment that exceeded the narrative standards for A-1 waters (USFS, unpublished report). This data won’t be provided in detail since it does not represent current conditions very well.

Beneficial use support determinations for sediment, either in suspension or on the streambed, need to consider implementation of BMPs since the 1990s. These have occurred on both public lands in the headwaters and private lands in the valley portions of the watershed. Improvements to roads and changes in grazing management strategies have likely improved conditions in this stream with regard to sediment pollution. The following is a discussion of restoration activities as well as a description of existing conditions.

In response to concerns regarding sediment pollution in the Doolittle Creek watershed, the USFS made several changes in management during the 1990s. This included a considerable investment in improving roads to reduce sediment delivery to streams supporting genetically pure westslope cutthroat trout. Road improvements totaling $270,000 included surfacing roads adjacent to streams, armoring of erosion sites, installing rock lining in ditches, moving culverts, installation of drivable dips to channel water, and armoring cattle crossings to reduce bank and channel disturbance from hoof shear. Monitoring of these improvements by the USFS indicate these improvements have been successful in reducing sediment loading from roads.

Most available information focuses on USFS holdings; data on the privately owned reaches of Doolittle Creek are relatively scarce. USFS narratives provided qualitative descriptions of land use and history of these sites, which landowners along Doolittle Creek confirmed or revised. The two properties at the lower end of Doolittle Creek have been under conservation easement since the 1970s.

The lowest reach on Doolittle Creek (DC04) rated as having moderate to sparse riparian shrub cover as observed from aerial photos, but field observers in 2004 noted that although the riparian corridor was relatively narrow, a buffer of willows occurred along almost the entire reach during aerial photo reconnaissance for site selection. Reaches upstream on the monitoring location appeared to have healthy stands of shrubs.

Sediment TMDL monitoring during 2004 provided an opportunity to evaluate the response of riparian and instream conditions to management changes over the past decade on USFS lands and provided a ground truth observations from aerial imagery (Confluence et al. 2003). TMDL monitoring occurred on reach DC03, just upstream of the reach discussed above. Results from sediment and riparian vegetation monitoring on Doolittle Creek indicate that a sediment TMDL is still necessary. However, an understanding of the spatial extent of these conditions needs to inform interpretation of these results. This reach represented the worst-case scenario for Doolittle Creek but was a relatively short reach (only about 1/5 the total stream length), and field notes suggest that conditions were improving due to a recent change in grazing management strategies. Other considerations include the geology of the basin, which may naturally contribute more sand than other watersheds in this area.

Comparison of existing conditions to sediment targets and supplemental indicators, that indicate the need for a TMDL included an eroding bank survey, vegetation assessment along the banks, and measures of substrate fines. Compared to valley reference streams, Doolittle Creek had an elevated level of bank erosion (**Table 5-3**). Low proportions of shrub cover combined with high levels of bare ground suggesting insufficient bank protection, which increases the risk of bank erosion (**Table 5-3**). Pebble counts and percent fines grid assessments indicated relatively high levels of fine particles. In contrast, several other monitored conditions met targets. Width-to-depth ratios were low suggesting the stream may have the ability to transport fine sediment (**Table 5-3**). Instream habitat data indicated an abundance of deep pools, which implies that aggradation of sediment particles is not limiting this important habitat feature in this area.

Biological monitoring on Doolittle Creek provides a direct measure of aquatic life, a key beneficial use. Aquatic insect community were monitored at two sites during 2003. A site located near the USFS boundary met biological health metric threshold. Not enough insects could be collected at a second site near the confluence with the Big Hole River to determine the health of the macroinvertebrate community. The reason for low aquatic insect numbers at this site is unknown.

5.2.1.1 Summary of Sediment Conditions and Conclusions

Sediment loading and transport are likely affected by human influences and are contributing to increased fine sediment within the stream channel (**Table 5-3**). Targets relating to the functional attributes associated with sediment loading (vegetation measures, eroding banks) suggested potential for increased sediment inputs from near channel sources. Fine sediment has accumulated on the stream bottom and may be limiting aquatic life use. Most sediment sources are likely historic, although human influences are still present, but recently many best management practices have been implemented in this watershed. A sediment TMDL will be provided in this document and will consider the overall condition of the watershed when determining the TMDL allocations and restoration approach.

Table 5-3: Summary of sediment targets and existing conditions for Doolittle Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value	Threshold	Threshold Met?
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	DC03	Target	**33**	≤ 22	**N**
	Pebble Counts Percent fines (≤ 2 mm in riffles)	DC03	Target	**23**	≤ 18	**N**
	Percent Fines Grid (≤6mm pool tailout)	DC03	Target	M = 55 25th = 38	Median ≤ 80 25th percentile ≤27	Y
	Pool frequency	DC03	Target	6	≤ 8	Y
	Width-to-depth ratio	DC03	Target	75th = 12 M = 8	75th percentile ≤ 20 Median ≤ 14	Y
	Understory shrubs along greenline	DC03	Target	**25th = 6** **M =9**	25th percentile ≥ 32 Median ≥ 58	**N**
	Eroding banks (ft^2)	DC03	SI	**1094**	≤ 212	**N**
	Macroinvertebrates	One site met biological threshold. Too few insects collected at another site to determine community health.				
	Human Sources Present	Yes, but mostly historic. Many BMPs are in place.				

5.3 Fox Creek

Fox Creek is a small stream in the southern end of the upper Big Hole River planning area (**Appendix K**, **Map 1**). Its headwaters begin in the Big Hole Divide between Dillon and Jackson on USFS lands. After leaving the forest, it flows through private lands for about ¾ of its length before its confluence with Governor Creek. Prior 303(d) lists included Fox Creek as partially supporting coldwater fisheries and aquatic life due to habitat alterations and siltation. This project assessed sediment/siltation conditions because of the prior listings. The 2006 303(d) List identifies phosphorus as likely limiting aquatic life and fishery use but was not assessed during this basin wide TMDL project because it is a relatively new listing.

5.3.1 Sediment

Initially, aerial photo assessments and USFS narratives were available for review. During TMDL development the USFS provided detailed stream narratives describing land uses and stream conditions. In addition, recent investigations have shed light on the current condition of Fox Creek with respect to sediment and related pollution. In 2003, the DEQ monitoring personnel conducted assessments to meet sufficient credible data requirements for Fox Creek. This included biological assessments, water chemistry, and application of a qualitative, rapid habitat assessment questionnaire. In 2004, field TMDL investigations included a significant reconnaissance effort and subsequent assessment of in-stream sediment conditions, stream channel characteristics, bank erosion assessments, and riparian vegetation quantifications.

Stream narratives provided by the US Forest Service (Wisdom Ranger District, unpublished reports) provide information on land use, fisheries, and stream health for the upper reaches of

Fox Creek. This basin is part of the Fox Creek grazing allotment with livestock occupying sagebrush flats and meadows adjacent to streams. One third of a mile of gravel and native surface roads per square mile occur in the basin, which is quite low. In addition, three road crossings exist in the 12 square mile watershed. No timber harvest has occurred in the Fox Creek watershed.

Fisheries investigations in the Fox Creek drainage include fish sampling on the mainstem and the North Fork of Fox Creek in the late 1980s and late 1990s. Eastern brook trout were the most abundant fish followed by westslope cutthroat trout. Westslope cutthroat trout presumably occur in the South Fork of Fox Creek although no fisheries data were available for this stream.

USFS hydrologists assessed the North Fork in 1999, which is not part of the listed segment but could contribute pollutants. The assessed reached rated as an overly wide C4 channel without an apparent trend in condition. Livestock trampling was the identified cause of changes in physical habitat on the North Fork, including formation of an overly wide and shallow channel. Also, aerial photo review indicates few mature shrubs in upper Fox Creek which may be an indication of poor grazing management. This degradation was apparently a recent development as a 1986 memo considered habitat conditions in the North Fork of Fox Creek to be 92 percent of optimum. Pebble counts conducted on the North Fork of Fox Creek indicate low surface fines.

During the field reconnaissance investigations, observers viewed both private holdings and USFS lands along Fox Creek. Field notes from this effort indicate most areas had intact riparian status and function and no indication of impairment from human activities. Dense growth of willows and sedges dominated many riparian areas and no indications of erosion were apparent. Relatively recent efforts in rehabilitating Fox Creek were apparent by presence of dead willow stakes in banks. Representatives of the landowner confirmed ongoing efforts to improve riparian health and fish habitat on private holdings through grazing management, maintenance of instream flows, and channel restoration.

Width-to-depth ratios were similar to or less than reference reaches (**Table 5-4**). Bank erosion was rare with only one of the two assessed reaches having eroding banks and this was less than the average of valley reference reaches (**Table 5-4**). Proportions of fine sediment from pebble counts were low, although fines measured with the viewing bucket were elevated at one site and the number of pools at this site were lower than expected (**Table 5-4**). The conditions at this site were likely influenced by irrigation structures and past placer mining and may not be due to increased sediment yield. All other measures met sediment targets and supplemental indicator thresholds. Although the aerial photo assessment indicated areas of the headwaters where riparian filtering and bank stability function may be impacted by grazing.

Macroinvertebrate community assessment results indicate the presence of a diverse community, likely due to a complex habitat and sediment regime which promotes a healthy macroinvertebrate population. MFISH reports that Fox Creek has populations of brook trout, mottled sculpin and westslope cutthroat trout. No information is reported for fish species within the North and South Fork of Fox Creek and Sawmill Creek.

Table 5-4: Summary of targets and existing conditions for Fox Creek.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value**	**Threshold**	**Threshold Met?**
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	FC02	Target	6	≤ 22	Y
		FC03		1		Y
	Pebble Count Percent fines (≤ 2 mm in riffles)	FC02	Target	5	≤ 18	Y
		FC03		1		Y
	Percent Fines grid (≤ 6 mm pool tailout)	FC02	Target	M = 62 **25th = 59**	Median ≤ 80 25th percentile ≤ 27	**N**
		FC03		M = 36 25th = 16		Y
	Pool frequency	FC02	Target	**24**	≤ 8	**N**
		FC03		8		Y
	Width-to-depth ratio	FC02	Target	75th = 10 M = 8	75th percentile ≤ 20 Median ≤ 14	Y
		FC03		75th = 16 M = 14		Y
	Understory shrubs along greenline	FC02	Target	25th = 32 M = 45	25th percentile ≥ 32 M ≥ 58	≥
		FC03		25th = 65 M = 69		Y
	Eroding bank (ft^2)	FC02	SI	NA	≤ 212	
		FC03		35		Y
	Macroinvertebrates	A diverse aquatic invertebrate community exists.				
	Human Sources Present	Many reasonable land soil and water conservation practices are in place for transportation system and grazing system, the two main human activities in the watershed. Some improvements in grazing system can be reasonably expected.				

NA = no visually eroding banks

5.3.2 Summary of Sediment Conditions and Conclusions

Almost all of the targets and indicators are met except for percent fines in pool tail out areas and pool frequencies at site FC02. These target exeedence conditions may be due to historic channel alterations yet human caused sediment sources do exist in the watershed and may influence sediment conditions. Almost all reasonable land, soil and water conservation practices that affect sediment production and transport are in place except for a potentially small area in the North Fork and other headwater areas. Therefore, a sediment TMDL for Fox Creek is pursued at this time and should be achievable via implementing riparian grazing management systems which reduce bank erosion and increase streamside shrub growth in specific areas of the watershed.

5.4 Francis Creek

Francis Creek drains from the east side of basin flowing to the northwest before its confluence with Steel Creek. The headwaters originate in USFS lands, but most of its length flows through state or private land. Francis Creek was identified in the 2006 303(d) List with sedimentation/siltation, alteration instreamside vegetation, nitrogen and phosphorus as the probable causes of impairment to fish and aquatic life.

5.4.1 Sediment

Stream narratives prepared by the USFS (Wisdom Ranger District, Beaverhead National Forest, unpublished reports) provide evidence of conditions likely to increase sediment loading to Francis Creek. The forested portions of the Francis Creek drainage have a significant amount of roads with 23 percent rating as low road density, 33 percent with moderate road density, and 23 percent with high density of roads. Road crossings provide a potential route of delivery of sediment to streams with 6 road crossings on perennial streams, and 26 road crossings on intermittent streams. In addition, timber sale monitoring for Francis Creek identified culvert failures as a source of sediment to surface waters in the drainage.

Livestock grazing practices also probably contribute fine sediment to Francis Creek (Wisdom Ranger District, Beaverhead National Forest, unpublished reports). Grazing allotments account for nearly all the USFS holdings in the drainage. Stream surveys in 1993 reported heavy trampling by livestock in Sheep Creek, a tributary of Francis Creek, and along the mainstem of Francis Creek. In sections of Francis Creek and Sheep Creek, the channels have down cut substantially. As a result, the stream can no longer access its floodplain to dissipate energy during high flows, which further increases the erosive power and contributes more sediment. In Sheep Creek, a shift in the median diameter (D_{50}) of streambed particles from 180 mm to 31 mm between stations above and below livestock caused bank damage suggested significant loading of fine sediment from this source.

Aerial photo assessments identified several conditions consistent with prior sediment 303(d) listing in Francis Creek. Notably, riparian shrub cover observable from aerial imagery was sparse for the non-forested portions of the stream. In addition, dewatering was apparently preventing transport of sediment resulting in a lack of channel definition. Field observations during TMDL sediment surveys in 2004 support inclusion of sediment as a probable cause of impairment for Frances Creek. Field notes corroborate a lack of channel definition and describe stagnant pools with accumulations of manure. Note that these descriptions are also suggestive of nutrient sources.

In general, sediment and stream channel surveys results support the need to complete a sediment TMDL for Francis Creek. Width-to-depth ratios were similar to or more than reference reaches (**Table 5-5**). There was no bank erosion in the assessed reach because of it's boggy nature and ill defined stream channel. Although willows or other riparian shrubs were lacking, herbaceous cover was high. The boggy nature of the ill-defined channel resulted in low frequency of pools and the pools present were shallow. Percent fines grids in pool tails sampled with the viewing bucket indicated relatively high levels of fine sediment averaging 82 percent of grid cross-sections. Pebble counts also indicate high levels of fine sediment.

The aquatic insect community metrics scored below their assigned thresholds indicating an impacted biological condition. Francis Creek has the following fish populations: Arctic grayling, brook trout, burbot, longnose sucker, mottled sculpin, mountain whitefish and white sucker (MFISH). Tributaries of Francis Creek are either fishless or there is no available fish information.

5.4.2 Nutrients

Very limited nutrient sampling has occurred on Francis Creek. Based on this information, it appears phosphorus levels are extremely high (**Table 5-5**). TMDL sediment monitoring results provide additional support for completing nutrient TMDLs for Francis Creek. Livestock grazing practices had eliminated riparian shrubs along most of this stream (**Table 5-5**). The reduced riparian vegetative cover relates to nutrient pollution because riparian shrubs and grasses filter runoff and uptake nutrients from groundwater derived from agricultural sources of nutrient.

5.4.3 Summary of Sediment and Nutrient Conditions and Conclusions

Sediment and nutrient TMDLs will be completed for Francis Creek. Sediment is accumulating in riffles and pools which likely affect fish spawning success and aquatic insect communities. Concentrations of nutrients in grab samples exceeded numeric targets and nutrient tolerant organisms dominated diatom and macroinvertebrate associations. Several observers noted accumulations of manure adjacent to the stream channel as a probable source of nutrient loading. Moreover, the functional attributes of nutrient uptake and conversion by riparian shrubs is impacted due to their absence. Although the information is limited, it identifies sources and nutrient impacts. Therefore, development of nutrient TMDLs for Francis Creek is warranted.

Table 5-5: Summary of targets and existing conditions for Francis Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value	Threshold	Threshold Met?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	FR01	Target	**18**	≤ 13	**N**
	Pebble Count Percent fines (≤ 2 mm in riffles)	FR01	Target	**16**	≤ 13	**N**
	Percent Fines grid (≤ 6 mm pool tailout)	FR01	Target	**M = 84** **25th = 76**	Median ≤ 51 25th percentile ≤ 42	**N**
	Pool frequency	FR01	Target	**12**	≤ 6	**N**
	Width-to-depth ratio	FR01	Target	75th = 12 **M = 11**	75th percentile ≤ 13 Median ≤ 10	~
	Understory shrubs along greenline (%)	FR01	Target	**25th = 0** **M = 0**	25th percentile ≥ 36 M ≥ 41	**N**
	Eroding bank (ft^2)	FR01	SI	NA	≤ 113	Y
	Macroinvertebrates	The aquatic insect community metrics do not meet threshold.				
	Human Sources Present	Grazing, hay, and transportation sources present.				
Nutrients	Total Nitrogen	7/24/2003 FR01	Target	167	< 320 ug/L	Y
		7/24/2003 FR03		157		Y
	Total Phosphorous	7/24/2003 FR01	Target	**287**	<49 ug/L	**N**
		7/24/2003 FR03		**223**		**N**
	Chlorophyll *a*	7/24/2003 FR03	Target	27.9*	<150 mg/m^2	Y
	Understory shrubs along greenline (%)	FR01	SI	**25th = 0** **M = 0**	25th percentile ≥ 36 M ≥ 41	**N**
	Shrubs along transect (%)	FR01	SI	**25th = 0** **M = 0**	25th percentile ≥ 64 Median ≥ 47	**N**
	Bare ground along transect (%)	FR01	SI	M = 0	Median ~ 0	Y
	Macroinvertebrates	The aquatic insect community metrics do not meet threshold.				
	Human Sources	Grazing and hay production sources are present.				

***estimated due to laboratory quality assurance**
NA = no visually eroding banks

5.5 Governor Creek

Governor Creek, a tributary of the Big Hole River, lies in the southern end of the upper Big Hole River planning area (**Appendix K**, **Map 1**). Its headwaters originate in the Beaverhead Mountains and flow northward to its confluence with the Big Hole River near Jackson, Montana. About 2 miles of the length of Governor Creek flow through mountainous topography on USFS holdings. The remaining 20 miles occupy a rangeland environment on private land. Probable causes of impairment in Governor Creek have included sediment on past lists and now include related pollution such as dewatering, alteration instream side vegetation, and physical substrate habitat alterations on the 2006 list. In addition, Governor Creek is listed for copper on the 2006 303(d) List.

5.5.1 Sediment

Descriptive narratives written by the USFS (Wisdom Ranger District, Beaverhead National Forest, unpublished documents) provide information on land use and stream status on US Forest Service holdings in the headwaters of Governor Creek. Roads may be a factor in the basin with an average road density of 1.2 miles of road/mile^2 area. Road density varies across the drainage with 20 percent considered low road density, 54 percent being moderate, and 26 percent being high road density.

Livestock grazing is another activity on public lands in the headwaters. Habitat and hydrologic assessments in the mid 1980s and late 1990s indicated livestock grazing on USFS holdings resulted in alterations to the physical integrity of this stream. Near the Forest boundary, this resulted in loss of undercut banks and formation of an overly wide channel. Surveyed cross sections indicate relatively narrow channel in monitoring reaches on Governor Creek.

Pebble counts conducted at two locations on USFS holdings suggest that land use activities were resulting in accumulations of harmful levels of fine sediment on the streambed. The downstream sampling site, had high levels of particles less than 1 mm in diameter. Particles in this size class are detrimental to coldwater fisheries and associated aquatic life by clogging interstices in the streambed. This limits habitat available to benthos and decreases survival to emergence for salmonid fry by smothering eggs (Kondolf 2000).

The aerial assessment conducted for TMDL reconnaissance efforts showed evidence of riparian clearing and associated bank line erosion in numerous reaches. Nevertheless, two reaches identified as having potential as reference reaches based on observed channel and riparian conditions were eliminated from this consideration following field reconnaissance. Although the riparian corridor was relatively intact, reconnaissance investigations in these potential reference reaches found substantial channel instability.

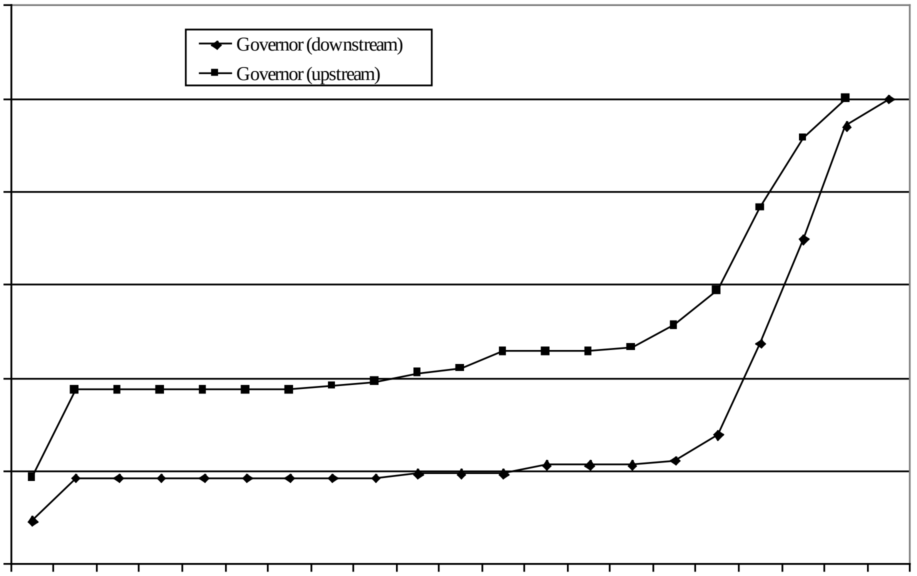

Figure 5-4: Cumulative percent frequency of particles sampled in pebble counts on the Governor Creek in 1999 collected by USFS.

Field observations during TMDL monitoring surveys provide insight into site conditions on Governor Creek. Assessed reaches were typically overly wide with evidence of trampling and vegetation removal. Field observers also noted accumulations of fines on the streambed due to the reduced sediment transport abilities of the overly wide channel. Conditions observed were usually attributed to lack of healthy riparian vegetation.

Data collection supporting the sediment TMDL also indicate that sediment conditions are effected by lack of riparian vegetation in Governor Creek (**Table 5-6**). Compared to the valley reference reaches, reaches on Governor Creek were overly wide and shallow and entrenchment ratios suggested downcutting, or channel degradation. In addition, reduced shrub cover and high proportions of bare ground occurred on all three assessed reaches on Governor Creek.

The bank erosion survey results indicated accelerated bank erosion in assessed reaches of Governor Creek compared to reference reaches (**Table 5-6**). One reach in particular had over 800 square feet of eroding bank in the highly erodible category. In comparison, reference reaches typically had less than 212 square feet of eroding bank in this category.
The area of eroding banks exceeded targets substantially on two of the three assessed reaches. Moreover, measures of riparian cover classes indicated reaches had reduced shrub cover and elevated levels of bare ground along the banks; these conditions reduce filtering capacity and decrease bank protection. None of the three assessed reaches met the target for width-to-depth depth ratio indicating an overly wide channel which likely reduces sediment transport capabilities.

Results of pebble counts indicated low proportions of fines; however, percent fines measured with the viewing bucket in pool tail out areas were high compared to reference reaches. Measures of substrate composition were contradictory with low percent fines measured in pebble counts and elevated percent fines measured with the fines grid on 2 of the 3 reaches (**Table 5-6**).

No aquatic insect community assessments are available from Governor Creek. Governor Creek has known populations of brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, mountain whitefish, rainbow trout, westslope cutthroat trout and white suckers (MFISH). Although it is thought that grayling may occur rarely in Governor Creek, they have not been found in this part of the watershed by the FWP grayling monitoring efforts in over a decade (Lamoth and Petersen 2007). The culverts at the Skinner Meadows Road crossing have the potential to become a seasonal velocity barrier to grayling migration. The energy focused by these structures coupled with changes to the riparian vegetation downstream is causing alterations to the local stream channel morphology and habitat quality (Lamoth and Petersen 2007).

5.5.2 Copper

Governor Creek is listed for likely impairment on the 2006 303(d) List due to elevated copper concentrations in several grab samples collected in the early 1980s. A significant amount of uncertainty remained on the appropriateness of this listing for several reasons. First, detection limits from older analyses were often too high for reliable application of the numeric standards and data reliability at levels near the standards is questionable. This uncertainty results in an increased probability of false violations when using data from this vintage. In addition, data currency, or the extent to which these data represented current conditions, was unknown. Finally, a lack of land use activities likely to increase loading of metals suggested these results were anomalous or unrelated to actual contamination of surface waters by copper (**Appendix K**, **Map 3**).

Because of the uncertainty surrounding the potential for copper to impair beneficial use support in Governor Creek, DEQ undertook additional sampling of water and sediment chemistry during 2004. Copper was undetected in water samples. Copper associated with benthic sediment was present in the concentration of 14.2 mg/kg. This falls below the lowest evaluated effect level for benthic invertebrates (NOAA SQIRTs) indicating low risk to benthic organisms in contact with these substrates. Together, these results indicate copper likely does not present a constraint to beneficial uses in Governor Creek. Because of the uncertainty of data from the 1980s and results of the 2004 monitoring, a copper TMDL will not be completed at this time.

5.5.3 Summary of Sediment and Copper Conditions and Conclusions

Comparison of conditions in and along Governor Creek to sediment targets and supplemental indicators provides support for pursuing sediment TMDL development (**Table 5-6**). Sediment accumulation in pools and poor instream habitat conditions likely affect aquatic insect and fish communities. Channel geometry is over wide and likely impacts sediment transport.

Copper was below detection limits in recent water sampling and less than concentrations with known effects for aquatic organisms in benthic sediments. Human caused copper sources are not present in the watershed. Therefore, a copper TMDL will not be pursued.

Table 5-6: Summary of sediment and metals targets and existing conditions for Governor Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Threshold	Threshold Met?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	GC04	Target	9	≤ 22	Y
		GC06		2		Y
		GC11		0		Y
	Pebble Count Percent fines (≤ 2 mm in riffles)	GC04	Target	8	≤ 18	Y
		GC06		2		Y
		GC11		0		Y
	Percent Fines grid (≤ 6 mm pool tailout)	GC04	Target	**M = 95** **25th = 92**	Median ≤ 80 25th percentile ≤ 27	**N**
		GC06		M = 80 **25th = 76**		**N**
		GC11		M = 5 25th = 4		Y
	Pool frequency	GC04	Target	**10**	≤ 8	**N**
		GC06		**10**		**N**
		GC11		7		Y
	Width-to-depth ratio	GC04	Target	**75th = 35** **M = 18**	75th percentile ≤ 20 Median ≤ 14	**N**
		GC06		**75th = 33** M = 15		**N**
		GC11		75th = 21 **M = 20**		**N**
	Understory shrubs along greenline	GC04	Target	**25th = 0** **M = 0**	25th percentile ≥ 32 M ≥ 58	**N**
		GC06		25th = 30 **M = 33**		**N**
		GC11		**25th = 23** **M = 26**		**N**
	Eroding bank (ft^2)	GC04	SI	149	≤ 212	Y
		GC06		**350**		**N**
		GC11		**840**		**N**
	Macroinvertebrates	None Available				
	Human Sources Present	Grazing and transportation systems present.				
Copper	Copper in benthic sediments	8/24/2004 GOV01	target	14.2	< 35 mg/kg	Y
	Copper in water column	8/24/2004 GOV01	target	ND	5.2 ug/L @ 50 mg/L hardness	Y
	No known human caused copper sources.					

*ND = Non detect

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5.6 Johnson Creek

Johnson Creek lies in the northwest portion of the upper Big Hole River Valley and is a tributary of the North Fork Big Hole River. Its headwaters originate in the Anaconda Pintler Range and it flows southward approximately eleven miles to its confluence with North Fork Big Hole River. Probable causes of impairment on the 2006 303(d) List for Johnson Creek include sedimentation/siltation and several associated types of pollution including flow alterations and alterations instream side vegetation. Prior 303(d) lists have included metals listings but the TMDL project provided updated information that removed these causes of impairment from the most recent list. The 2006 list also added total kjehldahl nitrogen (TKN) to a list of potential causes of impairment in this stream. The TKN listing occurred after the TMDL project was initiated and will not be addressed at this time.

5.6.1 Sediment

Information addressing sediment as a constraint on beneficial use support comes from various sources including watershed narratives developed by the USFS, aerial photo analysis conducted during TMDL development, and TMDL field monitoring results. Narrative stream descriptions prepared by the Beaverhead National Forest provide a description of land uses and management activities in the basin. Roads and multiple use trails are a significant feature in the basin with 22 percent rating as low road density, 32 percent as moderate density, and 15 percent as high density of roads. The remaining 30 percent of the basin has no roads. Thirty-one road crossings occur in the basin on the USFS lands with all but nine crossing intermittent streams. Timber harvest is a historic activity in the watershed. Livestock grazing is another land use with 75 percent of the basin within a grazing allotment. Natural disturbance is also a feature of this sub-watershed with 27 percent of the area affected by wildfire in 2000.

Historic mining, in the form of placer mining, is another human influence with potential effect on water quality in Johnson Creek. This relates primarily to sediment pollution to the extent that channel alterations alter delivery or transport of sediment. Observers during 2004 field surveys noted evidence of placer mining and piles of waste rock on the floodplain in both of the assessed montane reaches of Johnson Creek.

The USFS conducted hydrologic evaluations in the 1980s, 1990s, and 2000s. These investigations describe Rosgen B3 channels comprising a significant portion of Johnson Creek with instream habitat provided by scours and large woody debris. Evaluations in the 1980s indicated areas where livestock management practices were incompatible with riparian health and function resulting in an overly wide channel and relatively high embeddedness. These conditions improved in subsequent decades with a narrowing of the channel and reduction of embeddedness due to implementation of grazing BMPs.

Aerial photo assessments provided several indications that human activities were likely increasing delivery of fine sediment to Johnson Creek. In the valley reaches, reductions in riparian shrub cover and extensive storage of sediment on point bars was evident in aerial images. The lowest reach on Johnson Creek showed evidence of multiple irrigation diversions.

Results of sediment TMDL monitoring in the montane portions of Johnson Creek reflected mainly natural disturbance from the Mussigbrod fire that burned much of the basin in 2000. This event drastically altered vegetation and probably contributed considerable quantities of fine sediment to the stream. For example, woody vegetation, in the form of trees or shrubs, was nearly absent from assessed reaches on Johnson Creek. In contrast to every other reach assessed in the upper Big Hole River planning area, herbaceous ground cover was the dominant vegetative feature comprising nearly 100 percent of both line transects and the green line. The proliferation of herbaceous ground cover probably reflected an early stage of succession following a catastrophic fire that burned the riparian vegetation in these areas.

Measures of substrate composition also indicated a high level of sediment with recent disturbance being a probable source of sediment loading. Field observations and pebble counts (**Table 5-7**) described elevated levels of fine sediment on the streambed. Although roads and timber harvest may have a role in long term sediment loading to Johnson Creek, inputs associated with wildfire probably dwarf these contributions in the short term.

Results from sediment TMDL monitoring in the valley portions of Johnson Creek (JC07) indicate a relatively healthy riparian corridor and stream channel, although fine sediment accumulation may impact the fishery. Width-to-depth ratios on the valley portion of Johnson Creek are equivalent to valley tributary reference reaches (**Table 5-7**). The amount of understory shrubs along the green line was similar to reference reaches (**Table 5-7**). The bank erosion survey assessments indicate existing vegetative conditions are sufficient to maintain bank stability in this reach of Johnson Creek (**Table 5-7**). Bank erosion conditions in the lower reach of Johnson Creek were similar to reference reaches. This suggests in-channel contributions of sediment in this area are not elevated above natural. In-channel measures of habitat quality were inconsistent with impacts from siltation. Pool frequency was almost equivalent compared to reference reaches (**Table 5-7**), also pool depths were similar to reference. Substrate fines in riffles were low compared to reference but the distribution of sediment in pool tailouts is elevated compared to valley reference sites.

Aquatic insects were assessed at two sites, one on the forest service and one site about a mile above the confluence with the North Fork Big Hole River. Both sites showed borderline aquatic insect community health. Johnson Creek has populations of brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, mountain whitefish, sculpin, westslope cutthroat trout, white sucker and westslope cutthroat and yellowstone cutthroat hybrids (MFISH).

5.6.2 Summary of Sediment Conditions and Conclusions

Comparison of available data to targets and supplemental indicators for Johnson Creek provides mixed results. Sediment conditions for assessed reaches of Johnson Creek varied (**Table 5-7**). With regard to width-to-depth ratios, montane reaches occupied B channels, which are resilient to lateral adjustments making this parameter less applicable. However, the valley reach (JC07) approximated the target for valley tributaries. Comparisons of area of eroding banks with the supplemental indicator suggests in-channel contributions of sediment were within natural levels. Pool frequency was comparable or better than reference at all sites. Measures of substrate fines were variable with mixed results among reaches although the fire has probably influenced instream sediment conditions within the upper portion of the watershed.

Targets addressing vegetative characteristics on montane portions mainly reflected the recent wildfire that had altered vegetative cover. Shrubs and trees were largely absent leaving the riparian zone dominated with ground cover. Bare ground was another significant component of riparian cover suggesting impacted filtering of sediment and nutrients from upland sources. Nevertheless, bare ground was unattributable to human activities with no evidence of livestock use.

A detailed sediment source assessment will be pursued in Section 8 because sediment indicators imply elevated sediment conditions within the stream. Recent fire confounds the interpretation of instream monitoring results and a more detailed source assessment is needed to determine how long term sediment and water yield conditions could be affected by transportation and grazing systems within the watershed.

Table 5-7: Summary of sediment targets and existing conditions for Johnson Creek.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value**	**Threshold**	**Threshold Met?**
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	JC02	Target	21	≤ 13	**N**
		JC02R		11		Y
		JC03		44		**N**
		JC07		5	≤ 22	Y
	Pebble Count Percent fines (≤ 2 mm in riffles)	JC02	Target	13	≤ 13	Y
		JC02R		7		Y
		JC03		34		**N**
		JC07		5	≤ 18	Y
	Percent Fines grid (≤ 6 mm pool tailout)	JC02	Target	M = 64 25th = 40	Median ≤ 10 25th percentile ≤ 5	**N**
		JC02R		M = 3 25th = 2		Y
		JC03		M = 99 25th = 96		**N**
		JC07		M = 51 25th = 46	Median ≤ 80 25th percentile ≤ 27	**N**
	Pool frequency	JC02	Target	5	NA	NA
		JC02R		6		NA
		JC03		5		NA
		JC07		9	≤ 8	~
	Width-to-depth ratio	JC02	Target	75th = 18 M = 17	75th percentile ≤ 15 Median ≤ 13	**N**
		JC02R		75th = 14 M = 12		Y
		JC03		75th = 23 M = 12		**N**
		JC07		75th = 17 M = 15	75th percentile ≤ 20 Median ≤ 14	~
	Understory shrubs along greenline	JC02	Target	25th = 0 M = 0	NA	NA
		JC02R		25th = 4 M = 5		NA
		JC03		25th = 0 M = 0		NA
		JC07		25th = 51 M = 59	25th percentile ≥ 32 M ≥ 58	Y
	Eroding bank (ft2)	JC02	SI	NA	≤ 113	NA
		JC02R		NA		NA
		JC03		70		Y
		JC07		122	≤ 212	Y
	Macroinvertebrates	Two sites sampled 2004 indicate borderline aquatic community health when compared to metric thresholds.				
	Human Sources Present	Transportation and grazing sources are present. Recent fire also influences sediment yields.				

NA = no visually eroding banks

5.7 Joseph Creek

Joseph Creek is a small tributary of Trail Creek lying entirely in montane areas of the upper Big Hole River planning area on the west side of the basin. Probable causes of impairment for Joseph Creek include sedimentation/siltation, copper and lead in addition to a habitat related listing linked to sediment conditions.

5.7.1 Sediment

Information relating to sediment pollution in Joseph Creek comes from stream narratives developed by the USFS, an MDT road sanding study, aerial photo assessments, and also clean water act and TMDL sediment and habitat related monitoring. According to the USFS narratives, Highway 43 is a major influence on Joseph Creek and parallels the stream for much of its length. This includes three bridge crossings. Although this is a paved road, road traction sanding is a potential source of sediment input to this stream. Results from a MDT road sanding inventory indicate that very small portions of the creek receive road sand inputs because most of the stream length has adequately wide, low gradient, well vegetated, buffer where road sand is trapped. The reported traction sand load is likely not significant at a watershed scale although localized sections of stream do receive road sand.

Evidence from USFS narratives indicates livestock grazing was formerly a constraint on water quality; however, implementation of BMPs in the 1990s was successful in recovering channel morphology and riparian vegetation. Moreover, this resulted in a decrease in embeddedness from 40 percent to 10 percent. Evaluations of aerial photos indicated encroachment of Highway 43 resulted in the channelization of a considerable portion of Joseph Creek. Limited timber harvest was also observable in the headwaters from aerial images.

When considered all together, the TMDL sediment and streamside habitat monitoring results do not indicate that sediment standards are exceeded in Joseph Creek. Parameters specific to channel morphology and bed form indicate a narrow, deep channel with high frequency of pools that benefit fish (**Table 5-8**). Vegetation measures indicated intact function of the riparian zone with low proportions of bare ground and dense stands of willows. These functional components serve to filter sediment contributed from upland sources and protect streambanks from erosion. Furthermore, both measures of instream sediments indicated low proportions of fine sediment on streambed surfaces (**Table 5-8**). In-channel sources of sediment were lacking with eroding banks being rare on Joseph Creek.

Aquatic insect communities were assessed at two sites. Monitoring at one site did not produce the number of insects needed to assess the community, the reasoning for this is unknown. The other site failed to meet supplemental indictator thresholds but it appears that sediment and stream habitat conditions are not likely the cause. Joseph Creek has populations of brook trout, burbot and mottled sculpin (MFISH). All of the tributaries of Joseph Creek contain populations of brook trout and sometimes mottled sculpin.

5.7.2 Metals

Evidence for metals contamination in Joseph Creek comes from data collection efforts in 2001. Further monitoring was completed during 2004. Data from both years suggest metals were not a problem at the upper sampling site; however, indications of metals were pronounced at a site lower in the watershed during 2001. Both copper and lead in grab samples exceeded acute aquatic life standards in 2001 at the lower sampling site (**Table 5-8**). In 2004 copper levels found in sediment samples in the watershed were below the thresholds that are likely to cause biological response. Biological evidence for metals contamination was not pronounced.

A confounding factor in TMDL planning for metals in Joseph Creek is an apparent lack of mining activity in the watershed. Examination of four databases housing mine location data (DEQ’s abandoned hard rock database, Department of State Lands abandoned mines database, the Montana Bureau of Mines and Geology abandoned and inactive mines database, and the US Geological Surveys abandoned mine database) uncovered no mining activity in the Joseph Creek watershed (**Appendix K**, **Map 3)**. Field reconnaissance did not find evidence of past or present mining activity. When inquired, the Montana Department of Transportation indicated no toxic spills along the lost trail pass transportation corridor. The absence of mining activity suggests that high levels of metals in Joseph Creek are a natural phenomenon in a mineralized basin and therefore does not require a TMDL.

Table 5-8: Summary of targets and existing conditions for sediment and metals in Joseph Creek

Pollutant	Parameter	Reach or Site Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	JO02	Target	15	≤ 13	~
	Pebble Count Percent fines (≤ 2 mm in riffles)	JO02	Target	8	≤ 13	Y
	Percent Fines grid (≤ 6 mm pool tailout)	JO02	Target	M = 48 25th = 31	Median ≤ 50 25th percentile ≤ 42	Y
	Pool frequency	JO02	Target	4	≤ 6	Y
	Width-to-depth ratio	JO02	Target	75th = 12 M = 12	75th percentile ≤ 13 Median ≤ 10	Y
	Understory shrubs along greenline	JO02	Target	25th = 58 M = 59	25th percentile ≥ 36 M ≥ 41	Y
	Eroding bank (ft^2)	JO02	SI	NA	≤ 113	Y
	Human Sources Present	Transportation along with limited silviculture and grazing systems are present in the watershed.				

Table 5-8: Summary of targets and existing conditions for sediment and metals in Joseph Creek

Pollutant	Parameter	Reach or Site Name	Target or SI	Value/ Score	Target Column	Met target?
Copper	Benthic sediments	J-2 8/24/2004	target	17.1	<35 mg/kg	Y
	Water column	J-2 7/2/2001	target	**14**	Acute = 4 and Chronic = 3 ug/L @ 25 mg/L hardness	**N**
	Water column	J-2 5/24/2004	target	ND	Acute = 4 and Chronic = 3 ug/L @ 25 mg/L hardness	Y
	Water column	J-2 8/25/2004	target	ND	Acute = 5 and Chronic = 4 ug/L @ 32 mg/L hardness	Y
Lead	Benthic sediments	8/24/2004	target	9	< 35 mg/kg	Y
	Water column	J-2 7/2/01	target	**29**	Acute = 14 and Chronic = 0.5 ug/L @ 25 mg/L hardness	**N**
	Water column	J-2 5/24/04	target	ND	Acute = 19 and Chronic = 0.75ug/L @ 25 mg/L hardness	Y
	Water column	J-2 8/25/2004	target	ND	Acute = 19 and Chronic = 0.75ug/L @ 25 mg/L hardness	N
Metals Sources	No known human caused sources.					
Biology	Macroinvertebrates	Two macroinvertebrate community assessments indicate potentially impacted conditions but could be the result of other influencing factors.				

NA = no visually eroding banks

5.7.3 Summary of Sediment Conditions and Conclusions

Review of existing data confirms metals contamination; however, there are no known human caused sources. Therefore, lead and copper TMDLs will not be pursed at this time. The possibility exists that elevated metals are a natural feature in this mineralized basin. If this is the case, a TMDL is not required as the contamination is natural and not subject to clean up under the Clean Water Act.

Potential human sources of sediment loading to Joseph Creek include limited contributions from road traction sanding, grazing, and upland sources associated with timber harvest and unpaved roads. Even though limited human caused sources are present, it appears that reasonable management of the watershed results in stream conditions that are not likely to affect aquatic life. Because of this, a TMDL will not be pursued at this time.

5.8 North Fork Big Hole River

The North Fork Big Hole River begins at the confluence of Trail Creek and Ruby Creek on the west side of the upper Big Hole River basin. The stream flows to the northeast for about 15 miles before joining the Big Hole River. The 2006 303(d) List indicates probable causes of impairment for the North Fork Big Hole River as low flow alteration, alteration instream-side vegetation, and sedimentation/siltation. Credible evidence also indicates this stream may have thermal alterations as well, although this is not currently a listed probable cause of impairment.

5.8.1 Sediment

Available information includes the aerial photo assessment initial TMDL planning (Confluence 2003), temperature monitoring by Montana Fish, Wildlife & Parks, TMDL field surveys conducted in 2004, and biological assessments conducted by DEQ personnel.

Aerial photo analyses identified two primary concerns for the North Fork Big Hole River, riparian degradation and reduced stream flows (Confluence et al. 2003). Reduced shrub cover was often associated with channel migration and meander cutoffs suggesting inputs of fine sediment from channel adjustments.

Sediment TMDL field measures further supported that a sediment TMDL is needed for the North Fork Big Hole River. Compared to internal reference reaches, impacted reaches on this stream were significantly wider and shallower and showed a greater degree of entrenchment suggesting greater horizontal and vertical channel adjustments. These adjustments can produce sediment and also locally reduce the streams ability to transport sediment. Vegetative differences varied markedly between reference and impacted reaches with reference reaches having significantly greater cover of riparian shrubs and lower proportions of bare ground. Channel adjustments likely have reduced pool abundance with lower reaches having very few pools.

The amount of surface fines varied between habitats that were measured (**Table 5-9**). Pebble counts indicated low proportions of fines at all sites except at a transitional area just as the Ruby and Trail Creeks exit the mountains and form the North Fork Big Hole River. In contrast, fines measured within pool tailouts were lower at the upper reach and increased considerably downstream. In areas that riparian vegetation has been impacted, sediment levels appear to be high where fish are likely to spawn.

Bank erosion surveys provide a strong case that streamside management practices are increasing sediment loading to the North Fork Big Hole River (**Table 5-9**). Within reference reaches on the North Fork Big Hole River, eroding banks were a minor feature and comprised around 200 square feet of eroding bank. In contrast, the area of eroding banks on impacted reaches ranged between 1500 and 1800 square feet with most rating within the “high” category of erodibility. These results indicate bank erosion is a significant source of sediment within this watershed. The amount of bank erosion at all sites measured on the North Fork of the Big Hole River was directly and inversely related to the amount of riparian shrub cover. An aerial photo review indicates that the four sites measured represent the overall stream well. In general, shrub growth along the stream corridor is reduced in vigor in a downstream direction.

Pebble count and grid toss results suggest deposition of sediment likely hurts fish and aquatic life. Width-to-depth ratios on impacted reaches were elevated considerably compared to reference. Moreover, pool frequency, as expressed by average bankfull width per pool, was substantially depressed at the lowest reach (**Table 5-9**). This suggests that lateral adjustments relating to eroding banks had reduced the sediment transport capacity to the point that the stream could no longer maintain quality pool habitat in the lower reach. This represents a form of sediment pollution and is a constraint on the support of coldwater fisheries, which rely on pool habitat.

Aquatic insects were assessed at two sites (see **Table 5-9**). The aquatic insect community health was below regional reference metric thresholds at both sites. The North Fork of the Big Hole River has several species of fish, including: arctic grayling, brook trout, burbot, longnose Dace, longnose sucker, mottled sculpin, mountain whitefish and rainbow trout.

Table 5-9: Summary of sediment targets and existing conditions in North Fork Big Hole River.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value/ Score**	**Target Column**	**Met target?**
Sediment	Pebble Count Percent fines (≤6mm in riffles)	NF02	Target	**16**	≤ 12	**N**
		NF06		7		Y
		NF07		8		Y
		NF11		9		Y
	Pebble Count Percent fines (≤2mm in riffles)	NF02	Target	**14**	≤ 9	**N**
		NF06		5		Y
		NF07		5		Y
		NF11		7		Y
	Percent Fines grid (≤ 6 mm pool tailout)	NF02	Target	M = 11 25th = 11	Median ≤ 25 25th percentile ≤ 11	Y
		NF06		**M = 38** **25th = 38**		**N**
		NF07		**M = 39** **25th = 39**		**N**
		NF11		**M = 100** **25th = 100**		**N**
	Pool frequency	NF02	Target	5	≤ 8	Y
		NF06		8		Y
		NF07		8		Y
		NF11		**17**		**N**
	Width-to-depth ratio	NF02	Target	75th = 25 M = 22	75th percentile ≤ 28 Median ≤ 24	Y
		NF06		75th = 29 M = 26		~
		NF07		**75th = 44** **M = 28**		**N**
		NF11		**75th = 51** **M = 42**		**N**
	Understory shrubs along greenline	NF02	Target	25th = 45 M = 51	25th percentile ≥ 36 M ≥ 43	Y
		NF06		**25th = 32** **M = 36**		**N**
		NF07		**25th = 7** **M = 12**		**N**
		NF11		**25th = 0** **M = 1**		**N**
	Eroding bank (ft^2)	NF02	SI	176	≤ 212	Y
		NF06		**224**		**N**
		NF07		**1497**		**N**
		NF11		**1827**		**N**
	Macroinvertebrates	Community metrics do not meet thresholds based upon regional reference conditions.				
	Human Sources Present	Grazing, hay production, transportation and silvicuture management systems are present. Recent fire may also influence sediment yields.				

5.8.2 Summary of Sediment Conditions and Conclusions

Comparison of conditions in and along the North Fork of the Big Hole River to sediment targets and supplemental indicators provides support for pursuing sediment TMDL development (**Table 5-9**). Sediment accumulation on the stream bed and poor instream habitat conditions likely affect aquatic insect and fish communities, especially in the lower reaches of this river. Channel geometry is over-wide and likely impacts sediment transport and in-channel sorting of sediment sizes. Human caused sediment sources are present. A sediment TMDL for the North Fork of the Big Hole River is provided in this document.

5.9 McVey Creek

McVey Creek flows to the northwest joining the Big Hole River towards the northern end of the planning area (**Appendix K**, **Map 1**). Much of this stream flows upon public lands. Its headwaters begin in Forest Service holdings and a sizeable amount of the valley portions of the stream flows through state lands. McVey Creek is listed for sedimentation/siltation and alteration instream side vegetation. Recently, McVey Creek was also listed for nitrogen and phosphorus. This TMDL document will not address the nutrient listings because these listings are very recent arrivals to Montana’s 303(d) List. Sediment related listings will be addressed in this document.

5.9.1 Sediment

Several land uses in the upper, forested portions of the watershed present potential risks for increased sediment delivery to streams. Roads are concentrated north of McVey Creek but are also present south of the creek. Road crossings on USFS land include one perennial stream crossing (native material) and five intermittent stream crossings (3 native material and 2 gravel). Current USFS land uses include recreational activities associated with an multiple-use trail system and cattle grazing. Grazing allotments exist for 7,228 USFS acres, which comprises most of the USFS land.

Notes taken during reconnaissance for the 2004 monitoring effort indicate a significant portion of the reaches on the Big Hole Valley reach (not USFS) of McVey Creek is an overgrazed E channel (Rosgen 1996) with a graminoid dominated riparian zone. Willows were absent. Eroding banks were a significant feature contributing fine sediment. The overall impression from field notes is of an overgrazed stream that would probably respond favorably to temporary rest from livestock followed by implementation of grazing BMPs.

Sediment and stream channel assessments during 2004 indicate that a sediment TMDL is necessary. This is mostly due to reductions in the cover and function of riparian vegetation. No shrubs were encountered on either the line transects or the green line survey. In addition, the assessed reach on McVey Creek had significantly greater proportions of bare ground than reference reaches.

On the other hand, despite the reduced riparian vegetation, the channel had maintained much of its integrity. Width-to-depth ratios were similar to reference and the stream rated as non-entrenched (**Table 5-10**). Despite the low width-to-depth ratio that enhances the ability of the stream to transport its sediment, sedimentation was apparent in McVey Creek by exceptionally high percent fines measured with both pebble counts and viewing bucket, and the near absence of pools (**Table 5-10**). Bank erosion was also a significant feature on McVey Creek. McVey Creek exceeded levels of bank erosion encountered on reference reaches and included nearly 900 square feet of bank within the "very high" category of erodibility. These results suggest in-channel sources of sediment are significant.

Aquatic insects were assessed at two sites. Aquatic insect community health was far below regional reference metric thresholds. Only a few aquatic insects were found at one of the sites. Brook trout and westslope cutthroat trout (MFISH) have been found in McVey Creek.

Table 5-10: Summary of sediment targets and existing conditions in McVey Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Count Percent fines (≤6mm in riffles)	MV03	Target	**67**	≤ 22	**N**
	Pebble Count Percent fines (≤2mm in riffles)	MV03	Target	**60**	≤ 18	**N**
	Percent Fines grid (≤ 6 mm pool tailout)	MV03	Target	**M = 100** **25th = 100**	Median ≤ 80 25th percentile ≤ 27	**N**
	Pool frequency	MV03	Target	**71**	≤ 8	**N**
	Width-to-depth ratio	MV03	Target	75th = 10 M = 10	75th percentile ≤ 20 Median ≤ 14	Y
	Understory shrubs along greenline	MV03	Target	**25th = 0** **M = 0**	25th percentile ≥ 32 M ≥ 58	**N**
	Eroding bank (ft^2)	MV03	SI	**902**	≤ 212	**N**
	Macroinvertebrates	**Community metrics do not meet thresholds based upon regional reference conditions.**				
	Human Sources Present	Grazing and transportation systems are present.				

5.9.2 Summary of Sediment Conditions and Conclusions

The available information for McVey Creek confirms the need for sediment TMDL development. Livestock grazing has reduced riparian vegetation resulting in accelerated bank erosion and a reduction in the filtering capacity of streamside vegetation. Fine sediment accumulation in pool and riffle habitat impacts the fishery and aquatic insects. Although, the lack of vertical and lateral adjustments in the channel due to vegetation removal indicates that recovery of this stream is likely with relatively simple changes instream corridor management.

5.10 Miner Creek

Miner Creek flows northeast from the west part of the basin before its confluence with the Big Hole River. Over half its length lies on USFS lands with the remainder occurring on private lands in the valley. Miner Creek appears on Montana's 303(d) List for sedimentation/siltation.

5.10.1 Sediment

Stream narratives prepared by the USFS suggest a low risk of sediment delivery from land use practices in the headwater portions of the watershed. Road density in the forested portions of the basin is low with over 90 percent of Forest Service holdings designated as inventoried roadless lands. Road crossings are limited to one crossing on a perennial stream and four on intermittent waters. Although much of the basin is in a grazing allotment, livestock use appears to have little effect on surface waters in the USFS holdings. A hydrological assessment in the mid-90s indicated a functioning stream with no indications that livestock grazing negatively affected either riparian function or channel stability (Bengeyfield 1995).

Assessment of aerial imagery for Miner Creek identified no impact in terms of riparian or geomorphic condition. Riparian vegetation consists of dense to moderate shrubs for most of the stream's length. This extent of shrub and ground cover benefited the streambanks with no eroding banks encountered in the assessed reach (**Table 5-11**). Measures of channel morphology indicate a relatively narrow, deep channel with full access to its floodplain. The riparian corridor consisted of dense stands of willows both along the green line for the entire extent of the flood prone area. Vegetative parameters met targets with dense shrub cover along the green line and line transects and no bare ground. Pool frequency and pool dimensions were similar to reference reaches (**Table 5-11**). These results indicate a relatively healthy stream corridor.

Even though much of the stream corridor appeared to have healthy riparian vegetation conditions and low levels of bank erosion, fine sediment in the stream appears higher than expected. Percent fines measured with pebble counts were slightly higher than local reference conditions but not alarmingly high. In contrast, percent fines measured with the viewing bucket were at 100 percent within the monitored reach.

Field observations of high numbers of young of the year fish provide evidence that Miner Creek provides reasonably suitable conditions for aquatic life. Similar to Little Lake Creek, Miner Creek appears to provide rearing habitat to fish in the mainstem Big Hole River. The physical setting and riparian condition probably contribute to this stream's ability to provide this vital habitat. Several fish species including arctic grayling, burbot, brook trout, longnose dace, mottled sculpin and mountain whitefish are present in Miner Creek (MFISH).

Table 5-11: Summary of sediment targets and existing conditions in Miner Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	MC06	Target	25	≤ 22	~
	Pebble Count Percent fines (≤ 2 mm in riffles)	MC06	Target	20	≤ 18	~
	Percent Fines grid (≤ 6 mm pool tailout)	MC06	Target	**M = 100** **25th = 95**	Median ≤ 80 25th percentile ≤ 27	**N**
	Pool frequency	MC06	Target	5	≤ 8	Y
	Width-to-depth ratio	MC06	Target	75th = 20 M = 19	75th percentile ≤ 20 Median ≤ 14	Y
	Understory shrubs along greenline	MC06	Target	25th = 47 M = 51	25th percentile ≥ 32 M ≥ 58	Y
	Eroding bank (ft^2)	MC06	SI	NA	≤ 212	
	Macroinvertebrates	Three samples do not meet supplemental indicator thresholds. The presence of Miner Lake may influence the results.				
	Human Sources Present	Limited grazing and transportation systems.				

NA = no visually eroding banks

5.10.2 Summary of Sediment Conditions and Conclusions

Although much of Miner Creek appears to have healthy riparian vegetation and stream channel conditions, fine sediment is somewhat high. The causes of the sediment conditions are not all that clear, but restoration of the limited areas with grazing or road impacts could be undertaken to address sediment conditions within the stream. A sediment TMDL for Miner Creek will be provided in **Section 8.0**, but the TMDL will contain a small sediment reduction since much of the watershed appears to be managed appropriately.

5.11 Mussigbrod Creek

Mussigbrod Creek is a tributary of the North Fork Big Hole River lying on the west side of the upper Big Hole River planning area. This stream originates in the Anaconda Pintler Range and flows for about 8 miles through a montane setting, then 5 miles through the valley until its confluence with the North Fork Big Hole River. The stream flows through Mussigbrod Lake near its headwaters. Historic 303(d) lists included Mussigbrod Creek as impaired due to flow alteration, other habitat alterations, and siltation. Current probable sources of impairment include lead, physical substrate habitat alterations, other anthropogenic substrate alterations, low flow alterations and alterations instream side vegetation. Although Mussigbrod Creek is identified on as impaired on Montana's list of impaired waters, the upper portion of this watershed is identified as in a reference condition. This section will review sediment and associated habitat conditions and also lead conditions within the watershed.

5.11.1 Sediment

USFS narratives provide descriptions of human activities and natural disturbance in the Mussigbrod Creek watershed that relate to sediment pollution. Roads and multiple use trails parallel the stream in limited areas. Nevertheless, road density in the forested areas of the basin is low with 77 percent of USFS lands considered roadless, 17 percent with low road density, and 6 percent with moderate road density. Recreation facilitated by roads and trails, livestock grazing, and limited timber harvest are uses of the basin.

Natural factors also relate to sediment in the Mussigbrod Creek drainage. Granitics comprise 90 percent of the basin, which indicates high natural loading of sand to surface waters. Wildfire is also a considerable factor in this watershed. During the 2000 fire season, 26 percent of the basin burned. Together, wildfire and granitics are major natural sources of sediment to Mussigbrod Creek. Aerial photo analyses associated with TMDL planning efforts implicated grazing practices in the Big Hole Valley reaches of Mussigbrod Creek as potentially increasing sediment loading, most notably on the lowest 3-4 miles of the stream.

Sediment TMDL monitoring results from two sites in portions of the stream located on the North Fork Big Hole Valley bottom provided support for completing a TMDL Mussigbrod Watershed. Although measures of channel morphology indicated low width-to-depth ratios along the two impacted reaches assessed, cross sections on one reach indicated moderate entrenchment (**Table 5-12**). Together, these measures indicate that the stream is laterally stable, although isolated areas of vertical adjustments may have occurred on assessed reaches. Vegetation data for Mussigbrod Creek indicated moderate cover of riparian shrubs and low proportions of bare ground, although targets were not met (**Table 5-12**).

Pool frequency is a potential measure of sediment pollution as aggradation of large particles or infilling with fine sediment can limit this important habitat feature. Pool frequency on both reaches of Mussigbrod Creek was relatively low, although maximum pool depths were similar to reference reaches (**Table 5-12**). Eroding banks comprised relatively small proportions of assessed reaches and were similar to reference reaches. Aerial photo assessment indicates that this may not be the case between the two monitored sites.

Fine sediment measurements gave variable results for the assessed reaches of Mussigbrod Creek. The upper sight, below the USFS boundary, met all fine sediment targets. In contrast, the lower site did not meet any of the fine sediment targets, suggesting siltation is likely affecting instream beneficial uses (**Table 5-12**). Field notes describing conditions on Mussigbrod Creek provide additional insight into status of this stream. Field observers described reach MC05 as having well managed livestock grazing that was consistent with channel form and riparian function. In contrast, MC07 was described as having a greater degree of bank alteration and trailing associated with livestock use. Nevertheless, willows conferred bank stability along much of this monitored reach.

High proportions of fine sediment were measured at the lower monitored site and are likely impact instream uses. Aerial photo review indicates grazing management between the two monitored sites may have the potential to introduce sediment to the stream via bank erosion and potentially via the irrigation management system which could explain the difference between sediment conditions at the two monitored sites. A sediment TMDL will be provided for the watershed to address silation in the lower reaches of Mussigbrod Creek.

Aquatic insects were assessed at one site, and showed low aquatic insect community health when compared to metrics. Arctic grayling, brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, mountain whitefish and westslope cutthroat trout have been observed in Mussigbrod Creek (MFISH).

5.11.2 Lead

Mussigbrod is listed for impairment on the 2006 303(d) List due to elevated copper concentrations in several grab samples collected in the early 1980s. A significant amount of uncertainty remained on the appropriateness of this listing for several reasons. First, detection limits from older analyses were often too high for reliable application of the numeric standards and data reliability at levels near the standards is questionable. This uncertainty results in an increased probability of false violations when using data from this vintage. In addition, data currency, or the extent to which these data represented current conditions, was unknown. The only known mining activity on Mussigbrod Creek was a placer mine on a small tributary. Although placer mining can disrupt channel morphology and sediment transport, it rarely results in contamination of surface waters with metals.

Water quality sampling in 2004 aimed to evaluate the appropriateness of this listing. Lead concentrations in surface waters were below detection limits (**Table 5-12**). Similarly, lead concentrations in benthic sediment were below concentrations known to have an adverse effect on benthic organisms (**Table 5-12**). The lack of evidence for lead contamination using credible lab methods that represent current conditions combined with the absence of a likely source of metals contamination suggests this listing may not be appropriate for Mussigbrod Creek (**Appendix K**, **Map 3**). A lead TMDL will not be pursued at this time.

Table 5-12: Sediment and lead targets and existing conditions in Mussigbrod Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	MC05	Target	15	≤ 22	Y
		MC07		**71**		**N**
	Pebble Count Percent fines (≤ 2 mm in riffles)	MC05	Target	11	≤ 18	Y
		MC07		**54**		**N**
	Percent Fines grid (≤ 6 mm pool tailout)	MC05	Target	M = 46 25th = 29	Median ≤ 80 25th percentile ≤ 27	Y
		MC07		**M = 84** **25th = 76**		**N**
	Pool frequency	MC05	Target	**22**	≤ 8	**N**
		MC07		**25**		**N**
	Width-to-depth ratio	MC05	Target	75th = 12 M = 11	75th percentile ≤ 20 Median ≤ 14	Y
		MC07		75th = 10 M = 9		Y
	Understory shrubs along greenline	MC05	Target	**25th = 25** **M = 46**	25th percentile ≥ 32 M ≥ 58	**N**
		MC07		25th = 38 **M = 43**		**N**
	Eroding bank (ft^2)	MC05	SI	60	≤ 212	Y
		MC07		126		Y
	Macroinvertebrates	One sample indicates poor community health when compared to regional reference based thresholds.				
	Human Sources Present	Transportation and grazing systems present. Very limited silviculture activity. Recent fire also influences sediment yields.				
Lead	Benthic sediments	UBHMUSS01 8/25/2004	target	6.6	<30 mg/kg	Y
	Water Column	UBHMUSS01 5/18/2004	target	ND	Acute = 5 and Chronic = 4 ug/L @ 14 mg/L hardness	Y
	Water Column	UBHMUSS01 8/25/2004	target	ND	Acute = 5 and Chronic = 4 ug/L @ 23 mg/L hardness	Y

5.11.3 Summary of Sediment and Lead Conditions and Conclusions

Lower Mussigbrod Creek contains high levels of fine sediment. Fine sediment accumulation in pool and riffle habitat likely impact the fishery and aquatic insects. A sediment TMDL will be pursued to address fine sediment accumulation in the lower reaches of Mussigbrod Creek. Although, the lack of vertical and lateral adjustments in the channel due to vegetation impacts indicates that recovery of this stream is likely with relatively simple changes along the lower portions of this stream. Low lead concentrations in both sediment and water column samples during recent monitoring, 303(d) listing was based upon older data which lacks credibility, and lack of human caused lead sources provide the basis for not pursuing a lead TMDL at this time.

5.12 Pine Creek

Pine Creek, a tributary of Governor Creek, lies in the southern end of the upper Big Hole River planning area. Its headwaters begin in USFS holding along the Big Hole Divide. It flows for about 4 miles on USFS managed lands before entering private lands. The most recent listing includes alteration instreamside vegetation and phosphorus as potential causes of impairment. The phosphorus listing will not be addressed by this document because it only recently appeared after this project began. The habitat listings will be addressed in terms of sediment and habitat together.

5.12.1 Sediment

Assessment of aerial imagery identified reaches with potential impacts from livestock grazing or other alterations in the valley reaches of Pine Creek. Riparian vegetation rated as sparse along most of the stream. In addition, numerous diversions and other alterations to the stream and floodplain associated with flood irrigation occurred in this stream.

Sediment TMDL monitoring and associated field notes on private reaches of Pine Creek suggest a stream with impacted riparian vegetation but intact channel dimensions. Compared to reference reaches, the assessed reach on Pine Creek had low width-to-depth ratios and good access to its floodplain (**Table 5-13**). This reach had a low area of eroding banks compared to reference tributaries. Yet, shrub cover was low compared to reference reaches and bare ground comprised a relatively large proportion of line transects. Finally, measures of pool frequency and quality were reduced compared to reference and high levels of fine sediment were measured in pool tailout areas (**Table 5-13**).

Aquatic insect community health was assessed at a site near the USFS boundary and at a site near the confluence with Andrus Creek. The upper site approximated regional expectations of a healthy aquatic insect community but the lower site indicates an impacted community. According to MFISH, no fish surveys have been conducted on this tributary.

Table 5-13: Sediment targets and existing conditions in Pine Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Count Percent fines (≤ 6 mm in riffles)	PN03	Target	13	≤ 22	Y
	Pebble Count Percent fines (≤ 2 mm in riffles)	PN03	Target	12	≤ 18	Y
	Percent Fines grid (≤ 6 mm pool tailout)	PN03	Target	**M = 89** **25th = 85**	Median ≤ 80 25th percentile ≤ 27	**N**
	Pool frequency	PN03	Target	**17**	≤ 8	**N**
	Width-to-depth ratio	PN03	Target	75th = 13 M = 12	75th percentile ≤ 20 Median ≤ 14	Y
	Understory shrubs along greenline	PN03	Target	**25th = 28** **M = 36**	25th percentile ≥ 32 M ≥ 58	**N**
	Eroding bank (ft^2)	PN03	SI	59	≤ 212	Y
	Macroinvertebrates	Site near USFS border indicates a relatively healthy community compared to reference based metrics. Site near mouth indicates an impacted aquatic insect community.				
	Human Sources Present	Grazing and limited transportation systems are present.				

5.12.2 Summary of Sediment Conditions and Conclusions

Although stream channel geometry and bank erosion are not severely impacted, available information for Pine Creek suggests livestock grazing practices are likely producing fine sediment accumulations in pools. Sediment levels are above reference conditions and thresholds that are likely to impact aquatic life and fish spawning. A sediment TMDL will be pursued.

5.13 Pintlar Creek

Pintlar Creek lies on the northwest side of the upper Big Hole Valley and the watershed represents the northwest boundary of the upper/North Fork Big Hole River planning area. Its headwaters lie in the Pintler Anaconda Range and it flows to the southeast to its confluence with the Big Hole River. Pintlar Creek is identified on the state's 303(d) List as limited by temperature, stream flow and physical substrate habitat alterations as the probable causes of impairment to aquatic life and fishery uses. Temperature and sediment related TMDL monitoring occurred in Pintlar Creek during 2004. Because of complications in determining if thermal conditions caused by human activities are within the allowable state standards, a temperature TMDL will not be completed at this time. Further temperature and stream flow monitoring and modeling will be needed to determine if existing conditions meet or exceed Montana's temperature standard. Existing sediment and habitat related conditions will be reviewed.

5.13.1 Sediment

A number of information sources provided information relevant to characterizing sediment conditions within Pintlar Creek. These include stream measurements and associated descriptions developed by the USFS, the TMDL aerial photo analysis, and TMDL monitoring. Information from the USFS describes severe damage from livestock for Pintler Meadows in the mid 1980s. Assessments that are more recent place this portion of Pintlar Creek in the category as "functioning at risk" with a downward trend. Channel widening and a lack of sinuosity were among concerns listed by the USFS, who stated this reach had not seemed to recover from historic grazing practices. Nevertheless, these conditions were relegated to Pintler Meadows, which has less than 1 mile of channel. The rest of the stream rated as properly functioning. Reexamination of aerial imagery confirms the impacted nature of the Pintler Meadows portion of Pintlar Creek. No shrubs were apparent from aerial photos and areas of channel instability were observable.

Evaluations of aerial imagery in the valley portions of Pintlar Creek indicate varied conditions with the most severely degraded reaches comprising a relatively small proportion of the stream (Confluence et al. 2003). These included fence line effects where differences in grazing management practices resulted in abrupt changes in riparian vegetation density and channel sinuosity. Nevertheless, the greatest proportion of Pintlar Creek had moderate shrub cover and relatively high sinuosity. Other features evident in aerial imagery were irrigation diversions that began near the USFS boundary.

Sediment TMDL monitoring results indicated intact riparian condition and channel morphology at sites that represent much of the valley portions of Pintlar Creek. Width-to-depth ratios were low and similar to reference reaches (**Table 5-14**). In addition, the stream had good access to its floodplain as expressed by high entrenchment ratios. Riparian shrub cover was dense and typically greater than reference. Field reconnaissance of the lowest portion of Pintlar Creek (reach PC06) indicates riparian and channel conditions similar to PC04.

Evidence that bank erosion was contributing excess sediment to Pintlar Creek was equivocal. On the assessed reach, measures of eroding banks varied between quality assurance replicates with one group finding little evidence of eroding banks and the other finding area of eroding banks elevated compared to reference reaches. In addition, measures of substrate composition indicated low to moderate proportions of fine sediment. Both pebble counts and percent fines grids showed proportions of fine sediment on the streambed were approximately the same as reference reaches except for when comparing the lowest quartile of data.

Field reconnaissance, sediment monitoring data and aerial photo analyses are used to estimate existing conditions. Approximately 1/4 mile of channel has markedly reduced riparian vegetation due to grazing practices. Field reconnaissance of the 1/4 mile of stream with reduced riparian cover in the valley portion of stream found no evidence of bank erosion. Sediment, produced via bank erosion in Pintler Meadows, likely becomes trapped in Pintlar Lake and is effectively removed from the system. Therefore, given the low proportion of degraded riparian area, riparian habitat alterations are unlikely contributors of excess sediment to Pintlar Creek.

5.13.2 Summary of Sediment Conditions and Conclusions

Review of existing information on Pintlar Creek suggests the listing for habitat alterations could be warranted. Temperature monitoring and source assessment results were uncertain. It does not appear that riparian shade conditions are likely to heat Pintlar Creek, but irrigation withdrawals and water use may impact temperature conditions. A more detailed irrigation assessment would be needed to determine if reduced water volume causes temperatures above Montana's standard and if irrigation water conservation management activities have been implemented. A temperature TMDL will not be completed at this time but a follow up monitoring strategy is identified in **Section 11.0** to determine if a temperature TMDL is necessary.

Table 5-14: Summary of targets and existing conditions in Pintlar Creek.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value/ Score**	**Target Column**	**Met target?**
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	PC04	Target	19	≤ 22	Y
	Pebble Counts Percent fines (≤ 2 mm in riffles)	PC04	Target	17	≤ 18	Y
	Percent Fines Grid (≤ 6 mm pool tailout)	PC04	Target	M = 81 **25th = 73**	Median ≤ 80 25th percentile ≤ 27	**N**
		PC04B		M = 64 **25th = 64**		**N**
	Pool frequency	PC04	Target	7	≤ 8	Y
		PC04B		**15**		**N**
	Width-to-depth ratio	PC04	Target	75th = 14 M = 14	75th percentile ≤ 20 Median ≤ 14	Y
		PC04B		75th = 11 M = 9		Y
	Understory shrub cover along greenline	PC04B	Target	25th = 46 M = 63	25th percentile ≥ 32 M ≥ 58	Y
		PC04		25th = 69 M = 75		Y
	Eroding bank (ft^2)	PC04B	SI	**297**	≤ 212	**N**
	Macroinvertebrates	No recent information				
	Human Sources Present	Grazing and transportation systems present. Granitic geology may naturally influence sediment production.				

5.14 Rock Creek

Rock Creek lies on the west side of the Upper Big Hole Valley and flows to the northeast. A recent restoration project restored the lower portion of Rock Creek so it now reaches the Big Hole River, but previously it was incorporated into irrigation ditches. The 303(d) List includes numerous causes of impairment for Rock Creek, including siltation as a pollutant requiring a TMDL. Nutrient conditions in Rock Creek will not be addressed in this document although they are likely an issue in Rock Creek. Nutrient conditions will be addressed in future TMDL efforts. Sediment and associated habitat listings will be addressed by this document.

5.14.1 Sediment

Pertinent sediment related information for Rock Creek includes narrative descriptions provided by the USFS, aerial photo assessments, and field assessments during 2004. Land ownership in the drainage includes a mixture of state, federal, and private lands. USFS holdings account for 38 percent of the watershed in headwater portions. After leaving the National Forest, Rock Creek flows through patches of BLM land, then state lands. The majority of the Rock Creek watershed (52%) lies on private, agricultural lands in the valley.

Land uses on the forested portions of the watershed include timber harvest, recreation, and livestock grazing and associated roads with these activities. Nearly 11 miles of road occur on USFS lands. Road density varies across the basin with 55 percent being roadless, 27 percent having low road density, 16 percent with moderate road density, and 2 percent with high road density. The greatest concentrations of roads occur along intermittent tributaries, Dry and Mifflin creeks. Road crossings include one crossing on a perennial stream and three crossings on intermittent tributaries, all composed of native materials. In addition, a trail system facilitates recreational access to the upper basin. Logging has occurred on about 6 percent of USFS lands with approximately 60 percent of trees removed on these 861 acres. Nearly 80 percent of the USFS lands are in a grazing allotment although a small portion of this area is suitable for grazing.

Investigations conducted by the USFS in the 1980s and early 1990s indicated a range of conditions in the upper Rock Creek drainage. Stream assessments in 1989 found Rock Creek to be a stable, functioning B3 channel (Bengeyfield 1998). Dry Creek, an intermittent tributary of Rock Creek, is a potential source of sediment loading to Rock Creek. Assessments indicate a non-functioning reach with an overly wide, unstable channel. These conditions were a result of former livestock grazing practices, which were more damaging than the current management practices.

Fisheries data indicate Rock Creek may be a priority for water quality planning. Sampling in 1998 found westslope cutthroat trout and brook trout. The tendency of brook trout to displace the native westslope cutthroat trout, especially in degraded streams (Shepard et al. 1998), is an important consideration for Rock Creek.

Assessments of aerial imagery during TMDL planning provide a spatially extensive view of conditions along the entire length of Rock Creek. Timber harvest to the stream channel occurred in portion of the montane reaches. This evaluation indicated riparian degradation and dewatering are present along this valley reaches. Riparian shrub density rated as sparse to moderate for many of the valley reaches. Hay production encroached on the stream, a practice that reduces shrub cover and therefore the functional attributes of riparian vegetation.

Reconnaissance investigations during 2004 confirm results of the aerial photo assessment for valley portions of Rock Creek. Field notes describe a lack of willows, with sedges being the dominant riparian vegetation. Some banks were actively eroding due to trampling by livestock. A lack of stream flow was attributable for channel narrowing. Instream habitat was also degraded. Fine sediment filled in pools and undercut bank habitat was lost due to trampling. Combined, these observations suggest that livestock grazing and dewatering were responsible for increasing loading of sediment to streams and decreasing sediment transport efficiency, which can reduce the stream's ability to support its beneficial uses.

Sediment TMDL monitoring assessments during 2004 on the valley portions of Rock Creek provide additional evidence of sediment problems. Width-to-depth ratios were elevated at one site compared to reference reaches indicating lateral adjustments in channel morphology and a decreased ability to transport fine sediment (**Table 5-15**). The increase in width-to-depth ratios may have been due to reduction in the functional attributes of riparian vegetation. Shrub cover was considerably lower than reference reaches and bare ground comprised a relatively large component of streambanks at this same site. Bank erosion varied, but appeared to meet targets. Pool numbers were low at one of the measured sites (**Table 5-15**). Percent fines measured through both pebble counts in riffles were found to be high at one site and the percent fines grid measurement in pools was high at the other site.

Aquatic insect communities are comparable to reference conditions at upper site on BLM land, but do not meet targets at a site in the Big Hole Valley. Rock Creek has brown, rainbow and brook trout populations (MFISH). There are several tributaries of Rock Creek that also contain populations of these three salmonid species.

5.14.2 Summary of Sediment Conditions and Conclusions

Although stream channel geometry and bank erosion are not severely impacted, it appears that riparian shrub growth is depressed. Fine sediment accumulation in pool and riffle areas likely impact aquatic insect and fish communities by filling critical habitat areas. Human influenced sources, mostly grazing and transportation systems, are present. A sediment TMDL will be pursued.

Table 5-15: Summary of sediment targets and existing conditions in Rock Creek.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value/ Score**	**Target Column**	**Met target?**
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	RO04	Target	**32**	≤ 22	**N**
		RO06		20		Y
	Pebble Counts Percent fines (≤ 2 mm in riffles)	RO04	Target	**19**	≤ 18	**N**
		RO06		13		Y
	Percent Fines Grid (≤ 6 mm pool tailout)	RO04	Target	M = 24 25th = 20	Median ≤ 80 25th percentile ≤ 27	Y
		RO06		**M = 98** **25th = 97**		**N**
	Pool frequency	RO04	Target	5	≤ 8	Y
		RO06		**13**		**N**
	Width-to-depth ratio	RO04	Target	**75th = 26** M = 14	75th percentile ≤ 20 Median ≤ 14	**N**
		RO06		75th = 15 M = 13		Y
	Understory shrub cover along greenline	RO04	Target	**25th = 18** **M = 22**	25th percentile ≥ 32 M ≥ 58	**N**
		RO06		**25th = 13** **M = 19**		**N**
	Eroding bank (ft^2)	RO04	SI	31	≤ 212	Y
		RO06		150		Y
	Macroinvertebrates	Aquatic insect communities are comparable to reference conditions at upper site on BLM land but do not meet targets at a site in the Big Hole Valley.				
	Human Sources Present	Grazing and transportation systems are present.				

5.15 Ruby Creek

The headwaters of Ruby Creek lie in the Beaverhead Mountains on the west side of the upper Big Hole River planning area. The majority of its 12-mile length is on the Beaverhead National Forest. The lower 4 miles flow through private lands before its confluence with Trail Creek where it becomes the North Fork Big Hole River. Ruby Creek is on the 303(d) List for several probable causes of impairment. Probable causes of impairment include sedimentation/siltation, the only listed pollutant, and several associated types of pollution including physical habitat substrate alterations, alteration instreamside vegetation, and low flow alterations. Sediment and related habitat conditions will be addressed in this section.

5.15.1 Sediment

USFS stream narratives describe conditions on the USFS lands which may possibly affect sediment production. Over 90 percent of the Ruby Creek watershed lies on USFS lands. These lands have a long history of multiple uses with effects still lingering. Roads and trails are significant features. These parallel the stream for much of its length. Road density varies in the basin with 49 percent lacking roads, 31 percent having low road density, 16 percent having moderate road density, and 4 percent with high road density.

Livestock grazing is also a significant use with grazing allotments covering most of the watershed. Livestock grazing in the past has resulted in severe degradation of riparian areas and channel stability on the federal lands. Several restoration projects have targeted this degradation and have been successful in restoring bank and channel stability.

Historic placer mining is another influence on channel morphology in Ruby Creek. The effects of this were probably severe at one time; however, these areas have recovered. The USFS no longer considers mining a significant type of impact on Ruby Creek.

Aerial photo analyses indicate variable conditions along the length of Ruby Creek. Several of the montane reaches had no identifiable impacts, although timber harvest and forest roads were apparent near other reaches. Irrigation withdrawals were observable in most of the valley portions of the stream. Riparian conditions were variable with a tendency for greatly reduced shrub cover in the lower reaches of Ruby Creek.

TMDL sediment survey results varied by site but indicate a sediment TMDL is needed. Width-to-depth ratios were low and similar to reference indicating the channel was relatively narrow and deep. In addition, high entrenchment ratios indicated assessed reaches had easy access to the floodplain during high flows. Measures of vegetation are generally consistent with riparian vegetation conditions at reference sites except, slightly less vegetation than reference at both the upper and lower site (**Table 5-16**). The extent and severity of bank erosion in the middle assessed reach on Ruby Creek was a concern. This reach exceeded the average area of eroding banks on reference reaches by a considerable margin.

Measures of surface fines suggested siltation may be impacting beneficial uses in some locations within Ruby Creek. Fines < 6mm measured in riffles at the lowest site were high (**Table 5-16**). Median levels of fine sediment in pool tailout areas at the lower sites were above targets. Fine sediment accumulation in riffles and pools in the lower sections of Ruby Creek may be impacting aquatic life and the fishery.

An aquatic insect assessment resulted in low diversity and therefore did not meet criteria for a healthy insect community. Ruby Creek has several fish species, including brook trout, burbot, longnose sucker, mottled sculpin and westslope cutthroat trout (MFISH). There are various tributaries within Ruby Creek that also contain the same fish species.

Table 5-16: Summary of sediment targets and existing conditions in Ruby Creek.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value/ Score**	**Target Column**	**Met target?**
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	RC04	Target	2	≤ 13	Y
		RC07		15	≤ 22	Y
		RC08		**26**		**N**
	Pebble Counts Percent fines (≤ 2 mm in riffles)	RC04	Target	0	≤ 13	Y
		RC07		11	≤ 18	Y
		RC08		18		Y
	Percent Fines Grid (≤ 6 mm pool tailout)	RC04	Target	M = 4 25th = 1	Median ≤ 51 25th percentile ≤ 42	Y
		RC07		M = 50 **25th = 42**	Median ≤ 80 25th percentile ≤ 27	**N**
		RC08		M = 54 **25th = 48**		**N**
	Pool frequency	RC04	Target	5	≤ 6	Y
		RC07		6	≤ 8	Y
		RC08		4		Y
	Width-to-depth ratio	RC04	Target	**75th = 16** **M = 15**	75th percentile ≤ 13 Median ≤ 10	**N**
		RC07		75th = 15 M = 11	75th percentile ≤ 20 Median ≤ 14	Y
		RC08		75th = 14 M = 10		Y
	Understory shrubs along green line	RC04	Target	**25th = 34** M = 45	25th percentile ≥ 36 M ≥ 41	**N**
		RC07		25th = 52 M = 57	25th percentile ≥ 32 M ≥ 58	Y
		RC08		25th = 36 **M = 47**		**N**
	Eroding bank (ft^2)	RC04	SI	95	≤ 113	Y
		RC07		**869**	≤ 212	**N**
		RC08		196		Y
	Macroinvertebrates	One sample did not meet supplemental indicator metrics.				
	Human Sources Present	Historic mining, silviculture, transportation and grazing systems are present. Granitic geology may also affect sediment production.				

5.15.2 Summary of Sediment Conditions and Conclusions

Comparison of conditions in and along Ruby Creek to sediment targets and supplemental indicators provides support for pursuing sediment TMDL development (**Table 5-16**). While the general condition of the watershed has been improving over the past few decades, fine sediment targets are not met in the lower portions of Ruby Creek and may be impacting fish and aquatic insects. Current and historic human caused sediment sources are present. A sediment TMDL will be pursued.

5.16 Steel Creek

Steel Creek is a tributary of the Big Hole River originating in the Pioneer Mountains on the east side of the upper Big Hole River valley. The upper, forested portion of the watershed lies on the Beaverhead Deerlodge National Forest. The remaining 22 percent of the watershed is on lower elevation private lands. Steel Creek has been identified on prior 303(d) lists for sediment as a cause of impairment. Currently listed pollutants include cadmium, copper and phosphorus. The latest 303(d) List includes the following potentially sediment related pollution categories: alteration instream side vegetation, physical substrate habitat alterations, other anthropogenic substrate alterations and low flow alterations. Eight identified abandoned mines may be responsible for metals loading to Steel Creek.

5.16.1 Sediment

Stream narratives prepared by the Beaverhead National Forest (BNF) describe land uses and stream conditions for the forested portions of the watershed. Roads are a significant feature with 20 percent of the USFS portion of the hydrologic unit rated as having a high road density, some of which encroaches within the riparian buffer. Livestock grazing occurs primarily along tributary streams on USFS lands. Timber harvest has been limited with only 2 percent of USFS lands.

Sediment TMDL monitoring results support the determination that fine sediment impacts beneficial uses, at least for the lower reaches of this stream. In contrast, the assessed reaches on or near the USFS lands met most comparisons to reference reaches although did not fully meet sediment targets for stream bed sediments.

Width-to-depth and entrenchment ratios deviated substantially from reference on the lower assessed reach on Steel Creek (**Table 5-17**). Width-to-depth ratios approached or were greater than the threshold for “very high” width-to-depth (Rosgen 1996). In addition, the median entrenchment ratio for this reach was at the limit between entrenched and moderately entrenched. Together, these results indicate an overly wide channel with limited access to its floodplain. This scenario relates to sediment impact in that the overly wide channel has less sediment transport capacity, while the entrenchment ratio indicates the stream exerts greater shear stress on its banks during high flows, thereby increasing the potential for streambank erosion.

Riparian vegetative characteristics on this lowest reach of Steel Creek also showed indications of impact. Understory shrub cover was exceedingly low on both line transects and along the green line with less than 5 percent of cover comprised of this vegetation type (**Table 5-17**). Similarly, bare ground comprised a considerable proportion of both perpendicular line transects and green line samples, and was substantially greater on reference reaches. These results suggest that a lack of vegetative cover reduces bank protection resulting in banks that are more erodible compared to reaches with less impacted riparian cover. The survey of eroding banks provided additional indication that near stream sediment sources are higher than expected. Over 800 ft^2 of eroding bank occurred within the high category of erodibility. In contrast, reference reaches had on average about 200 ft^2 of eroding banks.

5.16.2 Metals (copper and cadmium)

Steel Creek is listed for likely impairment on Montana's 2006 303(d) List due to elevated copper and cadmium concentrations in grab samples collected in the early 1980s. Although there are mining sources in the watershed, a significant amount of uncertainty remained on the appropriateness of this listing for several reasons (**Appendix K**, **Map 3)**. First, detection limits from older analyses were often too high for reliable application of the numeric standards and data reliability at levels near the standard is questionable. This uncertainty results in an increased probability of false violations when using data from this vintage. In addition, data currency, or the extent to which these data represented current conditions, was unknown.

Because of the uncertainty surrounding the potential for copper to impair beneficial use support in Steel Creek, the DEQ undertook additional sampling of water and sediment chemistry during 2004. Copper was undetected in water samples during 2004. Copper concentrations fall below the lowest evaluated effect level for benthic invertebrates (NOAA SQIRTs) indicating low risk to benthic organisms in contact with these substrates. Also, the DEQ's abandoned mine monitoring database indicates a sample collected below Clara mine in a small tributary during the 1990s may be above standards but the data is flagged indicating the sample should be considered an estimation because of lab quality assurance issues. This tributary does not usually express surface water to Steel Creek and the mine is a long distance from the Creek. Because of the uncertainty of data from the 1980s and the low copper concentrations found in Steel Creek during the 2004 monitoring, a copper TMDL will not be completed at this time.

Because of the uncertainty surrounding the potential for cadmium to impair beneficial use support in Steel Creek, the DEQ undertook additional sampling of water and sediment chemistry during 2004. Cadmium was undetected in all 2004 TMDL and 1990's abandoned mine water samples. Cadmium concentrations were above the lowest evaluated effect level for benthic invertebrates (NOAA SQIRTs) indicating there could be a slight risk to benthic organisms in contact with these substrates. The sediment samples were below probable effects levels that would likely exert toxic responses. Because of the uncertainty of data from the 1980s and the low copper concentrations found during the 2004 monitoring, a cadmium TMDL will not be completed at this time.

5.16.3 Nutrients

Nitrogen and phosphorus levels are above targets near the confluence with the Big Hole River (**Table 5-17**). Chlorophyll may be below targets because substrates algae would grow on in this area are smothered due to sedimentation. TMDL sediment monitoring results indicate that riparian filtering function is impacted and bank erosion as well as bare ground are elevated in this area. Grazing and hay production impacts increase in a downstream direction and nutrient conditions do likewise. Nutrient TMDLs will be provided in **Section 9**.

5.16.4 Summary of Sediment, Nutrient and Metals Conditions and Conclusions

Comparison of conditions in and along lower portions of Steel Creek to sediment targets and supplemental indicators provides support for pursuing sediment TMDL development (**Table 5-16**). Implementing improved grazing management practices would likely improve sediment and habitat conditions along most unforested portions of Steel Creek. Current and historic human caused sediment sources are present. A sediment TMDL will be pursued.

Sampling during 2004 results indicated low copper concentrations in Steel Creek sediment and water samples. Cadmium sampling results indicated slightly elevated levels of cadmium in sediments but no exeedences of water quality standards. These results indicate that metals TMDLs are likely not needed and will not be pursued at this time. Nutrient conditions in the lower reaches of Steel Creek are elevated and sources are apparent. Nutrient TMDLs will be pursued in this TMDL planning effort.

Table 5-17: Summary of targets and existing conditions in Steel Creek. Non-detectable values indicated by ND.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	SC02	Target	NA		
		SC03		**52**	≤ 22	**N**
		SC06		**26**		**N**
	Pebble Counts Percent fines (≤ 2 mm in riffles)	SC02	Target	NA		
		SC03		**32**	≤ 18	**N**
		SC06		**25**		**N**
	Percent Fines Grid (≤ 6 mm pool tailout)	SC02	Target	**M = 100** **25th = 100**	Median ≤ 51 25th percentile ≤ 42	**N**
		SC03		**M = 77** **25th = 69**	Median ≤ 80 25th percentile ≤ 27	**N**
		SC06		M = 46 **25th = 42**		**N**
	Pool frequency (Bank full width/pool)	SC02	Target	Not Applicable		
		SC03		**21**	≤ 8	**N**
		SC06		**10**		**N**
	Width-to-depth ratio	SC02	Target	75th = 5 M = 4	75th percentile ≤ 13 Median ≤ 10	Y
		SC03		75th = 8 M = 6	75th percentile ≤ 20 Median ≤ 14	Y
		SC06		**75th = 35** **M = 33**		**N**
	Understory shrubs along green line (%)	SC02	Target	25th = 75 M = 76	25th percentile ≥ 36 Median ≥ 41	Y
		SC03		25th = 49 M = 55	25th percentile ≥ 32 Median ≥ 58	Y
		SC06		**25th = 0** **M = 0**		**N**
	Eroding banks (ft^2)	SC02	SI	NA		
		SC03		**259**	≤ 212	**N**
		SC06		**818**		**N**
	Macroinvertebrates	No recent results available near most impacted areas.				
	Human Sources Present	Transportation and grazing systems present				

Table 5-17: Summary of targets and existing conditions in Steel Creek. Non-detectable values indicated by ND.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Copper	Benthic sediments	UBHSTEE 01 8/27/2004	Target	17.1	< 35 mg/kg	Y
		UBHSTEE 02 8/27/2004	Target	11.7	< 35 mg/kg	Y
	Water column	UBHSTEE 01 UBHSTEE 02 UBHSTEE 03 UBHSTEE 04 5/18/2004	Target	All NDs*	Acute = 4 and Chronic = 3 ug/L @ 25 mg/L hardness	Y
	Water column	UBHSTEE 01 UBHSTEE 02 8/27/2004	Target	All NDs*		Y
Cadmium	Benthic sediments	UBHSTEE 01 8/27/2004	Target	**1.36**	< 0.6 mg/kg	**N**
		UBHSTEE 02 8/27/2004	Target	**1.53**	< 0.6 mg/kg	**N**
	Water column	UBHSTEE 01 UBHSTEE 02 UBHSTEE 03 UBHSTEE 04 5/18/2004	Target	All NDs*	Acute = 0.52 and Chronic = 0.1 ug/L @ 25 mg/L hardness	Y
	Water column	UBHSTEE 01 UBHSTEE 02 8/27/2004	Target	All NDs*		Y
Metals Sources	Abandoned mines present					

Table 5-17: Summary of targets and existing conditions in Steel Creek. Non-detectable values indicated by ND.

Pollutant	**Parameter**	**Reach Name**	**Target or SI**	**Value/ Score**	**Target Column**	**Met target?**
Nutrients	Chlorophyll *a*	8/27/2004 SC02	target	12.3**	< 150 mg/m^2	**N**
		8/27/2004 SC05		49.7**		**N**
		8/27/2004 SC06		64.3**		**Y**
	Total Nitrogen	8/27/2004 SC02	target	ND*	< 320 ug/L	Y
		8/27/2004 SC05		ND*		Y
		8/27/2004 SC06		**600**		**N**
	Total Phosphorous	8/27/2004 SC02	target	11	< 49 ug/L	Y
		8/27/2004 SC05		17		Y
		7/1/1981 SC06		**90**		**N**
		9/28/1982 SC06		**220**		**N**
		8/27/2004 SC06		**118**		**N**
	Dissolved Oxygen		SI	2 of 17 samples collected from 1972-1978 were below standards		
	Understory shrubs along green line (%)	SC02	SI	25th = 75 M = 76	25th percentile ≥ 36 Median ≥ 41	Y
		SC03		25th = 49 M = 55	25th percentile ≥ 32 Median ≥ 58	Y
		SC06		**25th = 0** **M = 0**		**N**
	Shrubs along transect (%)	SC02	SI	25th = 78 M = 76	25th percentile ≥ 42 Median ≥ 64	Y
		SC03		**25th = 15** **M = 30**	25th percentile ≥ 20 Median ≥ 48	**N**
		SC06		**25th = 0** **M = 0**		**N**
	Bare ground along transect (%)	SC02	SI	M = 0	Median ~ 0	Y
		SC03		M = 0		Y
		SC06		**M = 17**		**N**
	Macroinvertebrates	The aquatic insect community metrics do not meet thresholds.				
	Human Sources	Grazing and hay production sources are present.				

NA = no visually eroding banks
ND = Under detection limit
** Estimated values due to sampling quality assurance review

5.17 Swamp Creek

Swamp Creek is a tributary of the Big Hole River flowing to the northeast from the west side of the basin. Unlike other streams in the watershed, Swamp Creek originates in the valley and lacks headwaters in the Beaverhead National Forest. Swamp Creek is identified in the most recent 303(d) List as being impaired due to sedimentation/siltation, nitrogen, phosphorus, low flow alterations and alteration instream side vegetation. The sediment and associated habitat listings will be addressed in this document but nutrient listings are not addressed due to their recent listing status.

5.17.1 Sediment

Results of the aerial photo assessment confirmed disturbances associated with land use. This included lack of channel integrity due to diminished stream flows and riparian degradation, presumably from livestock grazing. Density of riparian vegetation varied from moderate to sparse with differences in livestock management resulting in abrupt changes in riparian cover at fence lines.

The TMDL aerial photo assessment described several categories of disturbance with potential to contribute to siltation in Swamp Creek. Multiple flow diversions resulted in a loss of channel definition for significant portions of this stream. In addition, livestock grazing practices varied along the length of stream resulting in abrupt changes in riparian condition at fence lines. Sparse riparian shrub cover characterized significant portions of this stream.

Groundwater inputs are a significant portion of the flow in this stream and flood irrigation practices in the basin have possibly increased flows above natural. As the name Swamp Creek implies, this stream’s potential geomorphology may be different from snowmelt driven streams typical of the region.

TMDL sediment monitoring results varied between the two reaches assessed on Swamp Creek. In general, the upper reach had intact riparian and channel characteristics but pool frequency was low compared to reference reaches. The lower assessed reach had high width-to-depth ratios, low shrub cover, and high proportions of bare ground along the green line (**Table 5-18**). Measures of substrate fines, both in riffles and pools were usually above targets based on reference conditions and also above thresholds likely to impact aquatic life (**Table 5-18**).

The aquatic insect community metrics scored below their assigned thresholds indicating an impacted biological condition. The fish found in Swamp Creek include arctic grayling, brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, mountain sucker, mountain whitefish, rainbow trout and white sucker (MFISH).

Table 5-18: Summary of targets and existing conditions on Swamp Creek. Non-detectable values indicated by ND*.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	SW03	Target	**25**	≤ 22	**N**
		SW10		**27**		**N**
	Pebble Counts Percent fines (≤ 2 mm in riffles)	SW03	Target	**21**	≤ 18	**N**
		SW10		**24**		**N**
	Percent Fines Grid (≤ 6 mm pool tailout)	SW03	Target	**M = 91** **25th = 71**	Median ≤ 80 25th percentile ≤ 27	**N**
		SW10		M = 16 25th = 10		Y
	Pool frequency	SW03	Target	**13**	≤ 8	**N**
		SW10		6		Y
	Width-to-depth ratio	SW03	Target	75th = 13 M = 7	75th percentile ≤ 20 Median ≤ 14	Y
		SW10		**75th = 30** **M = 28**		**N**
	Understory shrubs along green line	SW03	Target	**25th = 38** M = 43	25th percentile ≥ 32 Median ≥ 58	**N**
		SW10		**25th = 2** **M = 2**		**N**
	Eroding bank (ft^2)	SW03	SI	NA	≤ 212	NA
		SW10		**1624**		**N**
	Macroinvertebrates	Two aquatic insect assessments indicate poor community health and do not meet thresholds.				
	Human Sources Present	Grazing and transportation systems present				

NA = no visually eroding banks

5.17.2 Summary of Sediment Conditions and Conclusions

Available information provides support for the need of a sediment TMDL to address nutrients and siltation in Swamp Creek. Nevertheless, this stream is unique in the upper Big Hole River planning area and probably has different potential than other streams. A major factor influencing this stream is its hydrology. It functions more as a spring creek than a snowmelt driven stream. Spring creeks tend to be more productive and have higher levels of fine sediment due to a lack of flushing flows. Therefore, TMDL planning efforts must incorporate these considerations through the adaptive management approach to ensure that targets are appropriate for Swamp Creek.

5.18 Schultz Creek

Schultz Creek is a small montane stream lying on the west side of the upper Big Hole River planning area, mostly on the Beaverhead National Forest. This stream flows for three miles until its confluence with Johnson Creek. Schultz Creek is on Monana's 303(d) List with sedimentation/siltation as a probable cause of impairment and silvicultural practices as the probable source of impairment.

According to stream narratives provided by the USFS, land use activities in the Schultz Creek drainage include timber harvest and roads. A road parallels the stream for much of its length but is usually about 300 feet from the stream, which for the most part, provides a buffer that filters out sediment produced from the road. Fish surveys found westslope cutthroat trout and tailed frogs. Most of the watershed burned during 2000 except for the areas that were harvested in the 1980-1990s.

5.18.1 Sediment

Sediment TMDL monitoring and associated field observations support the conclusion that Schultz Creek does not need a sediment TMDL. Representative measures of channel morphology, riparian vegetative cover, and substrate fines indicated a functioning stream (**Table 5-19**). Shrub cover was low; however, conifers comprised the streamside vegetation and likely shaded the undercanopy area. In addition, field notes report substantial recruitment of large woody debris forming habitat features for fish. Many of the riparian areas were burned severely in 2000.

Aquatic insect samples collected from Schultz Creek by the DEQ indicate a healthy community when compared to regional reference conditions. Schultz Creek contains populations of westslope cutthroat and westslope cutthroat x yellowstone cutthroat trout hybrids (MFISH).

Table 5-19: Summary of sediment targets and existing conditions in Schultz Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Counts Percent fines (≤ 6 mm)	SH01	Target	13	≤ 13	Y
	Pebble Counts Percent fines (≤ 2 mm)	SH01	Target	13	≤ 13	Y
	Percent Fines Grid (≤ 6 mm pool tailout)	SH01	Target	M = 8 25th = 5	Median ≤ 10 25th percentile ≤ 5	Y
	Pool frequency	SH01	Target	5	NA	NA
	Width-to-depth ratio	SH01	Target	75th = 13 M = 13	75th percentile ≤ 15 Median ≤ 13	Y
	Percent understory shrub cover along green line	SH01	Target	75th = 0 M = 0	NA	NA
	Eroding bank (ft^2)	SH01	SI	0	≤ 113	
	Macroinvertebrates	Aquatic insect community assessment metrics met criteria for a healthy community.				
	Potential Human Sources Present	Silviculture and unpaved road systems				

NA = Not applicable

5.18.2 Summary of Sediment Conditions and Conclusions

Although timber harvest and road development are potential sources of sediment loading to Schultz Creek, the available information describes a healthy montane stream supporting a native fishery. All instream or riparian based sediment targets and indicators are met. A sediment TMDL for Schultz Creek will not be completed at this time.

5.19 Tie Creek

Tie Creek is a montane tributary of the North Fork Big Hole River on the west side of the basin. It flows about 14 miles with all but the last 2 miles within the Beaverhead National Forest. Probable causes of impairment for Tie Creek include sedimentation/siltation, physical substrate habitat alterations and nitrogen. The sediment and associated habitat listings will be addressed in this document but nutrient listings are not addressed due to their recent listing status.

5.19.1 Sediment

Information allowing assessment of siltation in Tie Creek includes written watershed narratives, aerial photo assessments, and TMDL sediment sampling assessments. Stream narratives provided by the USFS describe potential human caused sediment sources. Tie Creek watershed has experienced substantial land use activities, although natural recovery and restoration activities by the USFS have reduced sediment production and delivery from its peak in the 1970s.

Beginning in the 1960s and continuing through the 1970s, timber harvest was significant with nearly 10 percent of the basin having 60 percent of its trees removed. Road construction accompanied timber harvest and roads and trails occur throughout the basin. Road density is higher than most other drainages in the upper Big Hole River planning area with 17 percent lacking roads, 31 percent having low road density, 30 percent having moderate road density, and 22 percent having high road density. Roads encroach within 300 feet of streams for 3.6 miles.

In response to concerns regarding sediment loading from roads, the USFS engaged in extensive road restoration activities in the early 1990s. Road treatments included installation of water bars, lining ditches with rocks, and placement of filter windrows at the toe of fill slopes. To reduce sediment delivery at road crossings, approaches were paved and some new cross-drain culverts were installed.

Livestock grazing is another land use on the National Forest that has resulted in sediment loading and channel alterations. In the 1980s, livestock grazing had resulted in destabilization of nearly 50 percent of streambanks, which caused channel widening. This caused high levels of embeddedness, including known spawning areas. During the mid 1990s, new, refined grazing management began on the USFS lands. The high degree of embeddedness decreased in subsequent decades, probably in response to implementation of BMPs, road improvements, and changes in grazing management.

Aerial photo analyses conducted during TMDL planning provide additional information pertaining to sediment pollution. Old clear cuts were apparent from aerial imagery. However, sensitive reaches within distinct valley portions appeared to have substantial shrub cover and a stable, sinuous channel.

Observations by DEQ personnel in 2001 provided additional insight into conditions in Tie Creek. Dense growth of young willows occupied much of the riparian area with mature shrubs being more scattered. Eroding banks were widespread at the upstream sampling site, but not the lower. Sand sized particles were a dominant gradation on the streambed.

Field observations during the 2004 sediment TMDL monitoring describe a riparian area recovering from past grazing practices. Willows were abundant but they were a relatively young stand. Beavers were apparently thriving in this reach and would likely increase pool habitat in the near future.

TMDL sediment and habitat monitoring suggest implementation of BMPs and restoration efforts have affected recovery in Tie Creek. The assessed reach had low width-to-depth ratio typical of a Rosgen E channel and was non-entrenched, indicating easy access to its floodplain during high flows. Shrub cover compared favorably to reference reaches with about 60 percent of both the green line and line transect comprised of shrubs (**Table 5-20**). Similarly, bare ground was rare suggesting vegetation protected banks from erosion. Slightly elevated bank erosion may be an artifact of past land use.

Pool habitat measures and proportions of surface fines provide information on the effect of in channel sediment on fisheries and aquatic life. Pool frequency was low compared to reference; however, this measure under represents pools as beavers had areas near this reach and should be considered a natural condition. High proportions of fine sediment were found in riffles, although fines in viewing buckets were relatively low (**Table 5-20**). This also could be related to beaver activity or past and present land use activities in the watershed.

Aquatic insect community metrics at two sites were slightly lower than criteria based upon regional expectations. Tie Creek has populations of brook, burbot, longnose dace, mottled sculpin and sucker.

5.19.2 Summary of Sediment Conditions and Conclusions

Although historic land use practices reportedly contributed considerable amounts of fine sediment to Tie Creek, subsequent recovery and restoration efforts have been successful in reducing sediment loading to streams. The existing conditions assessment indicates that fine sediment is at a level that may impact aquatic life and biological indicators are consistent with this assessment. Although, this existing conditions assessment does not indicate if the fine sediment conditions are lingering affects from existing and past management or from natural conditions such as granitic geology and beaver influences. A TMDL source assessment is provided in this document to investigate sediment sources more accurately and potentially provide allocations to those sources.

Table 5-20: Summary of sediment targets and existing conditions in Tie Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble Counts Percent fines (≤ 6 mm in riffles)	TI02	target	**33**	**≤ 13**	**N**
	Pebble Counts Percent fines (≤ 2 mm in riffles)	TI02	target	**26**	**≤ 13**	**N**
	Percent Fines Grid (≤6mm pool tailout)	TI02	SI	M = 9 25th = 6	Median ≤ 51 25th percentile ≤ 42	Y
	Pool frequency	TI02	SI	5	≤ 6	Y
	Width-to-depth ratio	TI02	target	75th = 10 M = 9	75th percentile ≤ 13 Median ≤ 10	Y
	Understory shrub cover along greenline	TI02	target	25th =49 M = 51	25th percentile ≥ 36 Median ≥ 41	Y
	Eroding banks (ft^2)	TI02	SI	**161**	≤ 113	**N**
	Macroinvertebrates	Aquatic insect community metrics are slightly lower than criteria based upon regional expectations.				
	Human Sources Present	Grazing, unpaved road and silviculture management are present.				

5.20 Trail Creek

The Trail Creek drainage is the largest montane watershed in the west side of the upper Big Hole River planning area. It originates along the Continental Divide and Idaho border then flows east to its confluence with the North Fork Big Hole River. The DEQ lists two segments of Trail Creek as impaired. The upper segment, which extends from its headwaters until its confluence with Joseph Creek, includes siltation and physical substrate habitat alterations as probable causes of impairment. The lower segment, which covers the remaining length of this stream, is listed for the same probable causes as the upper segment.

Trail Creek watershed is predominantly under management by the USFS with 91 percent of the basin within the Beaverhead National Forest. Eight percent of this watershed lies on private lands and less than 1 percent is on the Big Hole National Battlefield.

5.20.1 Sediment

The USFS also divides the Trail Creek watershed in its planning and management documentation. The upper portion is nearly entirely on USFS holdings, with only 0.4 percent lying on private lands. Land uses on this portion of the watershed include extensive roads, multiple use trails, and the related recreational opportunities. Road density varies across this portion of the watershed with 20 percent having no roads, 31 percent having low road density, and 31 percent and 18 percent having moderate and high road density respectively. Mining and logging have also occurred in the watershed. One known placer mine occurs in the drainage. During the 1970s and 1980s, nearly 11 percent of the drainage had 60 percent or more of the trees removed. Sediment inputs from timber harvest and associated activities were probably significant in the past.

Livestock grazing was traditionally a significant activity in this watershed; however, the USFS ceased grazing in the watershed in 2000. This management change, combined with natural recovery of logged areas, was attributable for improvements in riparian condition and reduced embeddedness.

Natural disturbance is another factor with potential to increase sediment loading and contribute to channel alterations in the Trail Creek watershed. The Gibbons Pass fire and Mussigbrod fire burned at least 16 percent of the watershed.

Roads are a significant factor in the lower Trail Creek watershed. Nearly 42 miles of roads occur on USFS lands with 18 percent having no roads, 22 percent having low road density, 33 percent having moderate road density, and 27 percent having high road density. Numerous road crossings occur in the drainage with 18 crossings over perennial streams and 29 crossings over intermittent streams. Road surfacing at crossing varies. Most crossings of perennial segments are asphalt with only six comprised of native materials. Intermittent road crossings are mostly of native materials with seven paved crossings and one gravel crossing. Road traction sanding along Highway 43 has potential for influencing Trail Creek as it parallels the stream for much of its length. Another road related source of sediment was an unauthorized channelization of Placer Creek associated with road construction, which delivered large amounts of sediment to Trail Creek in the past.

Stream assessments conducted by the USFS during 2000-2001 depict a stream influenced by wildfire but probably recovering from logging in the 1970s and 1980s and livestock grazing since exclusion in 2000. Assessed reaches showed evidence of past livestock use but were on an upward trend. Wildfire was often attributable for the highly mobile substrate in these E channels. Although not specifically mentioned in USFS descriptive narratives, the basin geology is probably also a factor in promoting a fine-grained streambed.

Aerial photo assessments conducted as part of TMDL planning provided information on geomorphology and land use in Trail Creek (Confluence et al. 2003). Geomorphology reflected landform with several reaches confined laterally by valley walls. Conifers comprised the riparian vegetation in these reaches. Several reaches occupying montane valleys had highly sinuous E channels with dense willows. Reach TC03 appeared to have experience riparian clearing; however, field investigations in 2004 indicated substantial recovery following removal of livestock. Timber harvest on adjacent hill slopes was apparent for much of Trail Creek.

Sediment TMDL monitoring provides more detailed instream sediment and habitat information on several reaches of Trail Creek. Of the four assessed reaches, three occupied montane valleys with dense stands of willows and a sinuous channel with low width-to-depth ratios (cross reference). The exception was reach TC08, which lies in a canyon reach with Highway 43 paralleling the stream for much of its length. Field notes suggest channelization by this highway contributed to habitat alterations in this reach of stream. In addition, given proximity of this road to Trail Creek, it is possible that road traction sanding is a source of sediment loading to Trail Creek.

Comparison of available data to numeric targets and supplemental indictors for Trail Creek indicate intact riparian and instream conditions for most reaches with a few exceptions (**Table 5-21**). Riparian shrubs on TC02 were below target; however, coniferous forest accounted for some of these apparent deficiencies. Reach TC08 also had considerable proportions of coniferous forest, which resulted in relatively low cover of riparian shrubs. Discrepancies between quality assurance replicates on TC08 were the result of beavers impounding the reach between site visits. Measured pool frequency generally met objectives (**Table 5-21**). Eroding banks were slightly high at a number of sites and could be related to human activities such as roads, historic grazing, or increase in water yields due to timber harvest or fire.

Most reaches failed to meet targets for percent fines measured with pebble counts or the grid counts in pools (**Table 5-21**). Nevertheless, these targets do not distinguish between natural or anthropogenic loading. Fire and natural sandy soils and geology are present but historic grazing, extensive unpaved roads, road sanding and past timber harvest may contribute to increased levels of fine sediment in a naturally sensitive watershed.

Aquatic insect communities have been assessed at five sites during 2001 and 2004. Most sites did not meet criteria for healthy aquatic insect communities (**Table 5-21**). Trail Creek contains populations of brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, mountain whitefish and sculpin (MFISH). Trail Creek has an abundance of tributaries that contain a number of fish species.

Table 5-21: Summary of sediment targets and existing conditions for Trail Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble counts percent fines (≤ 6 mm in riffles)	TC02	target	7	≤ 13	Y
		TC03		**42**		**N**
		TC07		**34**		**N**
		TC08		**29**		**N**
		TC08B		**28**		**N**
	Pebble counts percent fines (≤ 2 mm in riffles)	TC02	target	4	≤ 13	Y
		TC03		**27**		**N**
		TC07		**23**		**N**
		TC08		**19**		**N**
		TC08B		**23**		**N**
	Percent fines grid (≤ 6 mm pool tailout)	TC02	SI	25th = 35 M = 46	25th percentile ≤ 42 Median ≤ 51	Y
		TC03		25th = 14 M = 23		Y
		TC07		25th = 43 **M = 71**		**N**
		TC08		**25th = 27** **M = 37**	25th percentile ≤ 5 Median ≤ 10	**N**
	Pool frequency	TC02	SI	5	≤ 6	Y
		TC03		**8**		**N**
		TC07		6		Y
		TC08		9	NA	NA
	Width-to-depth ratio	TC02	target	75th = 13 M = 10	75th percentile ≤ 13 Median ≤ 10	Y
		TC03		75th = 11 M = 9		Y
		TC07		75th = 11 M = 10		Y
		TC08		**75th = 41** **M = 35**	75th percentile ≤ 15 Median ≤ 13	**N**
		TC08B		**75th = 22** **M = 22**		**N**
	Understory shrub cover along green line	TC02	target	**25th = 35** **M = 36**	25th percentile ≥ 36 Median ≥ 41	**N**
		TC03		25th = 42 M = 45		Y
		TC07		25th = 35 M = 40		Y
		TC08		25th = 50 M = 56	NA	NA
		TC08B		25th = 2 M = 7		NA
	Eroding bank (ft^2)	TC02	SI	36	≤ 113	Y
		TC03		**183**		**N**
		TC07		36		Y
		TC08		**327**		**N**
	Macroinvertebrates	1 of 5 samples met MMI 2 of 5 samples met O/E				
	Human Sources Present	Historic grazing, past timber harvest, and road sanding				

5.20.2 Summary of Sediment Conditions and Conclusions

Available information for Trail Creek confirms possible loading of sediment from several human activities. Past logging and roads may contribute sediment to Trail Creek and its tributaries. Road traction sanding is among the road related sources of sediment. In contrast, exclusion of livestock grazing since 2000 has resulted in recovery of riparian vegetation and its functional attributes but lingering sediment from grazing may be present in the stream. Sediment levels in Trail Creek are above targets that are likely to impact aquatic life and fish. A sediment TMDL source assessment will be pursued.

5.21 Warm Springs Creek

Warm Springs Creek is a second order tributary of the Big Hole River originating in the Pioneer Mountains on the east side of the basin (**Appendix K**, **Map 1**). The majority of the watershed lies on USFS lands with about 4 miles of channel flowing across private lands in the foothills and valley land type. Warm Springs Creek is named so because of thermal springs that enter the stream near Jackson. A portion of these springs are used for the Jackson Hot Springs Pool. DEQ monitoring personnel evaluated Warm Springs Creek in 2003 to meet requirements for updating the 303(d) listing. These data indicated sedimentation/siltation, nitrogen, phosphorus, and alteration instream side vegetation impaired beneficial uses. The nutrient listings were new to the 2004 list and the TMDL project had been initiated prior to this date, therefore nutrient listings are not addressed.

5.21.1 Sediment

Information allowing evaluation of sediment as a constraint on beneficial uses in Warm Springs Creek comes from a number of sources. These include stream narratives, aerial photo evaluations, and field investigations. Together, these confirm the appropriateness of this listing for Warm Springs Creek.

Livestock grazing is the major land use in the portions of the watershed within the national forest. Stream assessments by the USFS indicate livestock grazing has resulted in geomorphic shifts to the stream channel. Road density is low with 98 percent of USFS lands being “inventoried roadless”. Very little commercial timber harvest has occurred in the basin. The aerial photo analyses noted several types of impairment among reaches on Warm Springs Creek (Confluence 2003). Livestock grazing appeared to reduce riparian shrub cover and increase bank erosion for significant portions of this stream. Observed flow diversions may impact sediment transport.

TMDL monitoring field notes confirm the need for grazing BMPs to reduce sediment inputs to this stream. Two of the three assessed reaches were overly wide with vegetation removal and trampling indicated as the cause of channel alterations. Although grazing practices had not reduced shrub cover below targets, bare ground was prevalent suggesting limited bank protection during high flows. A survey of eroding banks found reaches on Warm Springs Creek to substantially exceed both area and erodibility ratings from reference reaches (**Table 5-22**). Despite high proportions of eroding banks, both pebble counts and pool tail monitoring results showed low levels of fines on the streambed (**Table 5-22**). Also, 303(d) List pebble count monitoring produced results lower than targets even though methods not the same as those used to derive sediment targets.

Aquatic insect communities appear to be mostly healthy. One metric at one site is moderately low but is likely influenced by natural hot springs. Warm Springs Creek contains populations of brook trout, burbot, longnose dace, longnose sucker, mottled sculpin, westslope cutthroat trout and westslope cutthroat x Yellowstone cutthroat trout hybrids.

The high proportion of eroding banks linked to livestock grazing practices suggests sediment loading is above natural, although sediment is not depositing or apparently affecting biological uses within the stream as it is transported. Because of this, a sediment TMDL will not be pursued at this time. Sediment production and habitat alteration does occur and restoration approaches to reduce sediment derived via bank erosion in the watershed should be pursued even though a TMDL is not needed. The TMDL allocation approach for the Upper Big Hole River will include addressing bank erosion in Warm Springs Creek.

Table 5-22: Summary of sediment targets and existing conditions for Warm Springs Creek.

Pollutant	Parameter	Reach Name	Target or SI	Value/ Score	Target Column	Met target?
Sediment	Pebble counts percent fines (< 6 mm in riffles)	WS07	target	6	≤ 13	Y
		WS10		1	≤ 22	Y
		WS11		11		Y
	Pebble counts percent fines (< 2 mm in riffles)	WS07	target	2	≤ 13	Y
		WS10		1	≤ 18	Y
		WS11		5		Y
	Percent fines grid (<6mm pool tailout)	WS07	SI	25th = 2 M = 8	25th percentile ≤ 5 Median ≤ 10	Y
		WS10		25th = 5 M = 6	25th percentile ≤ 27 Median ≤ 80	Y
		WS11		25th = 5 M = 8		Y
	Pool frequency	WS07	target	3	NA	NA
		WS10		7	≤ 8	Y
		WS11		6		Y
	Width-to-depth ratio	WS07	Target	75th = 30 M = 30	75th percentile ≤ 15 Median ≤ 13	N
		WS10		75th = 15 M = 15	75th percentile ≤ 20 Median ≤ 14	Y
		WS11		75th = 17 M = 7		Y
	Understory shrubs along greenline	WS07	target	25th = 74 M = 79	NA	NA
		WS10		25th = 50 M = 58	25th percentile ≥ 32 Median ≥ 58	Y
		WS11		25th = 37 **M = 48**		**N**
	Eroding banks (ft^2)	WS07	SI	**243**	≤ 113	**N**
		WS10		**608**	≤ 212	**N**
		WS11		**1834**		**N**
	Macroinvertebrates	Aquatic insect communities appear to be mostly healthy. One metric at one site is moderately low but may be influenced by natural hot springs.				
	Human Sources Present	Limited roads, moderate grazing use, and limited past timber harvest				

5.21.2 Summary of Sediment Conditions and Conclusions

Available information for Warm Springs Creek confirms possible loading of sediment from grazing and haying activities. Instream sediment, pool, and aquatic insect monitoring indicates that the sediment derived from bank erosion is likely not affecting beneficial uses. A sediment TMDL is not pursued at this time although the Big Hole River sediment TMDL allocation strategy will consider Warm Spring Creek as a source of sediments.

SECTION 6.0
DESCRIPTION OF TMDL COMPONENTS

A TMDL is basically a loading capacity for a particular water body and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. A TMDL can also be thought of as a reduction in pollutant loading resulting in attainment of water quality standards. More specifically, a TMDL is the sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background sources. In addition, the TMDL includes a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the pollutant conditions of the receiving stream. The allowable pollutant load must ensure that the water body being addressed by the TMDL will be able to attain and maintain water quality standards regardless of seasonal variations in water quality conditions, stream flows, and pollutant loading. TMDLs are expressed by the following equation:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

Each of the following three sections of the document (**Sections 7 – 9**) are organized by the four pollutants of concern in the Middle and Lower Big Hole TPA: sediment, nutrients, metals, and temperature. Each section includes a source assessment process for that pollutant, relevant water quality targets, a comparison of existing conditions to targets, quantification of loading from identified sources, TMDLs, and allocations to sources. Although the way a TMDL is expressed may vary by pollutant, these components are common to all TMDLs, regardless of pollutant. The major components that go into TMDL development are described in detail below.

6.1 Establishing and Evaluating Targets

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets and supplemental indicators are developed to help assess the condition of the water body relative to the applicable standard(s) and to help determine successful TMDL implementation. This document outlines water quality targets for each pollutant of concern in the Upper and Middle Big Hole TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric values are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets help to further interpret the narrative standard and provide an improved understanding of impairment conditions. Water quality targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to link each pollutant to impacted uses. This was completed in **Sections 4.0** and **5.0**. Targets also provide benchmarks to evaluate overall success of ongoing and future restoration activities.

6.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source permitted under the Montana Pollution Discharge Elimination System (MPDES) program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. Alternatively, a sub-watershed, tributary, or source area approach can be used; whereby, most or all nonpoint sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading (40CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches depending on the level of desired certainty for setting allocations and guiding implementation activities.

Figure 6-1 is a schematic diagram illustrating how numerous sources contribute to the existing load(s) and how a TMDL is determined by comparing the existing load(s) to that which will meet standards.

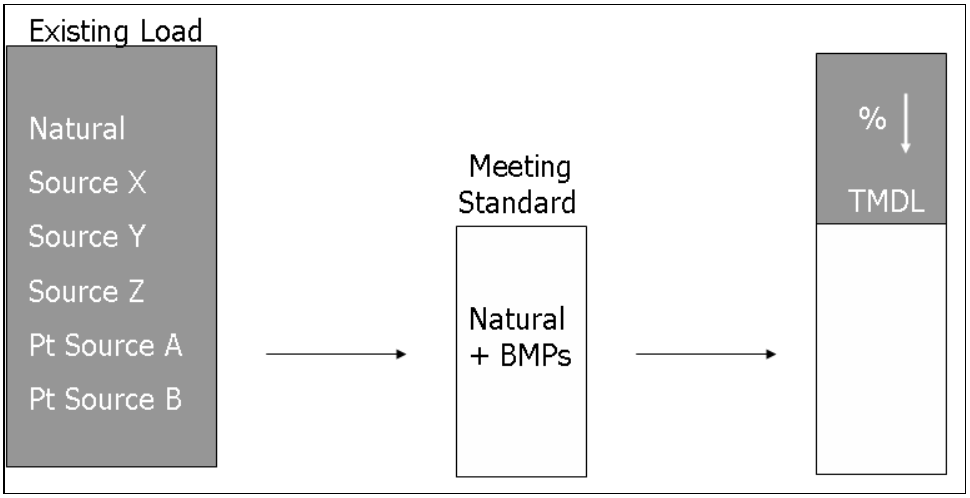


Figure 6-1: Schematic example of TMDL development.

6.3 Determining Allocations

Once the loading capacity (i.e. TMDL) is determined, that total must be divided, or allocated, among the contributing sources. Allocations are determined by quantifying feasible and achievable load reductions associated with the application of reasonable land, soil, and water conservation practices. Reasonable land, soil, and water conservation practices generally include BMPs, but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses. **Figure 6-2** contains a schematic diagram of how TMDLs are allocated to different sources using Waste Load Allocations (WLAs) for point sources and Load Allocations (LAs) for natural and nonpoint sources. Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure."* Allocations are typically expressed as a load, a percent reduction (from the current load), or as a surrogate measure, such as a percent increase in canopy density for temperature TMDLs. Load based allocations are typically desired if analysis allows; but, for certain pollutants such as nonpoint source temperature TMDLS, they may not be as useful as other more appropriate measures.

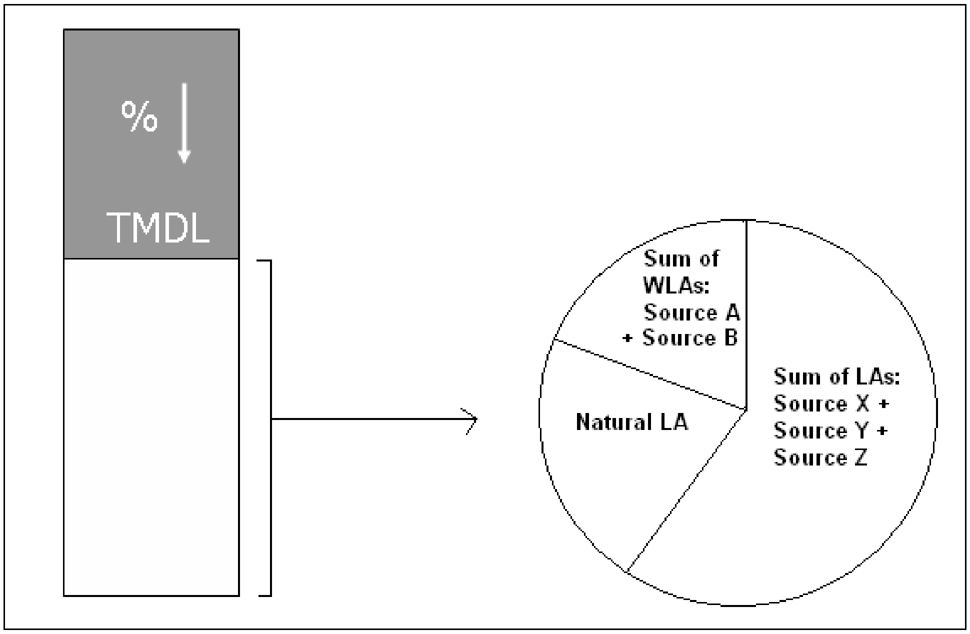


Figure 6-2: Schematic diagram of TMDL and allocations.

6.4 Margin of Safety

Incorporating a Margin of Safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (EPA, 1999). The TMDLs within this document incorporate an implicit MOS in a variety of ways that are discussed in detail by pollutant in **Sections 7-9**.

SECTION 7.0
TEMPERATURE SOURCE ASSESSMENT, LOAD ALLOCATIONS, AND MARGIN OF SAFETY

This section addresses three components of TMDLs associated with reducing the loading of pollutants to surface waters, specifically the source assessment, load allocations, and margin of safety. These interrelated elements provide the quantitative basis for reducing pollutants and meeting water quality standards, while addressing uncertainty.

A comprehensive source assessment is a critical component of water quality restoration planning and a required element of TMDL plans. The objective of the source assessment is to characterize the type, magnitude, and location of pollutant sources to surface waters. The first step in accomplishing this aim is a compilation of an inventory of all possible sources (EPA 1999). Procedures to achieve this vary with pollutant and stream; however, a number of general approaches apply. These include assessments of maps, reports, or field surveys. Because of the complexity of source loading and watershed delivery processes across basins, a combination of techniques is typically necessary.

Following source inventory, the next step is determination of the relative magnitude of loading from various sources with emphasis on the primary and controllable sources. Natural sources of a pollutant are also a consideration, although reduction of pollutant loading from these sources is not a goal. Modeling, statistical analyses, literature review, or a combination of methods facilitates estimating of the magnitude of pollutant loading from the identified sources.

With identification of sources and their relative contributions determined, the next step in the TMDL process is to allocate an allowable load to each of the identified sources. A load allocation is the component of the TMDL plan that assigns an overall load, or reduction in pollutant loading, for each source and is a required element of a TMDL plan. A TMDL is the sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (**Equation 7-1**). In addition, the TMDL includes a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream.

Equation 7-1:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

Monitoring, modeling, and extrapolation has provided much of the technical framework for developing allocations for pollutants across the basin. A brief review of modeling methods, results, and limitations are provided in this document, but details are provided in the technical appendices. Summaries of findings are provided for each pollutant and stream TMDL combination within the document. Allocations are provided to help prioritize restoration activities within the watershed and leverage future funding for restoration.

7.1 Thermal Alterations

In addition to TMDL guidance provided in **Section 7.0**, the Federal Code (40 CFR 130.7c2) provides additional guidance on developing temperature TMDLs and justification for incorporating flow volumes into TMDL planning efforts for temperature. Specifically, the Federal Code prescribes states to estimate the total maximum daily thermal load which cannot be exceeded in order to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife. Pertinent factors in these estimates include water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters.

Thermal alterations are among the listed pollutants of concern for two streams in the Upper Big Hole River TPA, the Big Hole River, and Pintlar Creek. A temperature TMDL for the Big Hole River will be provided in this section of the document. Pintlar Creek's thermal impairment condition is not obvious when assessing existing information, and the main source of thermal influence were irrigation withdrawals. Pintlar Creek Watershed's irrigation system is poorly understood at this time. Therefore, Pintlar Creek's thermal TMDL will be pursued at a later date.

There are no known point sources contributing to thermal loading in the watershed. Nonpoint source (NPS) thermal loading presents a scenario that differs from most pollutants because the "sources" are not heat sources in the true sense. Rather, alterations to riparian vegetation, channel geometry, and flow volumes lead to increased insolation of the water and decreased thermal inertia. These factors ultimately promote warmer or cooler water temperatures by influencing thermal transfer from the surrounding environment to the stream. As detailed in the existing conditions (**Section 5**), these alterations are pronounced along much of the Upper Big Hole River. Because of their role in influencing temperature regime and thermal loading, these "sources" will be referred to as influential factors.

Irrigation return flows, either surface returns via field runoff or from ditches, present another potential source of thermal loading to streams in the Upper Big Hole River TPA. Although these may be relatively discrete inputs, the ephemeral nature of these sources made them difficult to evaluate with available resources. Additionally, given the extent and severity of shrub removal, channel alterations, and dewatering, these sources are likely a minor component of heat entering the Big Hole River. A long-term monitoring and adaptive management approach includes provisions to evaluate irrigation returns and potentially mitigate their inputs.

Several investigations were used to identify and quantify thermal influences and link them to temperature conditions. An aerial photo analysis combined with field investigations identified reaches where modifications to riparian vegetation, channel geometry, and flow modification possibly impact temperatures. Continuous temperature monitoring devices were deployed along with stream channel, riparian vegetation, stream shading, and discharge field measurements. Thermal modeling was built upon temperature, stream flow, and riparian vegetation monitoring results, and modeling results provide the basis to allocate among influential thermal factors in the Big Hole. The influential factors investigated to determine their role in attenuating thermal loading included riparian vegetation, channel geometry, and flow volume.

7.1.1 Source Assessment

Aerial photo evaluations indicated reduced shrub cover was considerable along the Big Hole River with nearly one-third the length having sparse riparian vegetation (Confluence et al. 2003). These results indicate lack of shading is a significant potential factor influencing thermal loading on the Big Hole River. The expected riparian vegetation community is shrub dominated in this area. Sparse riparian conditions covering about one-third of the Upper Big Hole River segment, moderate conditions cover 44%, and dense riparian conditions covering about a quarter of the segment. Similarly, evidence of bank erosion visible in aerial photos provides a means to evaluate lateral channel adjustments which are usually associated with channel widening. Reaches with obvious evidence of bank erosion comprised over 33% of the entire length of the Big Hole River. Moreover, comparisons among vintages of aerial photos allowed calculation of bank migration, with some bend ways moving over 15 feet per year.

Six reaches on the Big Hole River were the subjects of thermal monitoring efforts, and four reaches were modeled using the SSTEMP model (**Table 7-1**). Modeling was used to provide a link between thermally influencing factors and instream temperatures. Two of the reaches were not modeled because of naturally braded stream channel conditions that could not be modeled easily. The studied reaches represented both least impacted and highly impacted reaches. All reaches lie within valley areas with an expected dominant shrub understory. Reference reaches provided the “potential” or least impacted channel dimensions and riparian shading characteristics for use in developing allocations (**Appendix C**). Also, the whole length of the Upper Big Hole River to the confluence of Pintlar Creek was modeled using averaged conditions along the entire reach to estimate overall effects of influencing conditions along the entire segment of the Upper Big Hole River (**Appendix D**).

Table 7-1: Reaches included in thermal modeling efforts for the Upper Big Hole River TPA.

Stream	Reach	Reference or Impacted	Monitored	Modeled
Big Hole River	BH09	Reference	Yes	No
Big Hole River	BH18	Reference	Yes	Yes
Big Hole River	BH19	Impacted	Yes	No
Big Hole River	BH22	Impacted	Yes	Yes
Big Hole River	BH26	Impacted	Yes	Yes
Big Hole River	BH28	Reference	Yes	Yes
Big Hole River	All	Both	See above	Yes

The stream segment temperature model or SSTEMP (Bartholow 2002) evaluates the thermal effects of proposed management strategies. The modeling is completed by first calibrating the model and then altering riparian vegetation, the physical characteristics of the stream, or altering stream withdrawals on individual stream segments. SSTEMP is a simplified version of the stream network temperature model (SNTEMP) designed to develop temperature models for large stream systems or networks (Bartholow 2002). SSTEMP is a physically based model that operates on basic energy balance principles. Data inputs include hydrology, meteorology, stream channel geometry, time of year, and shading (topographic and vegetative). SSTEMP includes a sensitivity and uncertainty analysis feature, which allows the modeler to see which input parameters have the greatest effect on the predicted output. The model gives predictions of mean daily and maximum water temperatures at the downstream end of the modeled reach.

Because of the reasoning reported in **Appendix B**, the model generally didn't calibrate with high certainty for the study reaches. An alternative was the development of a demonstrative model design using flow, temperature, and meteorological data available from the summer of 2004. This alternative was feasible given the relatively small data collection budget and the complex stream channel and irrigation systems in the study areas. Because it has not been fully calibrated, the drawback of the SSTEMP modeling effort is that it cannot be used to predict resultant temperatures over a wide range of hydrologic and meteorological conditions for the segments that were modeled. However, a semi-calibrated model can be used to provide comparisons of the relative significance of altered flow rate, riparian vegetation, and channel geometry on thermal loading and reach outflow temperatures.

Weather is the biggest driving force of temperature within the Upper Big Hole River, but was held constant for warm summer conditions during modeling. Modeling results indicate that summertime temperatures within the Upper Big Hole River is related to the three major human caused influential factors, riparian shading, stream flow, and channel geometry, in different ways. Based on analysis of *mean* daily outflow results of the SSTEMP models, the most significant factor influencing thermal pollution to the Upper Big Hole River is reduced riparian vegetation, followed by impacts from reduced stream flow and over-widened channel geometry (in decreasing order of significance). Based on analysis of *maximum* daily outflow results of the SSTEMP models, the most significant source of thermal influence to the Upper Big Hole River is reduced stream flow, followed closely by reduced riparian vegetation and over-widened channel geometry (**Appendix B**).

The model provides estimated temperature reductions which would come from implementing reasonable irrigation management practices, regenerated riparian shrubs, and restoring channel conditions. Almost all of the impacts influencing these conditions are resulting from agricultural practices. The modeling effort identifies that existing temperature conditions in the Upper Big Hole River exceed the applicable temperature water quality standard.

7.1.2 Temperature TMDL and Load Allocations

Monitoring and modeling results provide the technical framework for developing a surrogate based temperature TMDL and allocation approach within this document (**Appendix B**). If this surrogate based TMDL approach is employed, the thermal loading capacities provided in **Appendix B** will be met. Although a daily and instantaneous thermal loading capacity for heat is provided in **Appendix E**, they are not especially functional for restoration guidance. A surrogate-based TMDL approach provides utility in restoration efforts and is a sensible approach in this watershed because there are no point sources. The thermal loading capacities provided in **Appendix D** and the surrogate based approach, if implemented, will result in thermal loading reduction and assimilative capacity necessary to meet Montana's temperature standard applicable to the Big Hole River (**Section 3**). The surrogates for thermal loading are:

- The percent change in riparian canopy cover over the river that will achieve reference potential, applied to the sources that are currently limiting shade.
    - *Human Influences:* Almost all of the impact to riparian canopy cover is due to present or historic agricultural activities.
    - *Link to thermal conditions*:
        - More shading reduces sunlight, and thus heat, entering the stream.
        - Riparian vegetation creates a microclimate that is cooler than the surrounding landscape.
- Percent reduction in bankfull width to depth ratio of the Upper Big Hole River channel geometry.
    - *Human Influences*: Almost all of the impact to riparian canopy cover is due to present or historic agricultural activities.
    - *Link to thermal conditions*:
        - Lower width to depth ratio means a deeper, narrower channel that has small contact area with warm afternoon air.
        - Lower width to depth ratio will increase the effectiveness of shading produced by the riparian canopy.
- Reduction in warm water irrigation return flows via adaptive management approach.
    - *Human Influences*: Return flows may result from the agricultural irrigation system.
    - *Link to thermal conditions*:
        - Increased thermal load
- Increase instream flow volume due to voluntary reasonable irrigation water management practices and water leasing system that fit into existing water right framework. (This is not an allocation because it is not a true source of heat, but it influences the streams ability to buffer extreme temperature conditions.)
    - *Human Influences*: Agricultural activities.
    - *Link to thermal conditions*:
        - Increased water volume can attenuate a given thermal load to a lower temperature than a lesser volume of water.
        - More water in the stream channel decreases the surface area to water volume ratio. A decreased surface to volume ratio decreases the attenuation capacity of the stream.

Thermal conditions within the Big Hole River are largely the result of complex interactions among the factors outlined above, which prevents an easy interpretation of the influence of each one separate from the others. Modeling results indicate that all of these factors are affecting temperature in the Upper Big Hole River. **Table 7-2** provides a surrogate load allocation approach. The allocations indicate the relative change needed for each temperature influencing factor. If allocations are met in combination, they will achieve Montana's temperature standards. All thermal load reductions from the surrogate TMDL approach are allocated to agricultural activities and can be achieved by applying reasonable land, soil, and water conservation practices. The allocation approach was built upon reference conditions within the watershed where conservation practices are in use but the land is supporting agricultural activities. Daily and instantaneous thermal loading capacity (kilocalories/time) are provided in **Appendix D**.

Table 7-2: Temperature TMDL and allocations for the Upper Big Hole River.

Temperature Surrogates	Stream	Targets and Existing Conditions	Load Allocations - The thermal load reduction associated with:
Thermal Load Surrogates			
Canopy Density Measured Over the Stream	Big Hole River	Increase the median canopy density measured over the stream from 14% to ≥ 43	121% increase in canopy density
	Tributary Streams on the Big Hole River Valley Bottom	Increase the median canopy density measured over the stream from 49% to ≥ 63%	28% increase in canopy density
	Tributary Streams in Mountains	No decrease in canopy density unless conifer encroachment is proven	No change
Width-to-depth ratio	Big Hole River	Decrease the median W/D ratio from 34 to ≤ 22	35% decrease in width-to-depth
	Tributary streams in the Big Hole River Valley Bottom	Decrease the median W/D ratio from 15 to ≤ 14	6% decrease in width-to-depth
	Tributary Streams in Mountains	No human caused increases in W/D ratio	No change
Irrigation Return Flows	Big Hole River and Tributaries	Unknown but likely a minor source. Address in adaptive management	If present, reduce warm water irrigation return flows by 50%
Assimilative Capacity Surrogates follow (not a target):			
In-stream Flow	Big Hole River and Tributaries	Stream flows are often below the target of 60 cfs and the minimum survival flow of 20 cfs at Wisdom.	All reasonable irrigation water management practices with water savings applied to in-stream flow via a local, voluntary approach.

The allocation strategy and subsequent proposed restoration approaches consider that water rights can not be legally affected by any decisions provided in this document. Therefore, a locally coordinated approach is essential for achieving the goal of increasing summer time instream flows. Increasing thermal assimilative capacity via instream flow conservation must be accomplished within the sovereignty of Montana's water rights law.

7.1.3 Margin of Safety and Seasonal Considerations

Montana's temperature standard indicates there can be either a 0.5°F or 1°F increase in temperature above naturally occurring temperatures depending upon what the magnitude of the naturally occurring temperature. The margin of safety considerations for the thermal surrogate TMDL apply an implicit safety factor because if they are fully achieved, would reduce temperatures to naturally occurring levels without the standards consideration of 0.5°F or 1°F heating above naturally occurring temperatures.

Allocations to riparian shading incorporate data from a least impacted reach on the Big Hole River that had exemplary riparian conditions, in conjunction with well-managed livestock grazing. Similarly, desired channel geometry follows a conservative approach based on three reference reaches showing stable channel geomorphology and width-to-depth ratios considerably lower than impaired reaches. Another provision to ensure margin of safety involves assessing not only the factors that affect thermal loads, but also addressing in-stream flows that affect the streams capacity to absorb heat without increasing temperature.

Seasonal considerations are significant for temperature. Obviously, with high temperatures being a primary limiting factor for Arctic grayling in the Big Hole River, summer temperatures are a paramount concern. Therefore, focusing on summer thermal regime is the appropriate approach. Nevertheless, the types of perturbations in the Upper Big Hole River TPA may also limit overwintering habitat. Removal of canopy cover increases formation of anchor ice, ice jams and bank scour from ice, which may physically limit habitat for fish (Winegar 1977). This may be especially pronounced in overly wide sections where conditions for anchor ice formation are favorable. Therefore, although the allocations and restoration plans were developed chiefly with summer temperatures in mind, the aquatic community will also benefit during winter months because the restoration approaches will likely decrease extreme temperature fluctuations. In portions of the Big Hole River, anchor ice and ice scour conditions will likely be abated.

7.1.4 Uncertainty and Adaptive Management

The source assessments used as the basis for the percent reduction allocations to influencing factors assessed all sizeable thermal sources. Uncertainty in the linkage of influencing factors to thermal loading is addressed through an adaptive management approach where the TMDL and allocations from this document can be revised as additional information is collected. Adaptive management is part of the MOS and requires long-term monitoring to track BMPs and stream conditions to determine if targets have been achieved. This approach allows management recommendations and practices to be revised if targets have not been met. Monitoring recommendations are detailed in **Section 11.0.**

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

Noticeable improvement in habitat and reduction in sediment loading will not occur until most types of restoration mechanisms or management based activities have been in place for several years or more. Habitat improvements, due to grazing BMPs should be observable within 5-10 years after project implementation. Therefore, thermal reductions from the allocation process will be a long-term goal.

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

SECTION 8.0
SEDIMENT SOURCE ASSESSMENT, LOAD ALLOCATIONS, AND MARGIN OF SAFETY

TMDLs and load allocations will be developed for the streams in need of sediment TMDLs (**Section 5.0**). A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. More specifically, a TMDL is the sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background sources. In addition, the TMDL includes a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The allowable pollutant load must ensure that the water body being addressed by the TMDL will be able to attain and maintain water quality standards regardless of seasonal variations in water quality conditions, streamflows, and pollutant loading. Because there are no point sources within the Upper and North Fork Big Hole River TPA, WLAs are excluded and TMDLs are expressed by the following equation:

$$\text{TMDL} = \Sigma \text{LA} + \text{MOS}$$

The sediment TMDL process presented in this main document for the TPA will adhere to this TMDL loading function, but use an average annual sediment yield source assessment, a percent reduction in loading allocated among sources, and an inherent margin of safety. A percent reduction approach is used because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads creates a rigid perception that the loads are absolutely conclusive. A percent reduction allocation also considers the whole watershed as a source area and fits into a watershed wide water quality restoration planning approach. The total maximum daily load for each 303(d) listed water body is expressed as an overall percent reduction in the sediment load and is derived from the sum of the percent reduction allocations to varying sources.

Because there are no point sources and sediment generally has a cumulative effect on beneficial uses, an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation. EPA encourages TMDLs to be expressed in the most applicable timescale but also requires TMDLs to be presented as daily loads (Grumbles 2006); daily loads are provided in **Appendix F**.

8.1 Allocation Development

The percent reduction allocations are based on the modeled BMP scenarios for each major source type (i.e. unpaved roads, upland erosion, and streambank erosion) and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments of areas with reasonable conservation practices in place. Percent reductions are expected to be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. **Section 8.2** provides a brief review of sediment source assessment techniques. No point sources are located in the watershed and all wasteload allocations are zero.

8.2 Sediment Source Assessment Summary

Sediment is among the pollutants of concern for a majority of the listed streams in the Upper and North Fork Big Hole River planning area (**Table 8-1**). The current ability to quantify sediment loads from diffuse sources across a large landscape such as those found within the Big Hole Watershed provides relative sediment estimates rather than exact sediment yields. An inventory of sediment sources began with a field reconnaissance, and an aerial photo survey completed in the first phase of TMDL planning (Confluence et al. 2003). In conjunction with the existing stream condition surveys, specific sediment source assessment activities consisted of eroding bank surveys, evaluations of riparian community structure and assessment of human activities that influence bank erosion. Sediment derived from bank erosion was estimated along each reach that was monitored and extrapolated across the watershed. Road surveys and associated road runoff modeling evaluated potential inputs from road crossings. The Montana Department of Transportation evaluated contributions of sediment to streams from road traction sanding on highway 43 (Hydrometrics 2005). Finally, watershed scale modeling efforts allowed estimation of anthropogenic upland erosion sources of sediment and their relative contributions to streams across the basin.

Table 8-1: Sediment TMDLs provided in the Upper/North Fork Big Hole TPAs

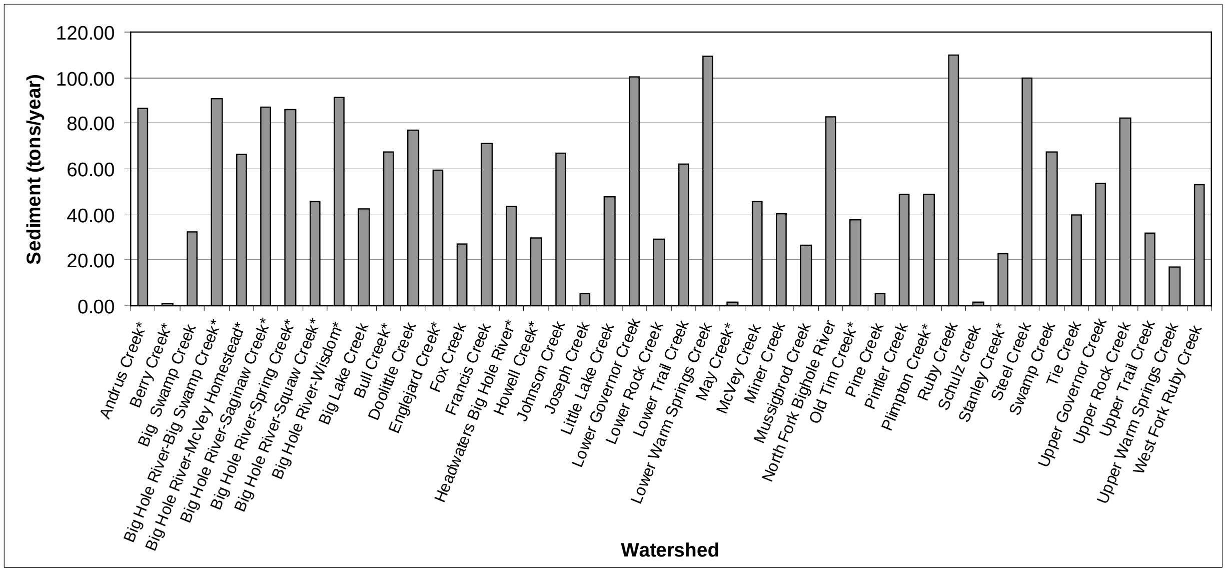
Big Hole River	North Fork Big Hole River
Doolittle Creek	Pine Creek
Fox Creek	Rock Creek
Francis Creek	Ruby Creek
Governor Creek	Schultz Creek
Johnson Creek	Steel Creek
Joseph Creek	Swamp Creek
McVey Creek	Tie Creek
Miner Creek	Trail Creek
Mussigbrod Creek	

8.2.1 Road Sediment Modeling

Fine sediment contributed from roads is a common source of sediment loading to streams. Factors relating to the potential for roads to contribute sediment to streams include road surface materials, proximity to streams, local topography, potential for conveyance, local road prism geometry, and cut/fill slope and vegetation cover. Application of the Washington road surface erosion model (WARSEM) allowed estimation of existing sediment loading from roads and potential reductions in loadings with implementation of road BMPs. The model is a Microsoft Access based model developed for and used by the State of Washington Department of Natural Resources for assessing sediment production and delivery to streams from roads under its jurisdiction. WARSEM is an empirical model, and estimates sediment production and delivery based on road surfacing, road use, underlying geology, precipitation, road age, road gradient, road geometry (including road configuration and ditch geometry), cut slope cover, and other factors (Dube et al. 2004).

To extrapolate the unpaved road runoff model results from the sampled road segments to the watershed as a whole, comprehensive datasets representing the locations of roads and streams were necessary. The GIS coverage of 2000 US Census Bureau's Topologically Intergrated Geographic Encoding and Referencing system (TIGER) road data for road locations, and the National Hydrography Dataset (NHD) for stream locations provided the basis for this extrapolation. Digitization of additional road locations from 1:24,000 scale digital orthophotos supplemented the coverage of local roads in the TIGER data. Sample sites were randomly picked from the road database and sampled. Site data was used for Washington Road Surface Erosion Model (WARSEM) modeling and ultimately the WARSEM results were extrapolated to the watershed scale using the initial GIS maps as the basis (**Appendix G**). Extrapolation to the entire watershed was based on three parameters, the lumped road class, road/stream orientation, and geology erosion factor.

Roads contribute variable sediment loads depending upon the local road network (**Figure 8.1**). The unpaved road runoff model indicates that various restoration approaches will provide considerable reduction in sediment loading to the watershed's stream network. The effectiveness of various BMPs, in terms of the amount of estimated reduction in sediment delivery, varies by sub-watershed. Reducing contributing road lengths that drain to streams along with roadside ditch BMPs will reduce loading significantly for most watersheds (**Appendix X**).



*watersheds with asterisks do not coincide with 303d listed tributaries but contribute to the overall load contributed to the upper Big Hole River segment. Some 303d listed watersheds may be broken into two reporting areas within this figure.

Figure 8-1: Sediment contribution from roads within watersheds in the upper Big Hole TPA.

8.2.2 Road Traction Sanding

Application of sand to highways during winter months has the potential to increase loading of fine sediment (< 2 mm in diameter) to surface waters in the Upper and North Fork Big Hole River planning area. Source assessments for this category of fine sediment delivery included spatial evaluations of roads adjacent to streams, and a study commissioned by the Montana Department of Transportation (MDT) to evaluate contributions to select streams in the basin (Hydrometrics 2005). Essentially, this study provides many components of the TMDL with respect to this potential source of fine sediment. This includes a source assessment, evaluation of the relative contribution, and a basis to allocate an allowable load from this source.

Field reconnaissance investigations indicated stream crossings and stream adjacent reaches of highway where the features associated with potential delivery of road traction sand to surface waters (Hydrometrics 2005). Sand entered highway adjacent reaches after being thrown or washed down embankments; however, presence of a flat, vegetated drainage bottom between the embankment and stream impeded most of the delivery to streams. Observers identified ten reaches presenting a sediment delivery risk (**Table 8-2**) and rated these according to their relative potential based on performance on a questionnaire that evaluated distance from road to stream, percent vegetative cover, slope of the embankment, observed presence of sand, and evidence of conveyance.

Table 8-2: Field reconnaissance results for Trail Creek stream segments proximal to Highway 43 (Hydrometrics 2005).

Stream Reach ID	Relative Road Sand Loading Potential (field inspection score)*	Stream Length Adjacent to Road Embankment	Average Distance Road Shoulder to Stream
TC-1	Low (10.0)	250	20
TC-2	Low (9.5)	300	30
TC-3	High (14.0)	300	15
TC-4	Low (9.0)	150	20
TC-5	High (12.5)	100	25
TC-6	High (12.5)	100	20
TC-7	High (12.5)	40	30
TC-8	Medium (12.0)	100	30
TC-9	Medium (12.0)	100	20
TC-10	Medium (12.0)	700	25

* Relative road sanding loading potential based on GIS analysis and field reconnaissance. Ratings are relative.

Stream crossings also presented risks for sediment loading along Highway 43 with 11 crossings identified as having moderate to high loading potential (**Table 8-3**). Factors contributing to delivery potential included distance of road to the stream, vegetative cover between road and stream, presence of road sand, and evidence of delivery of road sand to the stream. Road sand was attributable for a sharp contrast in substrate composition at several crossings. Sand comprised a majority of observed size fractions at these locations.

Table 8-3: Stream crossings with identified potential to deliver traction sand to surface waters in the Trail Creek drainage (Hydrometrics 2005).

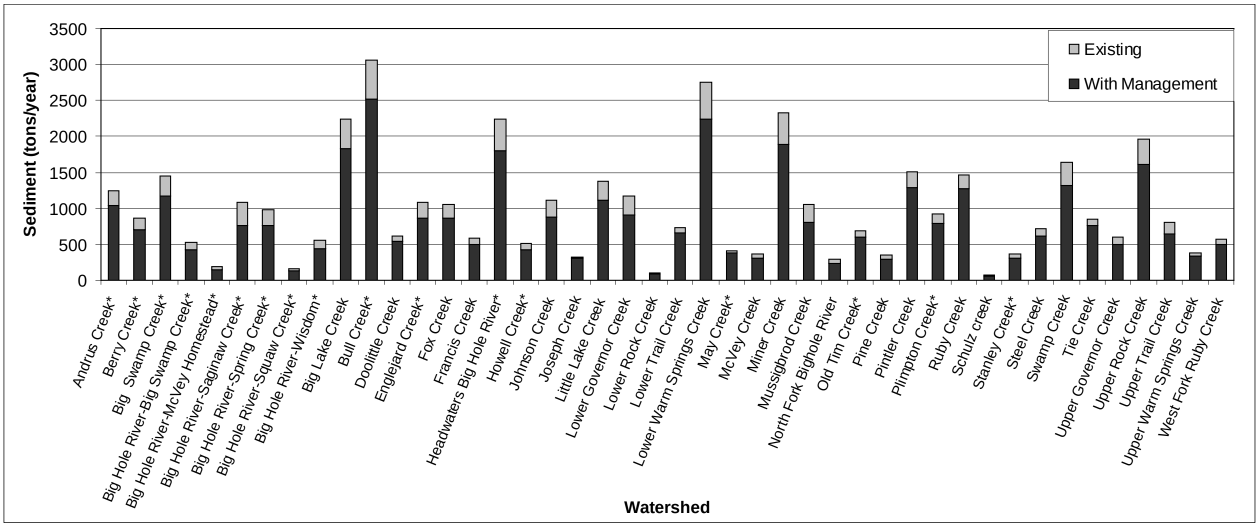
Site	Stream Name	Crossing Type	Relative Loading Potential
TCX-1	Trail Creek	Bridge	High
TCX-2	Sheep Creek	Culvert	Moderate
TCX-3	Trail Creek	Bridge	High
TCX-4	May Creek	Culvert	Moderate
TCX-5	Trail Creek	Bridge	High
TCX-6	Canyon Creek	Culvert	Moderate
TCX-7	Cascade Creek	Culvert	Moderate
TCX-8	Sage Creek	Culvert	Moderate
TCX-9	Runaway Creek	Culvert	Moderate
TCX-10	Placer Creek	Culvert	Moderate
TCX-11	Trail Creek	Bridge	High

* Relative loading potential based on GIS analysis and field reconnaissance.

The Hydrometrics study (2005) also assessed loads from the different source areas. Roadside embankments delivered 0.54 tons of sand to streams, and delivery at road crossings totaled 0.90 tons of sand, for 1.44 tons/year in the 2004-2005 winter season. Although road traction sanding and fill erosion are a small proportion of the overall sediment load for any 303d listed stream, allocations are provided. The allocation for road traction sand and any erosion from road prism fill is a 10 percent reduction. This reduction is based on the likelihood that BMP performances of restoration activities provided in the restoration section of this document will achieve at least a 10 percent reduction from road sanding and maintenance.

8.2.3 Upland Erosion

An upland erosion analysis using the universal soil loss equation estimates that hillslope erosion contributes approximately 43,000 tons of sediment per year to streams in the Upper and North Fork Big Hole River Watersheds (**Figure 8-2**). About 18 percent of upland erosion is attributable to human caused sources that can be reduced through the application of soil conservation practices. Similar to the relative amount of land use types found in the watershed, agriculture land and forest areas are the predominant sources of soil erosion within the Upper Big Hole Watershed. Timber harvest has the potential for transient short term (3-5 years) increases in sediment loading if located near streams. Yet the source assessment and allocation approach is valid because timber harvest is anticipated to occur at some level over time. As timber harvest areas reach 3-5 years in age, new areas will likely be harvested. Agricultural activities such as grazing and hay production provide sediment loads year after year in constant locations although hay production may produce higher short term loads when reseeded or rotated to alfalfa. **Appendix A** provides a review of the hillslope erosion rates by land cover type for all 6th code HUC watersheds in the basin. Agricultural practices that increase groundcover within the watershed have the most potential to reduce landscape erosion. Results of modeling agricultural practices that increase upland cover will be used to build sediment TMDLs and allocations, although increasing riparian vegetation's filtering capacity along the watersheds stream network is also an approach that will reduce sediment yield from upland sources (**Appendix A**).



*watersheds with asterisks do not coincide with 303d listed tributaries but contribute to the overall load to the upper Big Hole River segment. Some 303d listed watersheds may be broken into multiple watershed areas within this figure.

Figure 8-2: Estimated upland sediment load from watersheds within the Upper Big Hole TPA.

8.2.4 Sediment Contributed from Eroding Banks

Streambank erosion is an inherent part of channel evolution and contributes sediment to stream systems in response to a combination of climatic and physiographic factors. However, anthropogenic impacts, including poor land management, road systems, riparian vegetation removal, and/or channel alterations can result in elevated rates of streambank erosion and subsequent impacts to beneficial uses.

Sediment loading from streambank erosion was assessed in the upper Big Hole TPA by performing BEHI measurements and evaluating the Near Bank Stress (NBS) (Rosgen and Silvey 1996; Rosgen 2001). Measurements were made at 52 reaches along the Big Hole River and listed tributaries (**Appendix H**). BEHI scores were determined at each visually eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. In addition to BEHI data collection, surrounding land use practices and adjacent streamside vegetation condition were recorded. BEHI scores and estimates of sheer stress were used to estimate bank retreat rates using comparisons to regional bank retreat studies (**Appendix H**). Bank retreat rates, area of eroding bank, and bulk soil densities were used to estimate annual sediment load from monitored reaches.

Sediment loads from the reach scale were extrapolated to the watershed scale using aerial photos and GIS tools as described in **Appendix H**. Because riparian vegetation is crucial for bank stabilization, the existing and potential vegetation type and density were determined for all reaches. Average erosion rates associated with each reach type (based on land use and vegetation) were used to extrapolate bank erosion to each subwatershed within the TPA. To estimate the sediment reductions that could be achieved by the application of riparian BMPs, the loading rate was calculated for the potential vegetation type and density of each reach type when BMPs are in place. A more detailed description of this assessment can be found in *Sediment Contribution from Streambank Erosion*, which is included as **Appendix H**.

Bank erosion monitoring and modeling results indicate substantial reductions in sediment loading from eroding banks is possible with the recovery of riparian vegetative cover. Restoring riparian cover will result in an average 31 percent reduction of sediment loading from this source at a basin scale, or a reduction estimated at approximately 35,000 tons per year to the basin's streams (**Table 8-4**). Expressing this sediment load allocation by sub-watershed allows for prioritization of the largest contributors of sediment. Most human caused bank erosion in the Upper Big Hole Valley is caused by grazing and other agricultural activities, followed by road encroachment and road crossings.

Table 8-4: Bank erosion assessment results and allocations for sub-watersheds in the upper Big Hole River planning area.

6th Code HUC WS (Mod for 303d)	**Length of Streams in WS (ft)**	**Estimated Current Sediment Delivery (ton/yr)**	**Estimated Potential Sediment Delivery (ton/yr) Allocation by Sub-watershed**	**Percent Reduction**
Andrus Creek*****	158,037	3,106	1,411	55%
Berry Creek*****	63,938	115	115	0%
Big Swamp Creek	160,963	1,175	644	45%
Big Hole River-Big Swamp Creek*****	219,221	4,645	2,034	56%
Big Hole River-McVey Homestead*****	206,932	3,647	3,101	15%
Big Hole River-Saginaw Creek*****	164,496	2,972	1,461	51%
Big Hole River-Spring Creek*****	221,595	3,563	2,592	27%
Big Hole River-Squaw Creek*****	88,626	1,252	902	28%
Big Hole River-Wisdom*****	278,607	6,012	3,166	47%
Big Lake Creek	279,616	5,167	2,373	54%
Bull Creek*****	248,229	4,534	2,569	43%
Doolittle Creek	104,967	596	360	40%
Englejard Creek*****	166,425	1,392	953	32%
Fox Creek	95,167	1,671	745	55%
Francis Creek	139,896	1,625	1,203	26%
Headwaters Big Hole River*****	150,887	909	741	19%
Howell Creek*****	137,297	1,864	850	54%
Johnson Creek	166,451	1,135	810	29%
Joseph Creek	89,420	662	469	29%

Table 8-4: Bank erosion assessment results and allocations for sub-watersheds in the upper Big Hole River planning area.

6th Code HUC WS (Mod for 303d)	Length of Streams in WS (ft)	Estimated Current Sediment Delivery (ton/yr)	Estimated Potential Sediment Delivery (ton/yr) Allocation by Sub-watershed	Percent Reduction
Little Lake Creek	155,528	1,525	1,013	34%
Lower Governor Creek	237,202	5,645	2,735	52%
Lower Rock Creek	91,825	2,500	1,766	29%
Lower Trail Creek	178,277	772	759	2%
Lower Warm Springs Creek	273,215	4,306	2,852	34%
May Creek*	110,953	409	409	0%
McVey Creek	101,633	1,339	866	35%
Miner Creek	173,301	1,326	1,152	13%
Mussigbrod Creek	153,143	1,058	857	19%
North Fork Big Hole River	348,852	5,039	3,843	24%
Old Tim Creek*	109,531	1,581	1,198	24%
Pine Creek	40,745	604	227	62%
Pintlar Creek	160,145	1,222	1,140	7%
Plimpton Creek*	277,692	3,225	2,307	28%
Ruby Creek	238,309	1,715	1,598	7%
Schulz creek	17,672	32	32	0%
Stanley Creek*	131,206	2,844	1,674	41%
Steel Creek	164,910	1,755	910	48%
Swamp Creek	281,630	4,123	2,889	30%
Tie Creek	194,539	876	656	25%
Upper Governor Creek	133,856	2,251	1,112	51%
Upper Rock Creek	164,268	2,409	1,366	43%
Upper Trail Creek	174,824	1,283	970	24%
Upper Warm Springs Creek	121,202	1,460	1,133	22%
West Fork Ruby Creek	137,982	878	832	5%
Total/Average Percent Reduction	7,313,208	96,218	60,796	31%

***** watersheds from the table above do not apply to a specific 303d listed tributary, but cumulatively contribute to the Big Hole River's bank erosion load. Some 303d listed watersheds may be broken into multiple reporting areas within this table.

8.2.5 Margin of Safety and Seasonality Considerations Relating to the Sediment Source Assessments

No implicit or explicit margins of safety were included in sediment source assessment modeling. Modeling decisions and assumptions were driven by applicability to the Big Hole rather than artificially conservative estimates. All assessments and models estimate loads on an annual basis. Most of the sediment sources are associated with spring run off or summer thunderstorms result in episodic inputs. Source assessments based on annual load estimates are appropriate because the sediment TMDLs are provided to control siltation and sedimentation on the stream bed, these conditions are influenced during long term timeframes. Daily loads were extrapolated from these average annual source assessments in **Appendix F** in order to meet federal requirements.

8.3 Source Assessment Results, TMDLS and Allocations

The sources of sediment within the upper Big Hole Valley and surrounding mountain ranges that this TMDL planning area include, are generally similar in all of the tributary watersheds. Predominant sources are natural, livestock grazing in riparian areas, livestock grazing in uplands, hay production, unpaved road systems and timber harvest. Very localized impacts may include historic mining practices, urban areas and road sanding practices. Some localized sources that are likely not significant are not addressed in the sediment allocations.

Only a few watersheds have significant silvicultural activity during the past three decades. These include Johnson, Tie, Trail and Ruby watersheds. Many of the timber harvest activities in these areas may have left lingering sediment in the streams but recent large scale harvest has not occurred. Therefore, timber harvest activities are not targeted for reduction based allocations other than to keep sediment yields at or below existing contributions. Unpaved road systems that support recreation, livestock grazing and silvicultural activities in the mountains, foothills and valleys have various impacts on each watershed and allocation approaches differ widely depending on specific conditions within each area.

Historically, timber harvest and large scale fire suppression efforts have occurred. Recently, less fire suppression, a warming trend, biological factors and the lacking ability of the USFS to manage fuels have culminated to provide conditions where fires are influencing large portions of the forested landscape. Overall erosion rates may be lower or equal to natural fire regimes when implementing well managed harvest management and/or prescribed fire in a watershed but spatial and temporal sediment production may be altered by active forest management. Changes in temporal and spatial sediment production likely would affect beneficial uses differently than a natural fire regime. Sediment production from fire is considered in the upland sediment source assessments and attributed to natural loads for the TMDL source assessments.

Bank erosion is a very pervasive source of sediment that is influenced naturally, but also to a significant degree from agricultural practices. This source is usually significant and addressed in all TMDLs sediment reduction allocation approach. Grazing and hay production also have the potential to affect upland erosion rates. In some watersheds these sources are provided an allocation also. The allocation to upland sources may be met by increasing upland vegetation vigor or increasing riparian buffer filtering function by promoting re-growth of streamside vegetation. Mining activities that affect bank erosion are localized and captured within the bank erosion component of the allocation approaches.

The following sections provide sediment source assessment summary TMDLs and annualized percent reduction based sediment allocations in table format. The more preventable and controllable the human caused source, the larger the percent reduction within the allocation approach. Costs are considered in restoration approaches but in the Upper Big Hole Watershed, the two largest controllable sediment contributors are eroding banks and grazing sources, both controllable with fencing and grazing management. Roads also contribute sediment and may be slightly more costly to fix on a cost/benefit basis but well within the definition of reasonable land conservation approaches. Estimated daily sediment load TMDLs are provided in **Appendix F**.

8.3.1 Big Hole River

This segment of Big Hole River originates south of Jackson, Montana in the Beaverhead Mountains and flows northward ending at its confluence with Pintlar Creek (**Appendix K**, **Map 1**). Tributaries flow from the Beaverhead, Pioneer and Pintler mountain ranges. The major tributaries include the North Fork Big Hole River, Warm Spring, Steel, Swamp, Governor, Big Lake, and Rock Creeks. Pine forests dominate upper elevations of the watershed. The Big Hole Valley is a broad, low gradient valley dominated by hay and cattle production.

Unpaved roads in the Upper Segment of the Big Hole River's watershed are estimated to contribute less than 1 percent of the overall sediment yield, yet they may have localized impacts. Most of the sediment produced from bank erosion in this watershed is derived from livestock grazing systems and natural sources. Lessening the grazing impacts to the river and tributary streams corridors should be a priority. Overall, a large portion of riparian corridors within the watershed could benefit from upgrading current grazing management practices for reducing bank erosion and providing better filtering of upland sediment.

The TMDL for this segment of the Big Hole River is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as a 31 percent reduction in annual sediment load (**Table 8-5**).

Table 8-5: Sediment Source Assessment, Allocations and TMDL for Upper segment of the Big Hole River

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		2344	29% reduction
Eroding Banks		96,218	37% reduction
Upland Sediment Sources	**Silviculture**	459	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	32,699	23% reduction
	Natural Sources	10,256	NA
Total Sediment Load/TMDL		141,976	31% reduction

* A significant portion of bank erosion and grazing/hay are a natural load.

8.3.2 Doolittle Creek

Doolittle Creek is a tributary of the Big Hole River which flows from the Pioneer Mountains northwest to the confluence with the Big Hole River (**Appendix K**, **Map 1**). The predominant land uses in the watershed are livestock production, including rangeland grazing and irrigated pastures. Also, forest activities such as historic harvest and current forest recreation activities are present.

Unpaved roads in the Doolittle Creek watershed are estimated to contribute 6 percent of the overall sediment yield. A large effort to remedy road erosion from entering the streams in this watershed was undertaken and therefore the watershed wide sediment reduction from the road network is lower than other watersheds. Most of the sediment produced from bank erosion in this watershed is derived from natural sources or historic livestock grazing systems. Banks are healing in many reaches but need more time to recover. A small portion of the stream corridor could benefit from upgrading current grazing management practices for reducing bank erosion and providing better filtering of upland sediment.

The TMDL for Doolittle Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as a 26 percent reduction in annual sediment load (**Table 8-6**).

Table 8-6: Sediment Source Assessment, Allocations and TMDL for Doolittle Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		77	19% reduction
Eroding Banks		596	40% reduction
Upland Sediment Sources	**Silviculture**	0	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	373	22% reduction
	Natural Sources	246	NA
Total Sediment Load/TMDL		1,292	26% reduction

* A significant portion of bank erosion and grazing/hay loads are a natural load

8.3.3 Fox Creek

Fox Creek is a small stream in the southern end of the upper Big Hole River planning area (**Appendix K**, **Map 1**). Its headwaters begin in the Big Hole Divide between Dillon and Jackson on USFS lands. After leaving the forest, it flows through private lands for about ¾ of its length before its confluence with Governor Creek.

Unpaved roads in Fox Creek watershed are estimated to contribute less than 1 percent of the overall sediment yield. Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Sediment from eroding banks is one of the largest contributors of sediment and a large portion of this is derived from livestock grazing, especially on the public lands. Livestock grazing has less of an impact on private lands, but irrigation infrastructures may contribute to localized bank erosion here.

The TMDL for Fox Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads, a reduction of sediment from roads, and no long term modeled sediment load increase from timber harvest. The overall TMDL is presented as a 41 percent reduction in annual sediment load (**Table 8-7**).

Table 8-7: Sediment Source Assessment, Allocations and TMDL for Fox Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		27	22% reduction
Eroding Banks		1,671	55% reduction
Upland Sediment Sources	**Silviculture**	0	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	870	22% reduction
	Natural Sources	191	NA
Total Sediment Load/TMDL		2,759	41% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.4 Francis Creek

Francis Creek drains from the east side of the basin flowing to the northwest before its confluence with Steel Creek. The headwaters originate in USFS lands, but most of its length flows through state or private land. Francis Creek then flows into Steel Creek.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Sediment produced from eroding banks is one of the largest contributors of sediment and a large portion of this is derived from livestock grazing. Unpaved roads in Francis Creek watershed are estimated to contribute less than 3 percent of the overall sediment yield. Sediment contributions from past timber harvest is currently estimated at three tenths of one percent of the existing sediment yield.

The TMDL for Francis Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as a 23 percent reduction in annual sediment load (**Table 8-8**).

Table 8-8: Sediment Source Assessment, Allocations and TMDL for Francis Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		71	28% reduction
Eroding Banks		1,625	26% reduction
Upland Sediment Source	**Silviculture**	6	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	391	21% reduction
	Natural Sources	186	NA
Total Sediment Load/TMDL		2,279	23% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.5 Governor Creek

Governor Creek, a tributary of the Big Hole River, lies in the southern end of the upper Big Hole River planning area (**Appendix K**, **Map 1**). Its headwaters originate in the Beaverhead Mountains and flow northward to its confluence with the Big Hole River near Jackson, Montana. About 2 miles of the length of Governor Creek flow through mountainous topography on USFS holdings. The remaining 20 miles occupy a rangeland environment on private land.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Sediment produced from eroding banks is one of the largest contributors of sediment and a large portion of this is derived from livestock grazing. Unpaved roads in the Governor Creek watershed are estimated to contribute less than 2 percent of the overall sediment yield. Sediment contributions from past timber harvests is currently a minute fraction of the existing sediment yield.

The TMDL for Governor Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as a 41 percent reduction in annual sediment load (**Table 8-9**).

Table 8-9: Sediment Source Assessment, Allocations and TMDL for Governor Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		341	32% reduction
Eroding Banks		17,811	51% reduction
Upland Sediment Sources	**Silviculture**	72	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	6,528	21% reduction
	Natural Sources	894	NA
Total Sediment Load/TMDL		25,646	41% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.6 Johnson Creek

Johnson Creek lies in the northwest portion of the upper Big Hole River Valley and is a tributary of the North Fork Big Hole River. Its headwaters originate in the Anaconda Pintler range and it flows southward approximately eleven miles to its confluence with North Fork Big Hole River.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. The USFS grazing allotment (Tie-Johnson) receives light use from cattle, with limited time spent on BDNF due to cattle not preferring to occupy allotment (pers. con. Kevin Greenwood, Range Conservationist, Wisdom RD, BDNF). Sediment produced from eroding banks is one of the largest contributors of sediment and a large portion of this is derived from livestock grazing. Unpaved roads in Johnson Creek watershed are estimated to contribute less than 3 percent of the overall sediment yield. Sediment contributions from past timber harvest is estimated at about 3 percent of the existing sediment yield.

The TMDL for Johnson Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as an 18 percent reduction in annual sediment load (**Table 8-10**).

Table 8-10: Sediment Source Assessment, Allocations and TMDL for Johnson Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		69	20% reduction
Eroding Banks		1,167	28% reduction
Upland Sediment Sources	**Silviculture**	68	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	405	22% reduction
	Natural Sources	723	NA
Total Sediment Load/TMDL		2,432	18% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.7 Joseph Creek

Joseph Creek is a small tributary of Trail Creek lying entirely in montane areas of the upper Big Hole River planning area on the west side of the basin. Most of the sediment produced from bank erosion in this watershed is derived from natural sources or historic livestock grazing systems with a small amount derived from cut off of meanders and straightening of the stream due to highway 43 construction. Sediment produced from eroding banks is the largest contributor of sediment. Unpaved roads, road sanding on highway 43, and past timber harvest in Joseph Creek watershed are estimated to contribute a minute amount of the overall sediment yield.

The TMDL for Joseph Creek is solely to reduce sediment production from eroding banks via continuing the existing grazing management approach. Allocations to other sources include no long term sediment load increase from timber harvest, road sanding or the unpaved road system. The overall TMDL is presented as a 19 percent reduction in annual sediment load (**Table 8-11**).

Table 8-11: Sediment Source Assessment, Allocations and TMDL for Joseph Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Unpaved Roads		5	No increase
Hwy 43 Road Sanding		1	No increase
Eroding Banks		662	29% reduction
Upland Sediment Sources	**Silviculture**	6	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	82	No increase
	Natural Sources	234	NA
Total Sediment Load/TMDL		990	19% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.8 McVey Creek

McVey Creek flows to the northwest joining the Big Hole River towards the northern end of the planning area (**Appendix K**, **Map 1**). Much of this stream flows upon public lands. Its headwaters begin in Forest Service holdings and a sizeable amount of the valley portions of the stream flows through state lands.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Sediment produced from eroding banks is the largest contributors of sediment and a large portion of this is derived from livestock grazing. Unpaved roads in McVey Creek watershed are estimated to contribute about 1 percent of the overall sediment yield, yet may have localized impacts. There has been no timber harvest in this watershed during the last three decades.

The TMDL for McVey Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 25 percent reduction in annual sediment load (**Table 8-12**).

Table 8-12: Sediment Source Assessment, Allocations and TMDL for McVey Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		46	28% reduction
Eroding Banks		1,339	35% reduction
Upland Sediment Sources	**Silviculture**	0	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	269	22% reduction
	Natural Sources	100	NA
Total Sediment Load/TMDL		1,754	31% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.9 Miner Creek

Miner Creek flows northeast from the west part of the basin before its confluence with the Big Hole River. Over half its length lies on USFS lands with the remainder occurring on private lands in the valley. Sediment produced from eroding banks is a large contributor of sediment but most bank erosion is natural in Miner Creek. Unpaved roads in Miner Creek watershed are estimated to contribute less than 1 percent of the overall sediment yield, yet may have localized impacts. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Miner Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management from limited reaches of the stream, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 17 percent reduction in annual sediment load (**Table 8-13**).

Table 8-13: Sediment Source Assessment, Allocations and TMDL for Miner Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		40	25% reduction
Eroding Banks		1,326	13% reduction
Upland Sediment Sources	**Silviculture**	0	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	2,062	21% reduction
	Natural Sources	270	NA
Total Sediment Load/TMDL		3,698	17% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.10 Mussigbrod Creek

Mussigbrod Creek is a tributary of the North Fork Big Hole River lying on the west side of the upper Big Hole River planning area. The stream flows through Mussigbrod Lake near its headwaters. It originates in the Anaconda Pintler Mountain Range and flows for about 8 miles through a montane setting, then through the Upper Big Hole Valley until its confluence with the North Fork Big Hole River. Montana DEQ has included the upper watershed in a water quality reference data gathering project. Most of the impacts to sediment production are in the lower three or four miles of the watershed.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Unpaved roads in Mussigbrod Creek watershed are estimated to contribute about 1 percent of the overall sediment yield, yet may have localized impacts. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Mussigbrod Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management from limited reaches of the stream, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 14 percent reduction in annual sediment load (**Table 8-14**).

Table 8-14: Sediment Source Assessment, Allocations and TMDL for Mussigbrod Creek

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment LAs**
Roads		27	30% reduction
Eroding Banks		1,058	19% reduction
Upland Sediment Sources	**Silviculture**	5	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	424	22% reduction
	Natural Sources	620	NA
Total Sediment Load/TMDL		2,134	14% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.11 North Fork Big Hole River

The North Fork Big Hole River begins at the confluence of Trail Creek and Ruby Creek on the west side of the upper Big Hole River basin. The stream flows to the northeast for about 15 miles before joining the Big Hole River. Major tributaries also include Tie, Johnson and Mussigbrod creeks.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Unpaved roads in North Fork Big Hole River watershed are estimated to contribute about 2 percent of the overall sediment yield, yet may have localized impacts. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and these areas may contribute sediment via human influenced activities. Timber harvest is estimated to contribute less than 1 percent of the overall existing sediment yield.

The TMDL for the North Fork of the Big Hole River is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management from limited reaches of the stream, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term modeled sediment load increase from timber harvest. The overall sediment TMDL is presented as a 14 percent reduction in annual sediment load (**Table 8-15**). Road sanding loads are present but insignificant and should not increase over time.

Table 8-15: Sediment Source Assessment, Allocations and TMDL for North Fork Big Hole River

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		562	28% reduction
Eroding Banks		18,948	24% reduction
Upland Sediment Sources	**Silviculture**	245	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	4,386	23% reduction
	Natural Sources	4,501	NA
Total Sediment Load/TMDL		28,642	20% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.12 Pine Creek

Pine Creek, a tributary of Governor Creek, lies in the southern end of the upper Big Hole River planning area. Its headwaters begin in USFS holding along the Big Hole Divide. It flows for about 4 miles on USFS managed lands before entering private lands.

Pine of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Sediment produced from eroding banks is one of the largest contributors of sediment and a large portion of this is derived from livestock grazing. Sediment contributions from past timber harvest and silviculture are an insignificant fraction of the existing sediment yield.

The TMDL for Pine Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, and no long term sediment load increase from timber harvest or the road system. The overall TMDL is presented as a 46 percent reduction in annual sediment load (**Table 8-16**).

Table 8-16: Sediment Source Assessment, Allocations and TMDL for Pine Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		5	No increase
Eroding Banks		604	62% reduction
Upland Sediment Sources	**Silviculture**	0	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	211	30% reduction
	Natural Sources	141	NA
Total Sediment Load/TMDL		961	46% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.13 Rock Creek

Rock Creek lies on the west side of the Upper Big Hole Valley and flows to the northeast. A recent restoration project restored the lower portion of Rock Creek so it now reaches the Big Hole River, but previously it was incorporated into irrigation ditches.

Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Unpaved roads in Rock Creek watershed are estimated to contribute less than 2 percent of the overall sediment yield, yet may have localized impacts. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Rock Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management from limited reaches of the stream, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 31 percent reduction in annual sediment load (**Table 8-17**).

Table 8-17: Sediment Source Assessment, Allocations and TMDL for Rock Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		112	32% reduction
Eroding Banks		4,909	36% reduction
Upland Sediment Sources	**Silviculture**	21	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	1,849	20% reduction
	Natural Sources	193	NA
Total Sediment Load/TMDL		7,084	31% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.14 Ruby Creek

Ruby Creek lies on the west side of the Upper Big Hole Valley and flows to the northeast. A recent restoration project restored the lower portion of Ruby Creek so it now reaches the Big Hole River, but previously it was incorporated into irrigation ditches.

About 50 percent of the sediment production from this watershed is derived from bank erosion. Most of the sediment produced from bank erosion in this watershed is derived from natural sources and to a lesser extent from livestock grazing systems. Unpaved roads in Ruby Creek watershed are estimated to contribute slightly more than 3 percent of the overall sediment yield. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Ruby Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management from limited reaches of the stream, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 10 percent reduction in annual sediment load (**Table 8-18**).

Table 8-18: Sediment Source Assessment, Allocations and TMDL for Ruby Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		163	21% reduction
Eroding Banks		2,593	6% reduction
Upland Sediment Sources	**Silviculture**	21	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	1,170	23% reduction
	Natural Sources	844	NA
Total Sediment Load/TMDL		4,791	10% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.15 Steel Creek

Steel Creek is a tributary of the Big Hole River originating in the Pioneer Mountains on the east side of the upper Big Hole River valley. The upper, forested portion of the watershed lies on the Beaverhead Deerlodge National Forest. The remaining 22 percent of the watershed is on lower elevation private lands.

Over 70 percent of the sediment production from this watershed is derived from bank erosion. Most of the sediment produced from bank erosion in this watershed is derived from natural sources and livestock grazing systems. Unpaved roads in Steel Creek watershed are estimated to contribute less than 3 percent of the overall sediment yield. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Steel Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall sediment TMDL is presented as a 34 percent reduction in annual sediment load (**Table 8-19**).

Table 8-19: Sediment Source Assessment, Allocations and TMDL for Steel Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		194	31% reduction
Eroding Banks		6,224	39% reduction
Upland Sediment Sources	**Silviculture**	8	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	1,103	22% reduction
	Natural Sources	552	NA
Total Sediment Load/TMDL		8,081	34% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.16 Swamp Creek

Swamp Creek is a tributary of the Big Hole River flowing to the northeast from the west side of the basin. Unlike other streams in the watershed, Swamp Creek originates in the valley and lacks headwaters in the Beaverhead National Forest.

About 70 percent of the sediment production from this watershed is derived from bank erosion. Most of the sediment produced from bank erosion in this watershed is derived from natural sources and livestock grazing systems. Unpaved roads in the Steel Creek watershed are estimated to contribute about 1 percent of the overall sediment yield. A large portion of the watershed consists of upland grasses for livestock grazing systems or hay fields and sediment produced from these areas are partially influenced by human activities.

The TMDL for Steel Creek is a combination of allocations to reduce sediment production from eroding banks via riparian grazing management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, and a reduction of sediment from roads. The overall sediment TMDL is presented as a 27 percent reduction in annual sediment load (**Table 8-20**).

Table 8-20: Sediment Source Assessment, Allocations and TMDL for Swamp Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		67	33% reduction
Eroding Banks		4,123	30% reduction
Upland Sediment Sources	**Silviculture**	6	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	1,424	23% reduction
	Natural Sources	204	NA
Total Sediment Load/TMDL		5,824	27% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.17 Tie Creek

Tie Creek is a montane tributary of the North Fork Big Hole River on the west side of the basin. It flows about 14 miles with all but the last 2 miles within the Beaverhead National Forest. Eroding banks contribute approximately half of the sediment to the watershed. Most of the sediment produced from bank erosion in this watershed is derived from natural sources or livestock grazing systems. Unpaved roads in Tie Creek watershed are estimated to contribute slightly more than 2 percent of the overall sediment yield. Sediment contributions from past timber harvest is estimated at about 4 percent of the existing sediment yield.

The TMDL for Tie Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest. The overall TMDL is presented as an 18 percent reduction in annual sediment load (**Table 8-21**).

Table 8-21: Sediment Source Assessment, Allocations and TMDL for Tie Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		40	18% reduction
Eroding Banks		876	25% reduction
Upland Sediment Sources	**Silviculture**	79	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	312	27% reduction
	Natural Sources	464	NA
Total Sediment Load/TMDL		1,771	18% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.3.18 Upper and Lower Segments of Trail Creek

The Trail Creek drainage is the largest montane watershed in the west side of the upper Big Hole River planning area. It originates along the Continental Divide and Idaho border then flows east to its confluence with the North Fork Big Hole River. DEQ lists two segments of Trail Creek as impaired. The upper segment extends from its headwaters until its confluence with Joseph Creek. The lower segment covers the remaining length of this stream to the confluence with Ruby Creek where it forms the North Fork of the Big Hole River.

8.3.18.1 Upper Trail Creek TMDL (watershed above Joseph Creek)

Eroding banks are estimated to contribute about 60 percent of the sediment to the watershed. Most of the sediment produced from bank erosion in this watershed is derived from natural sources, transportation effects or past livestock grazing systems. Unpaved roads in the upper Trail Creek watershed are estimated to contribute between 1 and 2 percent of the overall sediment yield. Sediment contributions from past timber harvests are insignificant.

The TMDL for upper Trail Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest or road sanding. The overall TMDL is presented as a 20 percent reduction in annual sediment load (**Table 8-22**).

Table 8-22: Sediment Source Assessment, Allocations and TMDL for Upper Trail Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		32	16% reduction
Eroding Banks		1,283	24% reduction
Upland Sediment Sources	**Silviculture**	4	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	325	No increase
	Natural Sources	371	NA
Total Sediment Load/TMDL		2,015	16 % reduction

* A significant portion of bank erosion and grazing/hay loads are a natural load

8.3.18.2 Lower Trail Creek TMDL (whole watershed)

Eroding banks are estimated to contribute over half of the sediment to the watershed. Most of the sediment produced from bank erosion in this watershed is derived from natural sources, transportation effects or past livestock grazing systems. Unpaved roads in the upper Trail Creek watershed are estimated to contribute about 2 percent of the overall sediment yield. Sediment contributions from past timber harvest is estimated at about 4 percent of the existing sediment yield.

The TMDL for lower Trail Creek is a combination of allocations to reduce sediment production from eroding banks via riparian management, increasing riparian filtering of upland sediment loads derived from grazing and hay production, a reduction of sediment from roads, and no long term sediment load increase from timber harvest or road sanding. The overall TMDL is presented as a 12 percent reduction in annual sediment load (**Table 8-23**). This reduction may seem low but much of the sediment in the stream is due to past fire, silvicutlure and grazing activities and needs time to move via flood events. Also sediment loads from fire were quite high and may overshadow some of the more continuous human caused sources.

Table 8-23: Sediment Source Assessment, Allocations and TMDL for Trail Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Unpaved Roads		101	29% reduction
Hwy 43 Road Sanding		2.4	No increase
Eroding Banks		3,126	17% reduction
Upland Sediment Sources	**Silviculture**	65	No modeled increase in sediment delivery to the stream or tributaries
	Grazing/Hay Lands	788	66% reduction
	Natural Sources	1,313	NA
Total Sediment Load/TMDL		5,395	12% reduction

* A significant portion of bank erosion and grazing /hay loads are a natural load

8.4 Future Growth and New Sediment Sources

A limited potential for new sediment sources from future activities in the upper Big Hole Valley and surrounding mountains exists. Future developments within the Upper and North Fork Big Hole River TPA may have the potential to increase sediment loads to the stream network. Potential future development includes timber harvest, increased grazing, road construction and maintenance, new subdivision development, and increased recreational pressure. None of these activities currently have a sediment allocation within the TMDLs. If these activities cause significant sediment production, they will need to be considered in updated allocation and restoration approaches. If these sources arrive in the watershed they should use all reasonable land, soil and water conservation practices that reduce erosion.

Throughout the Upper and North Fork Big Hole Watersheds, care should be taken to avoid practices such as new road development or home/cabin site building near streams, including flood plains and river migration areas. Other practices that should be avoided are the addition of riprap along streambanks, placement of undersized culverts, and the removal of riparian vegetation in the stream corridors. Other negative impacts with the potential to increase sediment loads may arise on a site specific basis. If new, significant human caused sources of sediment are proposed in the watershed, a new allocation approach should be considered.

8.5 Uncertainty and Adaptive Management

The source assessments used as the basis for the percent reduction allocation assessed all sizeable sediment sources, but a few small sources may have been overlooked because of budgetary and temporal limitations of the TMDL project. The EPA sediment TMDL development guidance for source assessment states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the water body and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(G)). If the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired.

Because of the uncertainty in the source assessment, the allocations are established as percent load reductions rather than absolute load reductions. Sediment source assessment results are useful for determining the largest sources within each watershed and are useful, along with consideration of restoration costs, to determine an allocation strategy based on economic costs and environmental benefits. Due to current BMP implementation, allocated percent reductions may not be feasible at all locations. Conversely, the source assessment did not account for riparian buffers and associated reductions in sediment loading from upland erosion; the existing load from upland erosion may be lower due to current riparian conditions, and additional reductions will be achievable in many areas with the improvement of riparian buffers. Although the bank erosion assessment estimated percent reductions via improved riparian habitat, some eroding banks may require bank stabilization as well.

Uncertainty in loading estimates is addressed through an adaptive management approach where the TMDL and allocations from this document can be revised as additional information is collected. Adaptive management is part of the MOS and requires long-term monitoring to track BMPs and stream conditions to determine if targets have been achieved. This approach allows management recommendations and practices to be revised if targets have not been met. Monitoring recommendations are detailed in **Section 11.0.**

The loads and allocations established in this document are meant to apply to recent conditions of natural background and natural disturbance. Under some natural conditions, such as large wildfires or extreme flow events, it may not be possible to satisfy all targets, loads, and allocations because of natural short term background sediment load pulses. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant longer term excess loading during recovery from significant natural events.

Noticeable improvement in habitat and reduction in sediment loading will not occur until most types of restoration mechanisms or management based activities have been in place for several years or more. Habitat improvements, due to grazing, BMPs should be observable within 3 to 5 years after project implementation. Water quality improvement may not be noticeable within the first several years, as it may take up to 10 years for sediment to flush through the system, depending on flow management, climate, and the magnitude of excess deposition in different stream reaches. In fact, some of the TMDLs have very low reductions due to the fact that many of the sources have been addressed during the past decade but long term effects of past sediment sources are still noticeable in the stream. Therefore, sediment reductions to meet the allocations and targets will be a long-term goal.

8.6 Sediment Margin of Safety and Seasonality

Incorporating a margin of safety (MOS) is a required component of TMDL development. The margin of safety (MOS) accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (EPA, 1999). This plan incorporates an implicit MOS in a variety of ways:

- The use of multiple targets to help verify that sediment impacts to beneficial uses are reviewed thoroughly for assessing standards attainment after TMDL implementation.
- The use of supplemental indicators, including biological indicators, to help verify beneficial use support determinations and assess standards attainment after TMDL implementation.
- Standards, targets and TMDLs that address both course and fine sediment delivery.
- The supplemental indicators may also provide an early warning method to identify pollutant-loading threats, which may not otherwise be identified, if targets are not met.
- Conservative assumptions were used for the source assessment process, including erosion rates, sediment delivery ratio, and BMP effectiveness (see **Appendices A, G, and H**).
- Consideration of seasonality (discussed in **Section 5.3**).
- The adaptive management approach evaluates target attainment and allows for refinement of load allocation, targets, modeling assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development (discussed below and in **Section 8.5**).
- The use of “naturally occurring” sediment loads as described in ARM 17.30.602(17) to establish the TMDLs and allocations. This includes an allocation process that addresses all known human sediment causing activities, not just the significant sources.

Seasonal sediment impact to aquatic life is taken into consideration in the analysis within this document. Fine sediment deposition may impact fish spawning seasonally but impact aquatic insect food sources annually. Pool filling by either fine or course sediment usually impacts the quantity of adult fish habitat and thus, the adult fish population constantly throughout the year. Annual loads are reported within the main body of this document and are appropriate because the impacts of delivered sediment are a long term impact once sediment enters the stream network. It may take years for sediment loads to move through a watershed. Daily loads are provided in the appendix to meet EPA requirements but are not especially useful for watershed restoration within this watershed.

SECTION 9.0
NUTRIENT SOURCE ASSESSMENT, TMDLS AND ALLOCATIONS

9.1 Introduction and Background Information

Nutrients are elements or compounds essential for the growth and survival of organisms. Most living cells require large amounts of nutrients, such as nitrogen, phosphorus, carbon, hydrogen, oxygen, potassium, and calcium (macronutrients), and small amounts of micronutrients such as manganese, copper, and chloride. Nutrients circulate in cycles that involve exchanges between the organic and inorganic components of the environment, as well as between plants and animals. In these cycles, each nutrient undergoes chemical transformations that determine its availability to different organisms. Therefore, the supply of nutrients within an ecosystem has a substantial influence on both the abundance of plant and animal life and the types and variety of species that can inhabit an ecosystem.

Human activities can increase the biologically available supply of two key nutrients, nitrogen and phosphorus. An oversupply of nutrients, known as eutrophication, encourages excessive plant production in aquatic ecosystems. Several impairments often result from excessive plant growth related to nutrient loading. Over stimulation of benthic algae can cause aesthetic problems. Also, decaying or alive plant matter may stimulate too much respiration or decomposition which consumes oxygen when plants are not producing oxygen via photosynthesis at night. Eventually, dissolved oxygen is depleted, often to the point where fish and other species can no longer survive.

Framework Nutrient TMDLs

It is acknowledged that existing nutrient data for the Upper – North Fork Big Hole TPA is limited and targets are based on a numeric translation of Montana’s narrative nutrient standards. As a result, the extent of the nutrient problems is not defined as well as would be desirable although controllable sources of nutrients in the watershed are fairly straightforward to understand. The following nutrient TMDLs and allocations are presented as a framework starting point from which watershed stakeholders can voluntarily begin to address water quality problems in the Upper – North Fork Big Hole TPA. The nutrient targets are considered interim values that may need to be revised in the future, and compliance with the targets is currently considered voluntary. An adaptive management strategy to facilitate revision of the nutrient targets, TMDLs, and allocations is presented in **Section 9.5**.

Nutrients are among the pollutants of concern for a number of streams in the Upper/NF Big Hole River TMDL planning area (**Table 1-1**). Although ten streams have been listed for nutrients in this area, most were listed for nutrients as probable causes of impairment after this TMDL project initiated. Two watersheds were included in the nutrient assessment scope of this TMDL project: Steel and Rock Creeks. Rock Creek nutrient assessment work quickly became very complex and out of the original project scope due to irrigation water management activities, and therefore nutrient TMDL completion for this stream is postponed for the time being. Alternatively, Francis Creek is a tributary to Steel Creek and was listed as likely impaired due to nutrients after project initiation. Because it is a tributary to Steel Creek and modeling for this area was already completed, this TMDL was easily completed as part of this TMDL project. Nutrient TMDLs are provided for Steel and Francis Creeks in this document. Other nutrient listings will be addressed in the future according to Montana's TMDL completion schedule.

9.2 Nutrient Source Assessment Techniques

Methods to develop an inventory of sources of nutrient loading included field investigations and the aerial survey completed in the first portion of TMDL planning (Confluence et al. 2003). Specific activities consisted of field reconnaissance, nutrient sampling (**Section 5**), evaluations of riparian community structure and composition (**Appendix C**), bank erosion assessments(**Appendix C**), interviews with agency personnel regarding farming and grazing practices, and Generalized Watershed Loading Functions nutrient modeling (GWLF) (**Appendix I**).

9.2.1 Initial Nutrient Assessment Planning

Initial efforts in the upper/NF Big Hole River TMDL planning area allowed determination of broad categories of sources attributable to nutrient enrichment in basin streams with agriculture emerging as the only identifiable factor (Confluence et al. 2003). No point sources are present. Residential development, municipalities, and forestry practices are unlikely to contribute excess nutrients to streams for several reasons. Because of its low population density of humans, especially adjacent to nutrient-listed streams, nutrient enrichment from residential development is a negligible component of the human-caused load. Septic systems and fertilized lawns are a limited source of nutrients; however, aerial photo analyses did not detect residential development in proximity to nutrient listed streams. Logging can result in short-lived spikes in nutrient loading (Likens et al. 1967); however, timber harvest activities in the basin are relatively old or currently at small scale, making this an unlikely source. Therefore, agricultural sources are the sole attributable significant human caused category of anthropogenic nutrient loading to nutrient listed streams that was further investigated. Sources of nutrients from agricultural activities include accelerated bank erosion from livestock, reduced riparian filtering form livestock grazing and browsing, limited areas of upland vegetation reduction from livestock grazing, and fertilizer applications.

Field reconnaissance efforts to inventory sources of nutrient sources in the upper Big Hole River planning area noted a striking feature of the basin that presents an obstacle in identifying sources and evaluating their relative contributions. The extent of water management, with flows diverted and transported in a complex network of irrigation ditches, presents an impediment to identifying specific agricultural source areas using water chemistry and discharge assessments. In some cases, ditches transport water across sub-basins, thereby obscuring original source areas. Water, along with nutrients, are diverted and reused via the irrigation systems. Furthermore, flood irrigation practices result in exposure of water to areas with varying potential to contribute nutrients. The tributary watersheds where nutrient TMDLs are developed do contain irrigation infrastructure and irrigated pastures, but do not contain large inter-basin water transfer. A couple nutrient TMDLs were deferred for completion at a later timeframe because of the poor understanding about irrigation network and known inter-basin water transfers with only few water chemistry results for supporting the TMDL.

Despite the inherent difficulties in identifying sources of nutrient loading in the upper Big Hole, a number of categories of nutrient sources are obvious. Livestock are a significant potential source with accumulations of animal wastes across the landscape. Manure is a source of both nitrogen and phosphorus (Gilbertson et al. 1979) and contributes to eutrophication in streams. Also, fertilizer is used on hay fields and agricultural activities reduce the vegetation filtering capacity along streams. Grazing impacts also can reduce ground cover and stimulate higher overland and streambank erosion, and thus nutrients associated with soil loss. Natural landscape sources are also present; these include natural forest, grass and shrub land erosion and groundwater pathways. A land use and land cover based modeling approach was used to assess these human caused sources of nutrients along with other natural sources at a watershed scale.

9.2.2 Nutrient Watershed Source Assessment Modeling and Supporting Information

The Generalized Watershed Loading Functions Model (GWLF) uses weather, soils, instream nutrient, stream discharge, land cover types, agricultural statistics, riparian condition information, fertilizer use, and streambank erosion information for model setup and calibration (**Appendix I**). The model was calibrated using data from the USGS site near Melrose on the Big Hole River and validated using data from a USGS gauge in Willow Creek. After calibration, and existing condition model runs, the model was used for restoration scenario nutrient load assessments. The following paragraphs provided are about key data relative to human influenced sources used within the model, although **Appendix I** provides more detailed modeling information.

Riparian buffers serve as a nutrient filtering zone through a number of processes (**Appendix J**). Nutrient listed streams varied in terms of the potential for riparian buffers to filter and take up nutrients (**Table 9-1**). Lower portions of Steel Creek and all of Francis Creek rated as having low filtering potential due to the relatively high proportions of stream with sparse riparian cover observable from aerial photos and verified during field monitoring. This information, along with riparian condition information on USFS land, was used to determine riparian filtration function inputs into the GWLF model. Both existing and restored riparian filtration function were considered within the model. Bank erosion was also considered within the model and riparian function, aerial photo and bank erosion assessments were used to estimate existing and restored bank erosion conditions within the GWLF model in a similar manner that the riparian filtering function was assessed.

Table 9-1: Potential for riparian buffers to mitigate nutrient loading though filtering and uptake based on analyses of aerial imagery and vegetation indicators which influence nutrient filtering capacity along stream corridors.

Stream	Percent of Stream within Qualitative Riparian Cover Classes Observed from Aerial Imagery (Non-forested reaches)				Nutrient Filtering Capacity Indicators Measured on Stream Banks (Number of Assessed Reaches)			Existing Potential to Mitigate Nutrient Loads
	Dense	Moderate	Moderate to Sparse	Sparse	Percent Shrubs along	Percent Bare ground	Percent Shrubs	
Francis Creek	0	0	0	100	0 (1)	4 (1)	0 (1)	Low
Steel Creek	0	24	0	76	27 (2)	9 (2)	15 (2)	Low to Moderate

Fertilizer application rates were determined in coordination with NRCS, the Big Hole Watershed Committee, and local ranchers. Recent increases in costs, along with efforts to restore fluvial arctic grayling, have brought about a recent fertilizer application reduction. Pre winter 2007 application fertilizer rates were used for calibration since calibration data were from this timeframe and post 2007 rates are used for fertilizer reduction scenarios. Domestic animal numbers on the landscape were derived using 2000 census data and also verified in a few watersheds using USFS information and coordination with the local USFS range manager.

The nutrient model likely has underestimated nutrient loads in Francis and Steel Creek due to irrigated hay and pasture, which include fertilizer applications. Aerial photos were compared to the land cover data set used in the model and irrigated hay and pasture is underrepresented within the land cover data in the upper Big Hole Valley. The likely reason for this was that land cover images were attained during haying season when fields were dry in the upper Big Hole Valley. Therefore, the nutrient contributions from this source are likely higher than those identified in the source assessment and likely fall under the grassland load in the source assessment.

Upland erosion rates were assessed in the model via use of cover factors which represent existing conditions and those that represent conditions of healthy grass and shrubland range conditions. Domestic animal stocking rates were determined using data from U.S. Agricultural Statistics Service. Nutrient loads from animal waste are incorporated into each landscape they inhabit.

9.3 Francis Creek

See **Section 5.0** for Francis Creek’s existing nutrient conditions assessment and nutrient targets.

9.3.1 Nutrient Source Assessment Results

Nitrogen source assessment results indicate forest land as the most major contributor of nitrogen, yet this source is mostly natural except for limited grazing (**Figure 9-1**). Grassland and shrubland combined make the next largest source area and include natural background nitrogen loads but also the human influence of reduced vegetation from grazing. Another contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Bank erosion, both natural and unnatural, is another significant source of nitrogen to the stream. Hay/pasture nitrogen sources are likely higher than identified and will also be considered in TMDL allocations and restoration approaches. Suburban lands are a small source.

Francis Creek's phosphorus source assessment results reveal forest land as the most major contributor, yet this source is mostly natural except for limited grazing. Grassland and shrubland combined make the next largest phosphorus source and include both natural background and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Bank erosion is the next largest source of phosphorus to the stream, although it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing. Hay/pasture areas are likely a larger contributor of phosphorus than identified and will also be considered in TMDL allocations and restoration approaches. Suburban areas are a very small source of phosphorus in this watershed. Farm animal waste via grazing systems contributes a very minor contribution of phosphorus.

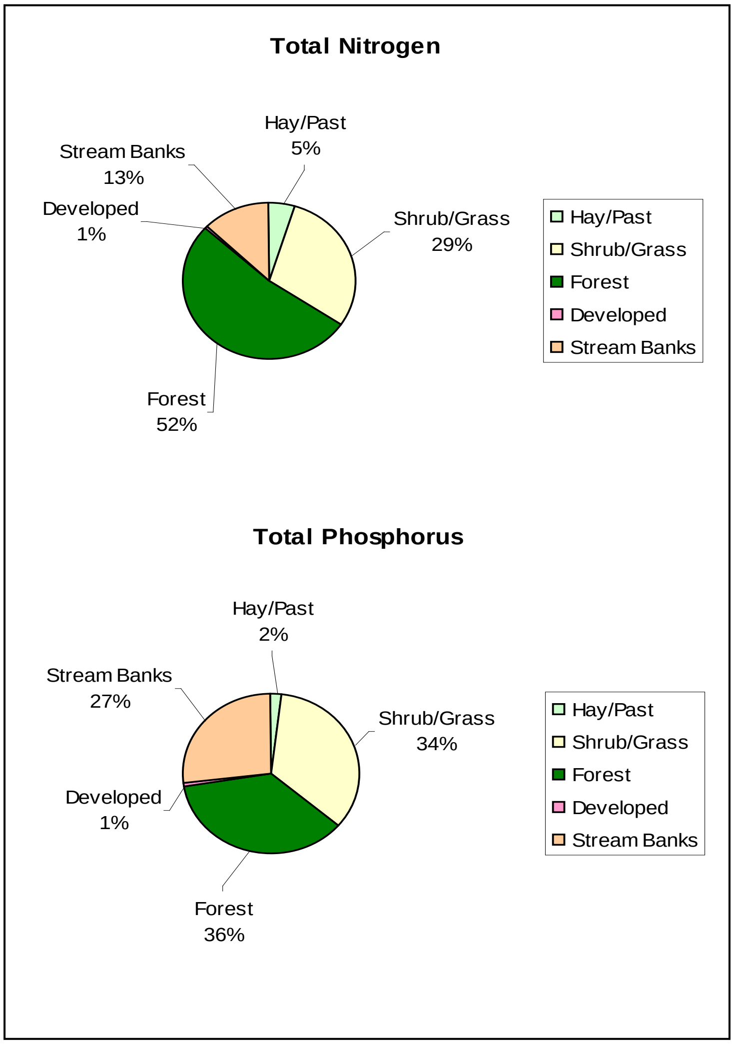


Figure 9-1: Francis Creek Nutrient Source Assessment Results

9.3.2 Francis Creek Nutrient TMDLs

Both total nitrogen and total phosphorus TMDLs will be provided for Francis Creek because the data available in this watershed is not robust and the restoration approaches in this landscape will address both nitrogen and phosphorus reductions. The total nitrogen TMDL is provided in **Equation 9-1** and the total phosphorus TMDL is provided in **Equation 9-2**. Future conditions will be considered meeting the TMDL if there is less than a 20 percent exceedance rate as long as exceedances are random during the summer months. This exceedance rate allows for natural variability yet will protect against nutrient conditions that impact any use of the water. The TMDLs are applied only to the summer growing season during July, August and September.

Equation 9-1.
Total Nitrogen TMDL = CFS*1.72
Where: CFS = Discharge in cubic feet per second
1.72 = Conversion factors combined with total nitrogen target from Section 4.0

Equation 9-2.
Total Phosphorus TMDL = CFS*0.264
Where: CFS = Discharge in cubic feet per second
1.72 = Conversion factors combined with total phosphorus target from Section 4.0

9.3.3 Francis Creek Nutrient Allocations

Comparison of the nutrient TMDLs to the GWLF modeling efforts provide an example of how existing and restored watershed conditions compare to the TMDL. The model estimates long term average stream flow and water quality conditions over many years. **Figure 9-2** provides an estimate of existing total nitrogen and phosphorus loads compared to the TMDLs for the calibrated hydrology in Francis Creek Watershed. While viewing the modeling results keep in mind that modeling efforts show average flow and water quality conditions over a multiple year period and the TMDL calls for 80 percent compliance rate. Even so, comparing the modeling results of both existing and restored conditions to the TMDL is very useful because it can indicate if the restoration approaches will likely achieve the TMDL and water quality targets. While making comparisons of the TMDL and model results, keep in mind that the TMDL must be met 80 percent of the time, not approximately 50 percent of the time as **Figure 9-2** may imply because the GWLF model was built upon average conditions. To account for this difference, the TMDL allocation approach will use the results of the modeled restoration implementation scenario where all reasonable land, soil and water conservation practices are in place, where the estimated median summer loads are about 1/3rd lower than the TMDL. This provides an explicit margin of safety in the TMDL and is expected to compensate for the frequency differences in the TMDL and modeling approaches.

Estimated load reductions within the GWLF model are based on agricultural restoration approaches. Reasonable agricultural restoration practices related to grazing and hay production included in the model are riparian vegetation restoration and management, fertilizer management and upland grazing management. The restoration approaches affect both nutrient production and filtering.

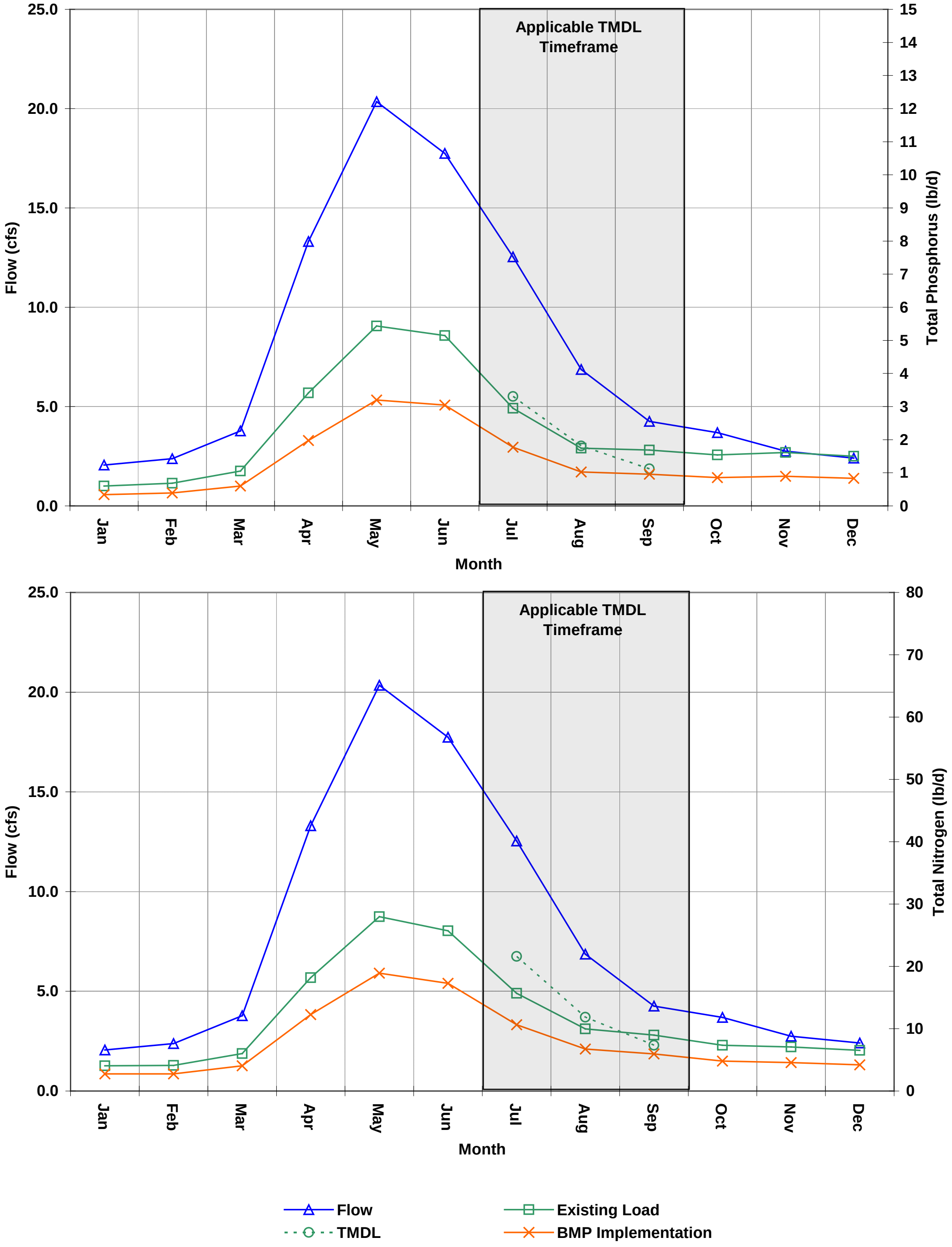


Figure 9-2: Long term average GWLF total nitrogen and phosphorus load modeling results for Francis Creek Watershed.

GWLF modeling is used to determine nitrogen and phosphorus reductions from each of the identified source reductions needed to meet the TMDL (**Appendix I**). Load reductions identified in modeling scenarios are based upon applying reasonable agricultural BMPs such as riparian vegetation restoration, riparian zone protections from grazing impacts, managing fertilizer applications rates, and moving hay production from riparian zone areas. These practices will reduce nutrients imported into the watershed, reduce bank erosion, and increase riparian filtering treatment of runoff and groundwater. Francis Creek’s nitrogen and phosphorus load allocations are provided in **Table 9-2** and **9-3** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that both nitrogen and phosphorus loads can be reduced the most by promoting natural riparian vegetation regrowth by managing grazing and moving hay production from these areas. Specific restoration approaches for riparian areas will depend upon how heavily impacted areas have been historically.

Allocations are provided for a yearly timeframe in the main document because the nonpoint source, landscape scale, restoration approaches will reduce nutrient conditions year round, even though the nutrient TMDL is provided only for the summer growing season. The yearly allocations will provide monthly BMP implementation loads during the summer time which are provided in **Figure 9-2.** The estimated summer monthly loads after restoration implementation are lower than the TMDL. Also, a yearly allocation approach will address sources of nutrients if they are introduced to streams during runoff but stored in channel and available during the summer growing season. All human caused significant sources are considered in the allocation approach and therefore the remaining load after implementation of restoration approaches is considered naturally occurring.

An example of the allocation approach for reducing hay and pasture nitrogen loading in Francis Creek is provided. The existing load for Hay/Pasture is 219 pounds. With fertilizer management in this source area, the existing load could be reduced by 17 lbs to 202 lbs. Of this 202 lbs, adjacent healthy stream side filter strips have the potential to reduce this load by an additional 50% down to 101 lbs, which is then the source area allocation to Hay/Pasture. This shows that just for this source area, the TN reduction can be greater than 50 percent with most of the reduction coming from improved riparian conditions (**Figure 9-3**).

Upland & Riparian BMP Allocation Scenario Example

Source	Existing Condition	Fertilizer Reduction and Grazing Management	Increased Riparian Buffer Filtration	Delivered Nitrogen Load
Hay/Pasture	219 lbs/yr →	202 lbs/yr →	50% reduction →	101 tons/yr

Figure 9-3. Riparian Zone Runoff and Groundwater treatment pathways (from Environment Southland, New Zealand)

Table 9-2: Francis Creek Average Annual Nitrogen Source Assessment and Restoration Load Estimation (allocation).

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(lbs)
Hay/Past	Grazing Hay Production Fertilizer	219	Fertilizer/Grazing Management	202	50%	101
			17		101	
Shrub and Grassland	Grazing	1275	Upland Grazing Management	1186	50%	593
			89		593	
Forest	Grazing	2259	NA	2259	15%	1920
					338	
Developed	Suburban	25	NA	25	0	25
Streambanks	Grazing Hay encroachment	549	Riparian Vegetation Restoration and Grazing Management	406	NA	406
			143			
Point Sources	Waste Load Allocation	0	NA	0	0	0
Future Sources*	All	0	NA	0	0	0
Total Estimated Annual Load		4326	248	4078	1033	3045
Estimated overall % reduction			6%		25%	30%

*If future nutrient sources occur, the allocation approach should be updated with new sources considered.

Table 9-3: Francis Creek Average Annual Phosphorus Source Assessment and Restoration Load Estimation (allocation).

Source Area	Associated Human Activities	Existing Tot. P (lbs)	Source Area Restoration Approach (reduction in lbs)	Source Area Allocated Tot. P (lbs)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)	Total Allocated Load From Source (lbs)
Hay/Past	Grazing Hay Production Fertilizer	19	Fertilizer/Grazing Management 11	8	50% 4	4
Shrub and Grassland	Grazing	285	Upland grazing management 37	248	50% 124	124
Forest	Grazing	301	NA	301	15% 45	256
Developed	Suburban	5	NA	5	0	5
Streambanks	Grazing Hay encroachment	227	Riparian Vegetation restoration and grazing management 59	168	NA	168
Point Sources	Waste Load Allocation	0	NA	0	0	0
Future Sources*	All	0	NA	0	0	0
Total Estimated Annual Load		836	107	729	173	557
Estimated overall % reduction (not a TMDL)			13%		24%	33%

*If future nutrient sources occur, the allocation approach should be updated with new sources considered.

9.4 Steel Creek

See **Section 5.0** for Steel Creek's existing nutrient conditions assessment and nutrient targets.

9.4.1 Steel Creek Nutrient Source Assessment

Nitrogen source assessment results indicate forest land as the most major contributor of nitrogen, yet this source is mostly natural except for limited grazing (**Figure 9-4**). Grassland and shrubland combined make the next largest source area and include natural background nitrogen loads but also the human influence of reduced vegetation from grazing. Another contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Bank erosion, both natural and unnatural, is another significant source of nitrogen to the stream. Hay/pasture nitrogen sources are likely higher than identified and will also be considered in TMDL allocations and restoration approaches. Suburban lands are a small source. Nitrogen produced from animal waste is a smaller, but significant, portion of the load from grass, shrub and hay/pasture lands.

Steel Creek's phosphorus source assessment results reveal forest land as the most major contributor, yet this source is mostly natural except for limited grazing. Grassland and shrubland combined make the next largest phosphorus source and include both natural background and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Bank erosion is the next largest source of phosphorus to the stream although it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing. Hay/pasture areas are likely a larger contributor of phosphorus than identified and will also be considered in TMDL allocations and restoration approaches. Suburban area is a very small source of phosphorus in this watershed. Farm animal waste via grazing systems contributes a very minor contribution of phosphorus.

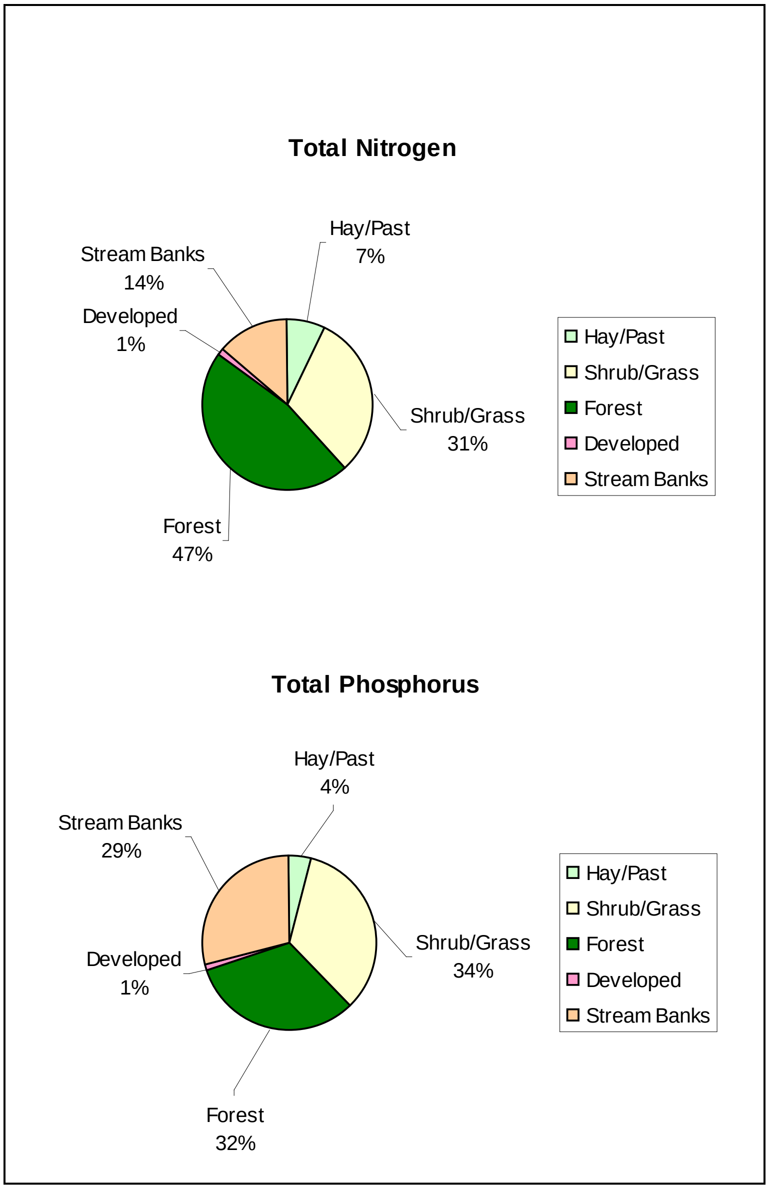


Figure 9-4: Steel Creek Nutrient Source Assessment Results

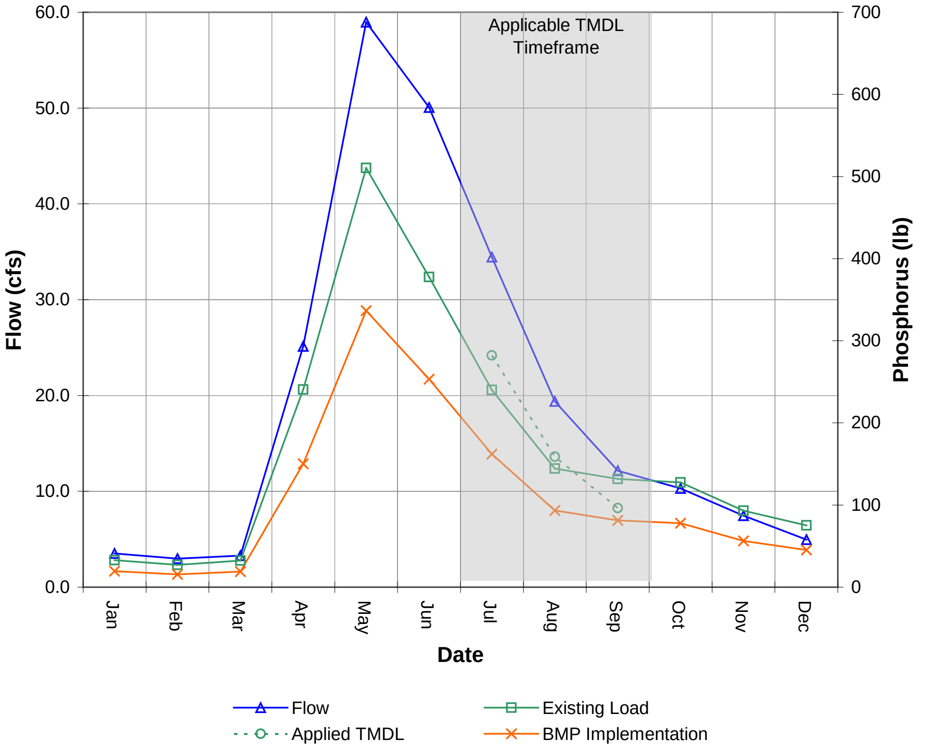
9.4.2 Steel Creek Nutrient TMDLs

Both total nitrogen and total phosphorus TMDLs will be provided for Steel Creek because the data available in this watershed is not robust and the restoration approaches in this landscape will address both nitrogen and phosphorus reductions. The total nitrogen TMDL is provided in **Equation 9-1** and the total phosphorus TMDL is provided in **Equation 9-2**. Future conditions will be considered meeting the TMDL if there is less than a 20 percent exceedance rate as long as exceedances are random during the summer months. This exceedance rate allows for natural variability yet will protect against nutrient conditions that impact any use of the water. The TMDLs are applied only to the summer growing season during July, August and September.

9.4.3 Steel Creek Nutrient Allocations

Comparison of the nutrient TMDLs to the GWLF modeling efforts provide an example of how existing and restored watershed conditions compare to the TMDL. The model estimates long term average stream flow and water quality conditions over many years. **Figure 9-5** provides an estimate of existing total nitrogen and phosphorus loads compared to the TMDLs for the calibrated hydrology in the Steel Creek Watershed. While viewing the modeling results keep in mind that modeling efforts show average flow and water quality conditions over a multiple year period and the TMDL calls for 80 percent compliance rate. Even so, comparing the modeling results of both existing and restored conditions to the TMDL is very useful because it can indicate if the restoration approaches will likely achieve the TMDL and water quality targets. While making comparisons of the TMDL and model results, keep in mind that the TMDL must be met 80 percent of the time, not approximately 50 percent of the time as **Figure 9-5** may imply because the GWLF model was built upon average conditions. To account for this difference, the TMDL allocation approach will use the results of the modeled restoration implementation scenario where all reasonable land, soil and water conservation practices are in place were the estimated median summer loads are about 1/3rd lower than the TMDL. This provides an explicit margin of safety in the TMDL and is expected to compensate for the frequency differences in the TMDL and modeling approaches.

Estimated load reductions within the GWLF model are based on agricultural restoration approaches. Reasonable agricultural restoration practices related to grazing and hay production included in the model are riparian vegetation restoration and management, fertilizer management and upland grazing management. The restoration approaches affect both nutrient production and filtering.



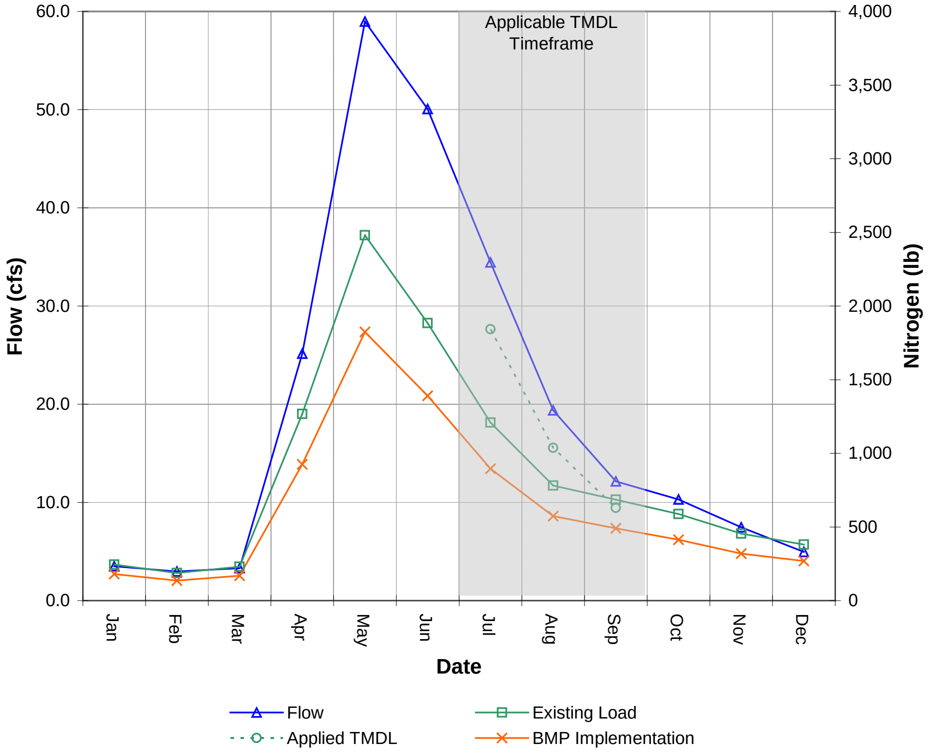


Figure 9-5: Long term average GWLF total nitrogen and phosphorus load modeling results for Steel Creek Watershed.

GWLF modeling is used to determine nitrogen and phosphorus reductions from each of the identified source reductions needed to meet the TMDL (**Appendix I**). Load reductions identified in modeling scenarios are based upon applying reasonable agricultural BMPs such as riparian vegetation restoration, riparian zone protections from grazing impacts, managing fertilizer applications rates, and moving hay production from riparian zone areas. These practices will reduce nutrients imported into the watershed, reduce bank erosion, and increase riparian filtering treatment of runoff and groundwater. Steel Creek's nitrogen and phosphorus load allocations are provided in **Table 9-4** and **9-5** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that both nitrogen and phosphorus loads can be reduced the most by promoting natural riparian vegetation regrowth by managing grazing and moving hay production from these areas. Specific restoration approaches for riparian areas will depend upon how heavily impacted areas have been historically.

Allocations are provided for a yearly timeframe in the main document because the nonpoint source, landscape scale, restoration approaches will reduce nutrient conditions year round, even though the nutrient TMDL is provided only for the summer growing season. The yearly allocations will provide monthly BMP implementation loads during the summer time which are provided in **Figure 9-5.** The estimated summer monthly loads after restoration implementation are lower than the TMDL. Also, a yearly allocation approach will address sources of nutrients if they are introduced to streams during runoff but stored in channel and available during the summer growing season. All human caused significant sources are considered in the allocation approach and therefore the remaining load after implementation of restoration approaches is considered naturally occurring.

An example of the allocation approach for reducing hay and pasture nitrogen loading in Francis Creek is provided. The existing load for Hay/Pasture is 747 pounds. With fertilizer management in this source area, the existing load could be reduced by 90 lbs to 657 lbs. Of these 657 lbs, adjacent healthy stream side filter strips have the potential to reduce this load by an additional 50 percent down to 329 lbs, which is then the source area allocation to Hay/Pasture. This shows that just for this source area, the TN reduction can be greater than 50 percent with most of the reduction coming from improved riparian conditions.

Table 9-4: Steel Creek Average Annual Nitrogen Source Assessment and Restoration Load Estimation (allocation).

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(lbs)
Hay/Past	Grazing Hay Production Fertilizer	747	Fertilizer/ Grazing Management	657	50%	329
			90		329	
Shrub and Grassland	Grazing	3250	Upland grazing management	3099	50%	1549
			151		1549	
Forest	Grazing	4834	NA	4834	0%	4834
					0.0	
Developed	Suburban	127	NA	127	0	127
Streambanks	Grazing Hay encroachment	1436	Riparian Vegetation restoration and grazing management	747	NA	747
			689			
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0
Future Sources[*]	All	0.0	NA	0.0	0	0
Total Estimated Annual Load		10394	931	9464	1878	7586
Estimated overall % reduction			9%		20%	27%

[*] If future nutrient sources occur, the allocation approach should be updated with new sources considered.

Table 9-5: Steel Creek Average Annual Phosphorus Source Assessment and Restoration Load Estimation (allocation).

Source Area	Associated Human Activities	Existing Tot. P	Source Area Restoration Approach	Source Area Allocated Tot. P	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	**(reduction in lbs)**	**(lbs)**	**(**reduction in lbs)	**(lbs)**
Hay/Past	Grazing Hay Production Fertilizer	82	Fertilizer/Grazing Management	34	50%	17
			48.5		17	
Shrub and Grassland	Grazing	683	Upland grazing management	621	50%	310
			62.5		310	
Forest	Grazing	653	NA	653	0%	653
					0	
Developed	Urban	21	NA	21	0	21
Streambanks	Grazing Hay encroachment	594	Riparian Vegetation restoration and grazing management	309	NA	309
			285			
Point Sources	Waste Load Allocation	0	NA	0	0	0
Future Sources*	All	0	NA	0	0	0
Total Estimated Annual Load		2033	396	1637	327	1310
Estimated overall % reduction			19%		20%	36%

*If future nutrient sources occur, the allocation approach should be updated with new sources considered

9.5 Uncertainty and Adaptive Management for Nutrient TMDLs

An adaptive management strategy is proposed to facilitate revision of the nutrient targets, TMDLs, and allocations for Steel and Francis Creek. Although there is uncertainty in the loading values and relative contributions, there is a relatively high level of certainty that the land use practices that can be addressed via the identified BMPs will provide the largest reductions in nutrient loading. This is supported by the modeling, review of literature, overall source assessment results and field observations.

Future nutrient and stream flow monitoring should occur in these streams to better characterize nutrient, discharge and water use conditions. The allocation approach is supported by GWLF modeling that was calibrated at the Big Hole Watershed scale. As new monitoring results applicable to each TMDL are attained they should be compared to the water quality targets, TMDLs and modeling results. If monitoring results do not fall in line with the allocation approach, new allocation approaches which match specific data from the watershed should be considered.

There are two primary regulatory mechanisms through which water quality targets and TMDLs may be modified in the future, as follows: (1) Montana Code Annotated 75-5-703(9)(c) provides a provision for revising the TMDL based on an evaluation conducted by DEQ five years after the TMDL is completed and approved and (2) DEQ has begun the initial steps of numeric standards development for nutrients. DEQ expects to start the formal rule making process for adoption of numeric standards within the next two years. Prior to the start of formal rulemaking, DEQ will provide opportunity for informal public comment, as well as for the formal public comment prescribed under statute. If Montana initiates the use of numeric nutrient criteria, these criteria may be used to revise the nutrient TMDLs provided in this document during future TMDL review. It is envisioned that the additional data collection and regulatory elements together will provide the needed data and information to revise the proposed interim nutrient targets, TMDLs and allocations.

9.6 Margin of Safety and Seasonal Considerations for Nutrient TMDLs

The nutrient margin of safety is inherently provided in conservative assumptions during the source assessment and BMP implementation modeling scenarios. The nutrient reduction BMP modeling scenarios indicate BMP implementation is likely achieve nutrient reductions lower than the TMDLs. The allocation approach is built upon the modeled BMP scenarios. Additionally, nutrient filtering efficiency by riparian areas was estimated on the low end of ranges that were investigated and existing conditions of riparian zones were also accounted for during the filtering capacity improvement portion of the nutrient reduction assessment. A moderate condition was used for the restorative conditions of upland cover in grazed landscapes. Fertilizer application rates used for the fertilizer management scenario were those that began to be applied during 2008 because of fertilizer cost increases. The allocations are built upon restoration scenarios that are reasonably achievable. These allocations are estimated to meet the TMDLs and protect all uses from nutrient enrichment. The adaptive management approach provided in **Section 9.5** also provides a feedback loop to address uncertainties.

The nutrient targets and TMDLs are provided to protect against nuisance algae growth during the summer and apply only during this timeframe. Allocations are provided for year round conditions to ensure summer timeframe targets are met. Modeling results indicate that targets and TMDLs are achieved during summer via the restoration and allocation approach which is based upon protecting riparian filtering zones, reducing fertilizer application rates, and increasing upland vegetation cover year round. Nonpoint source restoration approaches provided in **Section 10.0** should reduce nutrient concentrations and loads during all seasons. The allocation approach, which applies to all seasons, is also consistent in protecting downstream uses in nutrient impacted reservoirs downstream of this TPA.

SECTION 10.0
FRAMEWORK FOR WATER QUALITY RESTORATION

10.1 Summary of Upper Big Hole Restoration Strategy:

This section provides a framework strategy for water quality restoration in the Upper Big Hole Valley and surrounding mountains, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document. This section identifies which activities will contribute the most reduction in pollutants for each TMDL. Limited information about spatial application of each restoration activity will be provided.

This section should assist stakeholders in developing a more detailed adaptive Watershed Restoration Plan (WRP) in the future. The locally developed Watershed Restoration Plan will likely provide more detailed information about restoration goals and spatial considerations within the watershed. The WRP may also encompass more broad goals than this framework water quality restoration plan focuses upon. The to-be-developed WRP would serve as a locally organized “road map” for watershed activities, sequences of projects, prioritizing types of projects, and funding sources, towards achieving local watershed goals, including water quality improvements. Within this plan, the local stakeholders would identify and prioritize streams, tasks, resources, and schedules for applying Best Management Practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

10.1.2 Links Between Fishery and Water Quality Restoration

Many of the restoration strategies in this section fall in line with another important watershed conservation effort, the Candidate Conservation Agreement with Assurances (CCAA) (USFWS and MFWP, 2006). The CCAA agreement between MFWP and the US Fish and Wildlife Service affords private landowners who implement specified conservation practices on their lands protection from additional regulations in the event that the Arctic grayling would receive protection under the Endangered Species Act (ESA). In the Upper Big Hole, the majority of the Arctic grayling priority habitat areas are located on private lands, generally in the valley areas. Final goals of TMDL and CCAA efforts may differ, but the two processes are linked. Water quality laws in Montana are set to protect all beneficial uses of a stream, with fish and aquatic life being some of the most sensitive. TMDLs are provided to protect all uses, including grayling, against adverse conditions that increased pollutant loads may cause.

The CCAA specifies a series of key restoration actions for stream areas supporting Arctic grayling, including maintenance of clean water flows and riparian/stream restoration. In addition, the CCAA assigns agency and landowner responsibilities for implementation of conservation activities and provides extensive landowner participation. These CCAA elements facilitate implementation of restoration activities conserving Arctic grayling populations, as well as supporting beneficial water uses. Many of the CCAA fishery restoration activities will overlap with restoration activities outlined in this document, especially riparian habitat improvement, bank erosion restoration, stream channel stability, and stream flow improvements. Spatial consideration for implementation of CCAA fishery projects and TMDL water quality improvement restoration guidance may overlap at times, but each process also has independent spatial goals. Coordination of restoration activities between CCAA fishery restoration activities and TMDL water quality restoration activities should be coordinated.

10.2 Watershed Restoration Goals

The following are general water quality goals provided in this TMDL document:

- Provide technical guidance for full recovery of aquatic life beneficial uses to all impaired streams within the Upper and North Fork Big Hole TMDL Planning Areas (TPAs) by improving sediment, nutrient, and temperature water quality conditions. This technical guidance is provided by the TMDL components in the document.
- Identify a framework watershed restoration approach for water quality restoration activities that will attain sediment, temperature, and nutrient water quality standards in waters with TMDLs.
- Assess watershed restoration activities to address significant pollutant sources. Costs and benefits are both generally considered, although this analysis does not use a detailed cost/benefit analysis. General spatial guidance will be provided for restoration activities.

A Watershed Restoration Plan (WRP) is a locally derived plan that can be more dynamic than the TMDL document. It can be refined as activities progress and address more broad goals than those included in this TMDL document. The following may be elements provided in a stakeholder derived Watershed Restoration Plan (WRP) in the near future:

- Support for implementing Best Management Practices (BMPs) to protect water conditions so that all streams in the watershed maintain good water quality with an emphasis on waters with TMDLs completed.
- More detailed cost/benefit and spatial considerations for water quality improvement projects.
- Develop an approach for future BMP installments and efficiency results tracking.
- Provide information and education components for providing stakeholder outreach about restoration approaches, benefits, and funding assistance.
- Other various watershed health goals may be included.

Specific water quality goals are detailed in **Section 4** of this document. These targets serve as the basis for long-term effectiveness monitoring for achieving the above water quality goals (**Section 11**). These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of Big Hole waters. **Section 11** identifies a general approach to the monitoring recommendations designed to track implementation water quality conditions and restoration successes.

10.3 Framework Watershed Management Recommendations

Sediment TMDLs were completed for 18 watersheds, including the upper Big Hole River. The Big Hole River was addressed with a temperature TMDL, and nutrient TMDLs were completed for Francis and Steel Creeks. The **most important** restoration approach for reducing sediment, thermal, and nutrient loading in the upper Big Hole Valley is streamside riparian restoration and long term riparian zone management. Stream channel restoration may be necessary in areas that have lost channel integrity due to long term riparian vegetation impacts. Other sediment restoration actions would include unpaved road erosion control near streams. The most notable nutrient specific restoration approach, besides streamside riparian vegetation restoration, includes fertilizer and irrigation management. Temperature TMDL attainment will depend upon improving stream shade using increased riparian vegetation, stream channel narrowing/deepening, and irrigation and stockwater conservation management on both the upper Big Hole River and significant tributaries.

10.3.1 Sediment Restoration Approaches

Streamside riparian vegetation restoration and long term riparian area management are vital restoration practices that must be implemented across the watershed to achieve the sediment TMDLs. Vigorous native streamside riparian vegetation provides root mass which hold streambanks together. Suitable root mass density ultimately slows bank erosion. Riparian vegetation filters sediment from upland runoff. Sediment is also deposited more heavily in healthy riparian zones during flooding because water velocities slow in these areas and sediment drops from the stream's water.

Most of the sediment TMDLs identify eroding banks as the largest human influenced sediment source (**Table 10-1**). Riparian vegetation restoration will address this source, along with channel restoration, that may be necessary in heavily impacted stream reaches where channel stability has been compromised by long term riparian vegetation impacts. The predominant cause of riparian and stream channel degradation in the upper Big Hole Watershed comes from grazing of domesticated livestock in and near streams. Hay production encroaching into riparian zones also impacts riparian vegetation condition in numerous areas. **Table 10-1** provides a summary of load reductions along with ranked sources and possible Best Management Practices (BMP) associated with each source. The table also identifies general spatial guidance for each watershed with a sediment TMDL. Also see **Appendix K**, **Map 4** for spatial considerations when considering riparian vegetation improvement projects.

Erosion off of uplands was usually the second most predominant human influenced source of sediment in the TMDLs provided. The restoration approach for this source will be to increase streamside riparian area sediment filtering capacity by restoring streamside vegetation zones. This approach reinforces the idea that riparian vegetation restoration and long term riparian zone vegetation management should be the predominant restoration approach to reduce sediment.

On average, erosion off of unpaved roads fell next in line of controllable sediment sources in the upper Big Hole Watershed. Restoration approaches for unpaved roads near streams should be to divert water off of roads and ditches before it enters the stream. The diverted water should be routed through natural healthy vegetation, which will act as filter zones for the sediment laden runoff before it enters streams. Sediment derived from roads may cause significant localized impact in some stream reaches, even though at a watershed scale it may be a moderate or small source. Sediment loads from culvert failure and culvert caused scour were not assessed by the TMDL source assessment, but should be considered in road sediment restoration approaches.

All of these best management practices are considered reasonable restoration approaches due to their benefit and generally low costs. Riparian restoration and road erosion control are standard best management practices identified by NRCS and are not overly expensive to our society. Many riparian areas could benefit from more active grazing management along with some additional fencing costs and would recover naturally. Active vegetation planting along with bank sloping may increase costs, but still remains within a reasonable and relatively cost effective restoration approach. When stream channel restoration work is needed because of altered stream channels, costs increase and projects should be assessed on a case by case basis.

Historic placer mining activities may have very localized impacts that affect sediment production within the watershed. Large scale placer mining was not a predominant or common practice in this area when compared to most other areas of southwest Montana. If found, mining caused sediment sources that can be restored at reasonable costs could be prioritized into the watershed restoration plan. Any other unknown sediment sources could also be incorporated into the watershed restoration plan while considering cost and sediment reduction benefits.

For the whole upper Big Hole Watershed, sediment load reductions identified in this TMDL document are allocated from eroding banks (81 percent), grazing/hay lands (17 percent) and roads (2 percent). Past human influences, such as channel and flow alteration, and mining, also have contributed locally notable increases in sediment production. These human caused activities contribute to instream sediment loads which average 31 percent above levels achieving water quality targets. Current estimated watershed sediment loads total 141,976 tons annually, with this TMDL targeting a total watershed load reduction of 44,013 tons annually from the whole watershed. Through application of locally appropriate Best Management Practices, sediment loads in individual streams can be reduced between 12 and 46 percent (**Table 10-1**).

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Big Hole River -above Pintlar Creek	141,976	31%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Riparian willow vegetation restoration, Move haying from riparian green line	Eroding banks with insufficient riparian cover occur along significant but intermittent reaches of the Big Hole River. Some riparian areas are managed well and others need riparian restoration work. Tributaries should also be addressed to reduce sediment loads to the Big Hole River. See TMDLs and restoration summaries below for tributary information.
			2	Upland Sediment,	See eroding banks (above) restoration approach which also provide vegetation filter zones along streams	Riparian filtering capacity is highly variable along reaches of the Big Hole river. Tributary riparian filtering capacity should also be addressed. See TMDL water body summaries below for tributaries.
			3	Unpaved roads	Road maintenance and runoff BMPS	Road maintenance should occur on many unpaved road crossings. Spatial considerations are provided in Appendix G.
Doolittle Creek	1,292	26%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Riparian willow vegetation restoration,	Grazing improvements should continue in the mid section of Doolittle Creek, below Beaverhead Deerlodge National Forest boundary. Many areas need more time to revegetate and recover from past streamside grazing activities but currently have improved grazing management and are recovering.
			2	Upland Sediment from grazing	Riparian grazing management, Provide vegetation filter zones along streams	

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Fox Creek	2,759	41%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Riparian willow vegetation restoration, Move haying from riparian green line	Improvements could be achieved in tributaries and upper Fox Creek but riparian management appears to be fair to good along the mid/lower mainstem. There may also be some effects from irrigation infrastructure. Much of grazing effects occur on public lands.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
Francis Creek	2,279	23%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	The whole stream needs much more attention devoted to riparian management and promoting shrub species growth along streambanks. Many areas may need active vegetation restoration and channel restoration work completed. Moderate to high livestock impacts to upland vegetation in some areas. Spatial considerations for roads are provided in Appendix G.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
			3	Unpaved roads	Road maintenance and runoff BMPS	

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Governor Creek	25,646	41%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration Riparian willow vegetation restoration,	Intermittent portions of the stream need more attention devoted to riparian management. Inappropriate channel restoration design may have occurred in one reach. Moderate to high livestock impacts to upland vegetation in some areas. Spatial considerations for road system are provided in Appendix G.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
			3	Unpaved roads	Road maintenance and runoff BMPS	
Johnson Creek	2,432	18%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration,	In general, below the USFS boundary, streamside vegetation is in moderate condition with limited areas of both good and poor conditions. The whole portion of this stream in the North Fork Big Hole River valley would benefit from slight improvements in grazing management. Current grazing management is not bad in most areas, but less riparian brose at ground level from livestock is needed.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
Joseph Creek	990	19%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	Very little can be done to improve streamside vegetation. Natural conditions, beaver, sandy geology, and hydrologic impacts of the highway all may impact bank erosion. Historic human caused sediment loads may still be present in the channel. Road sanding BMPs should occur due to localized impacts even though they are a small load.

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
McVey Creek	1,754	31%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	Most of the non Beaverhead Deerlodge National Forest land needs more attention applied to riparian grazing management. State lands are most poorly managed. Active riparian restoration may be needed in specific areas. Channel restoration may be needed in places.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
Miner Creek	3,698	17%	1	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	Riparian areas are generally in good condition but there are limited sections of the stream that could benefit from riparian restoration. Road system should be looked at closely for BMP implementation. There are limited areas in need of restoration projects in this watershed.
Mussigbrod Creek	2,134	14%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	The whole portion of this stream in the North Fork Big Hole River valley would benefit from slight improvements in grazing management. Current grazing management is not bad, but less riparian brose at ground level from livestock is needed.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
North Fork Big Hole River	28,642	20%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration Riparian willow vegetation restoration,	Generally riparian grazing management improves in an upstream direction. Loss of riparian shrubs is evident in a downstream direction. Bank erosion increases from upstream to downstream. Many areas will need active riparian restoration approaches due to lar. Spatial considerations for road system are provided in Appendix G.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
			3	Unpaved and paved roads	Road maintenance and runoff BMPS	
Pine Creek	961	46%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration	Sediment loads would be reduced by grazing management practices that promote willow regeneration. This stream could recover naturally if riparian zones were rested and subsequently grazed periodically to lessen browse.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Rock Creek	7,084	31%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration Riparian willow vegetation restoration,	Most of the portions of this stream in the Upper Big Hole Valley appeared to need a rest from riparian area riparian grazing and subsequent long term grazing management that allows riparian shrubs to grow. Many areas of this stream may need active riparian restoration work. Some areas may need channel restoration work if a deep, narrow channel is wanted in a short timeframe. Spatial considerations for road system are provided in Appendix G.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
			3	Unpaved and paved roads	Road maintenance and runoff BMPS	
Ruby Creek	4,791	10%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration,	Riparian areas are generally in moderate to good condition but there are limited sections of the stream that could benefit from riparian grazing management. Active vegetation or channel restoration approaches other than fencing are likely not needed. Road system should be looked at closely for BMP implementation.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
Steel Creek	8,081	34%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	All non Beaverhead Deerlodge National Forest areas need more attention devoted to riparian management and promoting sufficient shrub species condition along streambanks. Many areas may need active vegetation restoration along with channel restoration work. Very limited areas of the BHNF may need riparian grazing management improved slightly.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Swamp Creek	5,824	27%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	Generally riparian grazing management should be conducted to improve streamside shrub growth throughout the Big Hole Valley portions of this stream. Many areas may need active restoration approaches in the lower reaches of this stream.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
Tie Creek	1,771	18%	1	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	Portions of Lower Tie Creek could use moderate improvements in riparian grazing management.
			2	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	
Trail Creek (upper – above Joseph Cr.)	2,015	20%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Stream side riparian vegetation restoration Riparian grazing management, Riparian willow vegetation restoration,	Portions of the eroding banks may be tied to increased water yield due to fires as well as direct impact from fire. Low riparian cover may also be linked to fire. Some of the eroding banks are remnant of past livestock grazing but are healing.

Table 10-1: Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial concerns
Trail Creek (lower)	5,395	12%	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration Riparian willow vegetation restoration,	Portions of Lower Tie Creek could use slight to moderate improvements in riparian grazing management. A portion of the bank erosion may be caused by historic channel alterations from the highway as well as historic grazing impacts. Many riparian areas are recovering from historic impacts.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	
			3	Unpaved roads	Road maintenance and runoff BMPS	
Warm Springs Creek	NA	NA	1	Eroding Banks needing sustainable riparian zone vegetative condition	Riparian grazing management, Stream side riparian vegetation restoration Riparian willow vegetation restoration,	Intermittent areas of Warm Springs Creek could benefit from riparian grazing management to increase riparian willows. Near Jackson, haying activities should provide a streamside buffer witch will allow willows to grow on banks.
			2	Upland Sediment from grazing	Riparian grazing management, Provide filter strips along streams	

10.3.1.1 Big Hole River and North Fork Big Hole River

Because of the differential response of the Big Hole River and the North Fork Big Hole River to reduce shrub cover, namely markedly increased width-to-depth ratio, these streams require different restoration approaches to achieve targets and allocations in a timely manner. The role of these streams in providing substantial habitat for Arctic grayling justifies a more intensive approach to meeting targets for the most-altered reaches. Three types of reaches were delineated in the aerial photo based riparian assessment and were linked to increased width-to-depth ratios and bank erosion (**Appendix K**, **Map 4**):

- Sparsely vegetated C channels (defined as less than 20 percent shrub cover) with a potential to be DA, C, or E channels with dense shrub cover (defined as greater than 35 percent shrub cover).
- Reaches with moderate shrub cover with a potential for dense shrub cover, and
- Reaches meeting their potential for dense shrub cover.

Restoration strategies for these three classes vary from a most-aggressive approach involving significant channel work to simple continuance of existing BMPs (**Table 10-1**)

10.3.1.2 Big Hole River Tributaries

Most tributary streams do not show the marked alterations in width-to-depth ratio with low shrub cover; therefore, primarily less intensive restoration options would apply to the tributary streams. A first restoration strategy is to stratify between Rosgen defined “B channels” and other channel types on tributaries (mostly Rosgen Cs, Es, and Das). The rationale is that coniferous forest dominated “B” channels do not have the potential to provide robust habitat for willows. Therefore, the Rosgen “B” channel stream reaches have notably different vegetative potential.

These Rosgen stream type Cs, Ds, and Es, (non-B tributaries) were classified as to their existing and potential shrub cover. Stream reaches with existing dense shrub cover and meeting their potential have a restoration strategy to continue implementing existing BMPs. Non-B tributary reaches having sparse shrub cover and a potential for dense shrubs should involve a combination of willow sprigging and grazing BMPs in most areas. Steel, Francis, and lower portions of Rock and Swamp creeks are notably different from the other tributaries due to the severity of eroding banks, lack of riparian vegetation, and high width-to-depth ratio. The condition of these streams necessitates a much more aggressive restoration approach than what is proposed for the other tributary streams (**Table 10-1**).

10.3.2 Nutrient Restoration Approaches

Nutrient TMDLs were developed for Francis and Steel Creeks using a nutrient model and land use information. Francis Creek is a tributary to Steel Creek, and both watersheds exhibited similar nutrient source assessment results. Nutrient source assessment results are provided by land use type as well as for eroding banks.

The largest nitrogen and phosphorus loads came from forested areas. Nutrient loading from upland forest areas is almost entirely natural in both watersheds. Only a small portion of forest land derived nutrient loads could be further removed by increasing adjacent riparian streamside vegetation vigor. Slight nutrient reductions could occur from forest nutrient loads at the watershed scale by restoring all adjacent streamside vegetation to reference conditions because most riparian areas adjacent to a forest are relatively healthy.

Upland dry shrub and grassland used for domestic livestock grazing contributes the next largest load of nitrogen and phosphorus. If upland grazing management could increase vegetation cover in these areas by 18 percent, watershed nitrogen and phosphorus loads would decrease by about 1 percent and 4 percent respectively. Alternatively, if streamside riparian conditions on the whole stream network adjacent to dry shrub and grasslands were managed similar to reference areas in the Big Hole Watershed, nitrogen and phosphorous loads at the watershed scale would be reduced by 14-16 percent depending upon the watershed and nutrient type.

Bank erosion is a significant source of nutrients in Francis and Steel creeks. Much more phosphorus than nitrogen is contributed from eroding banks when assessing the percentage of contribution eroding banks provide to the overall watershed load. Riparian vegetation restoration and management once again provide the avenue for increasing root mass in banks which reduces bank erosion and the associated nutrient loads. Reducing bank erosion to reference conditions will reduce nitrogen and phosphorus loads at the watershed scale by approximately 4 percent and 8 percent respectively in both watersheds.

Irrigated hay and pasture land is another controllable source. Fertilizers are used in these areas in conjunction with irrigation networks and together contribute nutrient loads to stream networks. Upland vegetation cover may also be impacted in these areas, and through active management, could reduce nutrient production. Nutrient loads from these areas are estimated as low when compared to other land types at the watershed scale, although the model likely underestimated hay and pasture land areas in the watershed. Nutrient loads from pasture and hay were quite high if normalized by area (on a pre acre basis). On-farm nutrient management should be pursued as a nutrient reducing restoration approach. Activities on hay and pasture land that may promote less nutrient reaching the stream network include irrigation management, fertilizer management, and manure management practices. Addressing adjacent riparian filtering function should once again be the priority restoration approach to reducing nutrient loads from irrigated pasture and hay fields. Also included in this category are Animal Feeding Operation areas (AFOs) that should be addressed via installing drainage routes away from streams and installing buffer zones along streams. If the preceding approaches are not feasible approaches, moving an AFO away from the stream may be necessary.

Stream side riparian vegetation restoration approaches are identified as the best way to mitigate nutrient loading to Francis and Steel Creek and should be top priority for restoration projects that will reduce nutrient loads. Other restoration activities that can be pursued are on-field nutrient management strategies (fertilizer and irrigation management) and upland grazing management to promote more vegetation cover. The TMDLs have the potential to be achieved via streamside riparian vegetation restoration approaches without the other two sources being considered; although, a monitoring and adaptive management approach would need to be considered if riparian vegetation restoration and management was the only restoration activity applied to these watersheds. Alternatively, on-farm nutrient management should be seriously considered because it may save overhead cost without affecting production and it will also benefit the environment.

10.3.3 Temperature Restoration Approaches

A temperature TMDL was developed for the Upper Big Hole River by means of a temperature model which utilized water temperature, stream flow, and streamside vegetation data. The approach for attainment of temperature targets is based upon reaching stream channel and streamside vegetation conditions equaling reference areas. Another very important restoration factor for meeting temperature conditions that support instream uses depends upon irrigation and stock water management with water savings being applied to instream flow during warm summer months. The two largest influences upon temperature of the Upper Big Hole River are the lack of riparian vegetation for shade and low summer time stream flow. The overly wide and less complex stream channel also is a significant contributor to heating, but estimated as less than the other influences.

Riparian grazing management, which promotes native shrub growth along streambanks to reference area levels, is a necessary restoration component for meeting the Big Hole River temperature TMDL. Increasing shrub density along streambanks that are not dominated by conifers is needed along the Upper Big Hole River and all impacted tributaries. The climax riparian condition is shrub dominated because cottonwood trees do not grow in the upper Big Hole Watershed because of the harsh climate. Conifer harvest within 300 ft of streams should demonstrate that stream shade is not significantly impacted. The riparian shrubs increase shade and promote cooler microclimates near the streams. Although the increased riparian vegetation may increase evapotranspiration in riparian areas, they are a very small percentage of the watershed area. Cooler temperatures in and near the stream will promote less evaporation from the stream surface itself. Restoring riparian shade, via vegetation growth, also falls in line with restoration approaches linked to sediment and nutrient reductions. Restoring natural riparian vegetation communities dominated by shrubs is a key element in reducing all pollutant loads including heat.

Irrigation efficiency projects which promote summer time instream flows should be considered as another primary restoration approach to reducing temperatures in the upper Big Hole River. Although no exact flow target is provided, modeling indicated that a 10cfs increase in flow would significantly cool stream water. All reasonable irrigation savings approaches with water savings applied to instream flows during July, August and early September should be pursued. This would have to be a locally lead, voluntary effort. Voluntary landowner, ditch company, DNRC, and FWP participation is necessary to obtain this goal. There is no regulatory authority to implement this objective. State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana’s water quality law (MCA 75-5-705); therefore, local coordination and planning are a necessary component of any irrigation management strategy. This document can not be used to divest water rights.

Over wide and shallow channels create conditions where heat can transfer to the streams more efficiently during hot summer afternoons. Reducing the width and increasing the depth of streams in the upper Big Hole Watershed ties into riparian vegetation restoration approaches. Many streams, including many portions of the Big Hole River, have been widened due to streamside shrub loss and subsequent bank erosion. Over a long term period, the sediment from the banks falls into the stream and larger sized cobbles can not be moved easily. These fill in the stream bottom and the process over-widens the stream. In some cases, protecting riparian vegetation so that it can naturally restore itself will promote deeper and narrower channels over time because the stream will create a new floodplain where sediments are trapped and the stream narrows from passive vegetation regrowth. Alternatively, in many areas channel restoration may be needed to change channel dimensions at a faster pace than passive restoration approaches provide. Riparian livestock grazing management must be a component of any active riparian or channel restoration projects to ensure the projects are successful.

10.4 Restoration Approaches by Source

General management recommendations are outlined below for the major sources of human caused pollutant loads in the Upper Big Hole watershed (grazing -including streambank/riparian disturbances, irrigation, and nutrients). Applying ongoing Best Management Practices (BMPs) are the core of the sediment reduction strategy, but are only part of the restoration strategy. Restoration activities may also address other current pollution causing uses and management practices. In some cases, efforts beyond implementing new BMPs may be required to address key sediment sources. In these cases, BMPs are usually identified as a first effort, and an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is also an important part of the restoration process. Monitoring recommendations are outlined in **Section 11**.

A wide variety of grazing management, riparian restoration, fencing, nutrient management, stockwater efficiency, irrigation efficiency, and other watershed restoration improvements have been implemented in recent years in many parts of the Upper Big Hole watershed, particularly under the Big Hole "Candidate Conservation Agreement with Assurances" (CCAA) for fluvial Arctic grayling in the upper Big Hole area.. The CCAA restoration efforts focus on improving fishery habitat (water quantity and riparian habitat), water quality (thermal and nutrient management), and fish habitat fragmentation (dewatering, barriers to migration, entrainment, and habitat simplification).

10.4.1 General Grazing Management BMP Recommendations

Improving riparian habitat, streambank erosion and channel condition through grazing BMPs are documented in the literature (Mosley et al., 1997). The restoration strategy for reducing impacts of grazing on water quality and riparian and channel condition includes implementation of multiple BMPs prescribed on a site-specific basis (such as through the CCAA landowner agreements). BMPs are most effective as part of a management strategy that focuses on critical areas within the watershed, i.e. those areas contributing the largest pollutant loads or sites which are susceptible to impacts from grazing. These riparian BMPs promote properly functioning riparian communities and reduce damage to streambanks. BMPs include managing the timing, intensity, and duration of grazing, establishment and maintenance of preferred vegetative cover, development of infrastructure such as fences and hardened crossings, and management of feeding areas, salt licks, and water availability to restore and maintain riparian vegetation and streambanks. In combination, these integrated approaches to riparian management promote vegetative vigor and protects near-stream soils. BMPs should be determined on a site-specific basis that incorporates the landowner's production needs and associated logistics, while promoting attainment of sediment/riparian allocations and targets.

Some general grazing management recommendations, and BMPs to address grazing sources of pollutants and pollution are listed below (**Table 10-2**). Specific recommendations for critical areas and streams are described in **Sections 10.2** (CCAA and recent BMPS), and **Section 10.3** (stream-specific BMPs).

For participants in the CCAA program, the MFWP and NRCS are developing grazing management plans with enrolled landowners agreeing to implement these measures to meet riparian targets. On lands not enrolled in the CCAA, implementation of BMPs is voluntary. However, other planning partners, including the Big Hole Watershed Committee and the NRCS, will be instrumental in involving individual landowners, developing site-specific plans, and obtaining funding assistance.

Table 10-2: General grazing BMPs and management techniques (from NRCS 2001, and DNRC 1999).

BMP and Management Techniques	Pollutants Addressed
Design a grazing management plan and determine the intensity, frequency, duration, and season of grazing to promote desirable plant communities and productivity of key forage species. In this case, native riparian	Sediment, temperature, nutrients
Encourage the growth of woody species (willow, alder, etc.) along the streambank, which will limit animal access to the stream and provide root support to the bank.	Sediment, nutrients, temperature
Establish riparian buffer strips of sufficient width and plant composition to filter and take up nutrients and sediment from concentrated animal feeding operations.	Sediment, nutrients,
Create riparian buffer area protection grazing exclosures through fencing.	Sediment, temperature, nutrients
Maintain adequate vegetative cover to prevent accelerated soil erosion, protect streambanks, and filter sediments. Set target grazing use levels to maintain both herbaceous and woody plants.	Sediment
Ensure adequate residual vegetative cover and regrowth by rest or deferment periods. Periodically rest or defer riparian pastures during the critical growth period of plant species.	Sediment, nutrients
Distribute livestock to promote dispersion and decomposition of manure and to prevent the delivery of manure to water sources.	Nutrients
Alternate a location’s season of use from year to year. Early spring use can cause trampling and compaction damage when soils and streambanks are wet. If possible, develop riparian pastures to be managed as a separate unit through fencing.	Nutrients, sediment
Provide off-site, high quality water sources.	Nutrients, sediment
Periodically rotate feed and mineral sites and generally keep them in uplands.	Nutrients, sediment
Place salt and minerals in uplands, away from water sources (ideally ¼ mile from water to encourage upland grazing).	Sediment, nutrients, temperature
Monitor livestock forage use and adjust strategy accordingly.	Sediment, nutrients, temperature
Create hardened stream crossings.	Sediment

10.4.1.1 Animal Feeding Operations

Animal Feeding Operations (AFOs) can pose a number of risks to water quality and public health due to the amount of animal manure and wastewater they generate. To minimize water quality and public health impacts from AFOs, and land applications of animal waste, the USDA and EPA released the Unified National Strategy for AFOs in 1999 (NRCS 2005). This strategy encourages owners of AFOs of any size or number of animals to voluntarily develop and implement site specific Comprehensive Nutrient Management Plans (CNMPs) by 2009. This plan is a written document detailing manure storage and handling systems, surface runoff control measures, mortality management, chemical handling, manure application rates, schedules to meet crop nutrient needs, land management practices, and other options for manure disposal. An AFO that meets certain specified criteria is referred to as Concentrated Animal Feeding Operation (CAFO), and in addition, may be required to obtain a Montana Pollution Discharge Elimination System (MPDES) permit as a point source. Montana's AFO compliance strategy is based on federal law and has voluntary as well as regulatory components. If voluntary efforts can eliminate discharges to state waters, in some cases no direct regulation is necessary through a permit. Operators of AFOs may take advantage of effective, low cost, practices to reduce potential runoff to state waters, which additionally increase property values and operation productivity. Properly installed vegetative filter strips in conjunction with other practices to reduce waste loads and runoff volume are very effective at trapping and detaining sediment and reducing transport of nutrients and pathogens to surface waters, with removal rates approaching 90 percent (NRCS 2005). Other installations may include clean water diversions, roof gutters, berms, sediment traps, fencing, structures for temporary manure storage, shaping, and grading. Animal health and productivity also benefits when clean, alternative water sources are installed to prevent contamination of surface water. Studies have shown benefits in red meat and milk production of 10 to 20 percent by livestock and dairy animals when good quality drinking water is substituted for contaminated surface water.

Opportunities for financial and technical assistance in achieving voluntary AFO and CAFO compliance are available from conservation districts and NRCS field offices. Voluntary participation may aide in preventing a more rigid regulatory program from being implemented Montana Nonpoint Source Management Plan for Montana livestock operators in the future.

Further information may be obtained from the DEQ website at: http://www.deq.mt.gov/wqinfo/mpdes/cafo.asp. Montana's NPS pollution control strategies for addressing AFOs are summarized in the bullets below:

- Work with producers to prevent NPS pollution from AFOs.
- Promote use of State Revolving Fund for implementing AFO BMP's.
- Collaborate with MSU Extension Service, NRCS, and agriculture organizations in providing resources and training in whole farm planning to farmers, ranchers, conservation districts, watershed groups and other resource agencies.
- Encourage inspectors to refer farmers and ranchers with potential nonpoint source discharges to DEQ watershed protection staff for assistance with locating funding sources and grant opportunities for BMPs that meet their needs. (This is in addition to funds available through NRCS and the Farm Bill).

- Develop early intervention of education & outreach programs for small farms and ranches that have potential to discharge nonpoint source pollutants from animal management activities. This includes assistance from the DEQ internal (Permitting Division), as well as external entities (DNRC, local watershed groups, conservation districts, MSU Extension, etc.).

10.4.1.2 Riparian Vegetation Restoration

Reduction of riparian vegetative cover is a principal cause of water quality and habitat degradation in the upper Big Hole area. Although implementation of grazing, irrigation and agricultural BMPs would promote recovery of riparian communities, the severity of the impairment, and critical status of Arctic grayling, suggests that natural recovery rates may be insufficient in many stream reaches to meet conservation goals in a timely manner for protection of this species of special concern. All areas that are actively restored with vegetation must have a reasonable approach to protecting the invested effort from further degradation from livestock or hay production.

Riparian planting will be necessary to achieve some stream targets within a desirable period. Riparian vegetation planting and transplanting measures are expected to be included in the CCAA landowner plans. Factors influencing the appropriate riparian restoration would include severity of degradation, site-potential for various species, and availability of local sources for transplant materials. In general, riparian plantings would promote establishment of functioning stands of native species (grasses and willows). The following recommended restoration measures would allow for stabilization of the soil, decreasing sediment delivery to the stream, and increasing absorption of nutrients from overland runoff.

- Harvest and transplant locally available sod mats with an existing dense root mass which provide immediate promotion of bank stability and filtering nutrients and sediments.
- Transplanting mature shrubs, particularly willows (*Salix* sp.), provides rapid restoration of in-stream habitat and water quality through overhead cover and stream shading as well as uptake of nutrients.
- Seeding with native graminoids (grasses and sedges) and forbs is a low cost activity where lower bank shear stresses would be unlikely to cause erosion.
- Willow sprigging would expedite vegetative recovery, involving harvest of dormant willow stakes from local sources.

10.4.1.3 Streambank/Floodplain Restoration BMPs

Bank erosion associated with willow removal and livestock grazing practices are a major source of sediment. Reductions in streamside willows appeared to have resulted in some overly wide and shallow channel segments. Over widened channels can lead to accumulations of fine sediment in pools, because of reduced sediment transport efficiencies and may produce a stream channel with fewer or lower quality pools containing increased sediments. Over widened channels increase sediment concentrations and water temperatures, thus reducing aquatic habitat quality.

These general restoration activities focus on enhancing suitable in-stream habitat for native fishes and fostering a quicker recovery time for stream channels, bank erosion and riparian vegetation shading. These restoration activities would assist in meeting sediment, temperature, and nutrient TMDL targets in stream reaches that have historically been heavily altered by grazing, channeling, mining, transportation, or haying activities. Actual restoration activities would be determined on a site-by-site basis and would depend on the relationships among shrub cover, width-to-depth ratios, eroding banks, and pool frequency.

The Big Hole River was a braided channel supporting dense stands of riparian shrubs. This system did not contain large woody debris from cottonwoods or large rocks providing grade control. Therefore, common stream restoration techniques such as root wads, rock veins, and log veins are inappropriate in the upper Big Hole. Moreover, the use of large wood may favor non-native brook trout. Instead, this restoration strategy proposes measures consistent with the historic nature of the Big Hole River and the habitat needs of the Arctic grayling. These stream restoration measures are:

- Braid reactivation of naturally braided Rosgen type Da channels where each channel is an E/C channel. This is a relatively inexpensive measure generally increasing habitat suitability and availability while decreasing stream temperature. This dissipates energy at higher flows and allows for more riparian shade, where appropriate.
- Mechanical bank stabilization using transplanted vegetation, sod mats, and willow cuttings to decrease sedimentation and enhance long term bank stability.
- Pool creation or enhancement includes excavation of a pool on the outside bend of a meander. Revegetation using sod mats, seeding, willow sprigging, or willow transplants would probably accompany these activities. This technique would be useful in increasing pool frequency and improving width-to-depth ratios as well as improving habitat for native fish and other aquatic life (see **Figure 10-1**).
- Channel narrowing and redefinition. Channel narrowing would be similar to pool creation, except it would occur on a greater scale. The basic steps would include excavation of pools combined with narrowing of the channel through construction of gravel point bars and revegetation/bank stabilization (see **Figure 10-1**). Complex woody debris may also be placed in pools with approval from MFWP.

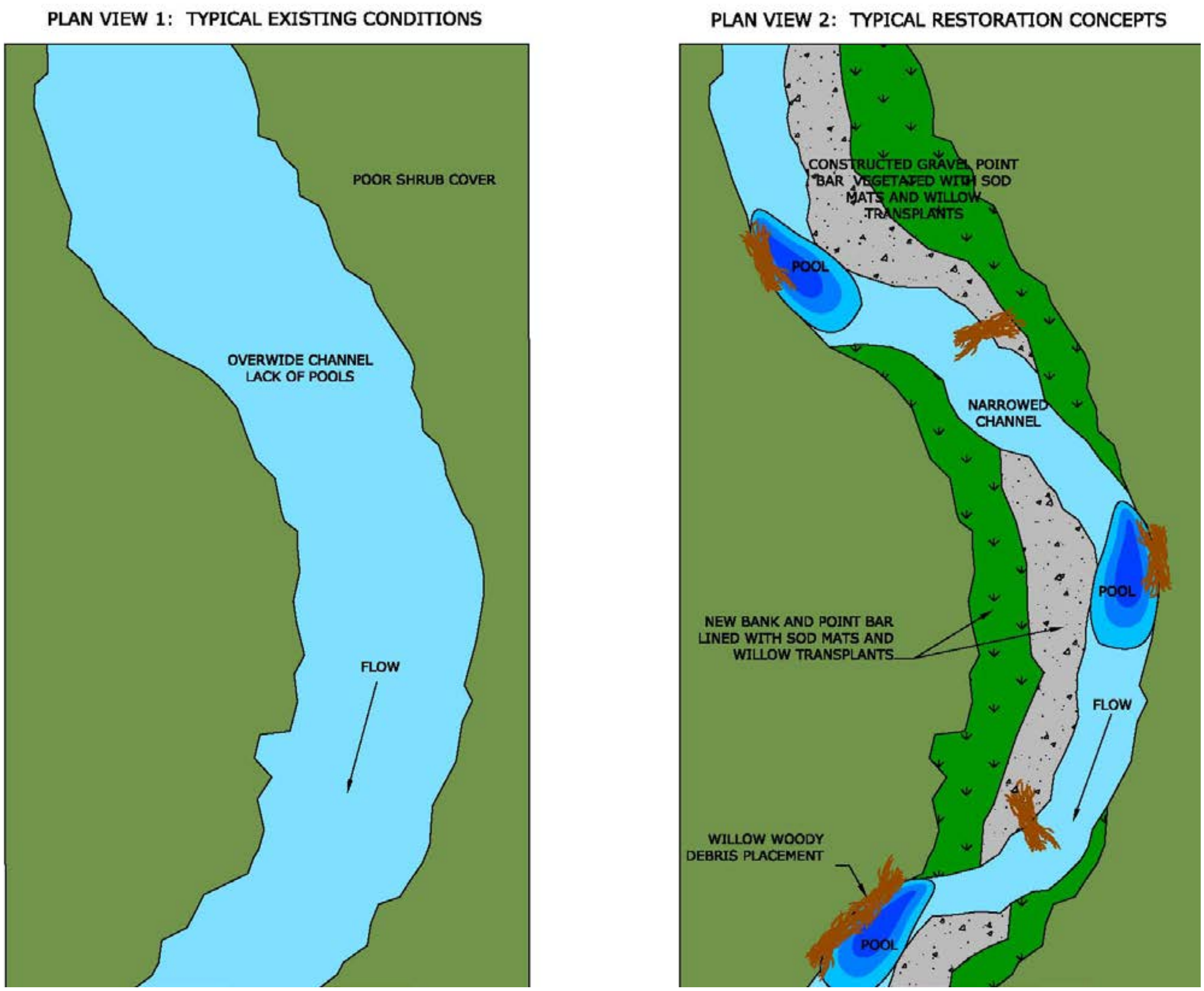


Figure 10-1: Schematic illustration of pool creation and channel redefinition in the Big Hole River.

10.4.2 Irrigation Management

Irrigation efficiency management practices in the Big Hole Watershed should involve investigating how to reduce the amount of stream water diverted during July and August while still growing crops on traditional cropland. It may be desirable to promote inefficient irrigation practices earlier in the year to promote groundwater return during July and August. Understanding irrigation water, groundwater, and surface water interactions is an important part of understanding how irrigation practices will affect stream flow during specific seasons.

Irrigation management is a critical component of attaining both Arctic grayling conservation and TMDL goals. The CCAA (MFWP and USFWS 2005) provides a plan to meet stream flow targets, and these stream flows will help meet temperature goals with increased flows. The CCAA landowner agreements detail a site-specific approach to irrigation management, the responsible parties, and an implementation schedule. This implementation strategy includes a brief description of these measures and some additional activities not covered in the CCAA.

The CCAA includes three categories of conservation actions to promote maintenance of adequate flows in the Big Hole River. These focus on irrigation diversions and delivery and are as follows:

- Improving the participating landowner's control of diversion, delivery, and measurement of water;
- Reducing the amount of diverted water; and
- Increasing the effectiveness with which diverted water is delivered to irrigated lands.

Overall, these activities are designed to increase water use efficiency to keep flows in the river while meeting the producer's forage production goals. Formal agreements for implementation of these actions are part of the CCAA for enrolled landowners. The CCAA partner agencies, NRCS and DNRC, will be responsible for developing water management plans for participating landowners and ensuring implementation of conservation measures. These landowner agreements include provisions for an implementation schedule requiring that implementation activities begin no later than the date upon which the site-specific landowner plan is finalized

10.4.2.1 Dewatering

Irrigation diversion has reduced the magnitude and duration of flows in the Big Hole River and tributary streams, especially during irrigation season from April through September. Flow reduction may increase water temperature, allows sediment to accumulate in stream channels, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation (Andrews and Nankervis 1995, Schmidt and Potyondy 2004). These alterations have the potential to result in sediment movement problems, temperature increases, and also result in reduction of aquatic organism habitat quality depending on location within the watershed.

Aerial photo analyses and field reconnaissance of the Big Hole River and tributary streams has identified some reaches where stream flows may be insufficient to maintain channel integrity. Streams and reaches with compromised channel definition below irrigation diversions have been inventoried for sections of the mainstem of the Big Hole River, Steel Creek, Warm Springs Creek, Governor Creek, Rock Creek, and Swamp Creek. Field observations identified stream channel alterations on these streams as well as Johnson Creek, Mussigbrod Creek, and North Fork Big Hole River. These alterations included excessive fine sediment on the streambed, and loss of streambed complexity (especially pool habitat). The effects of recent droughts have probably exacerbated these effects on channel integrity.

10.4.2.2 Irrigation Flow Restoration Recommendations

Achieve minimum flow targets/channel maintenance flows.
The CCAA establishes minimum flow targets for the Big Hole River, designed to provide adequate flows within critical habitat. It is unknown if these flows can be maintained by installing and using all reasonable irrigation efficiency management practices. All reasonable

irrigation efficiency management practices should be pursued on a voluntary basis. Maintaining these minimum flows in the Big Hole River will require that minimum flows also be maintained in at least some of the tributary streams within the CCAA area. Although these flows will benefit Arctic grayling and improve water quality, they will not affect streams outside of the CCAA area, and will not result in a flow regime that maintains sediment transport.

Channel maintenance flows help maintain the hydraulic conditions necessary for a channel to remain fully functioning for sediment transport and flow conveyance. Channel maintenance flows also help maintain instream habitat features for Arctic grayling, particularly deep pools for holding cover and development of gravel bars for spawning habitat. Channel maintenance flows should be considered as a viable restoration approach in all areas where channel definition and instream sediment sorting issues are identified.

Improving Irrigation Efficiency
Current irrigation practices are based on flood irrigation methods. Many head gates and ditches leak, which can decrease the amount of water in in-channel flows.

Irrigation Efficiency Restoration Recommendations
The following recommended activities would result in notable water savings.

- Install upgraded head gates for more exact control of water diversions, and to minimize leakage when not in operation.
- Develop more efficient means to supply water to livestock.
- Determine necessary amounts of water to divert that would reduce over watering and improve forage quality and production.
- Redesign irrigation systems.
- Upgrade ditches (including possible lining) to increase ditch conveyance efficiency.
- Redisign the composition and distribution of irrigated crops.

The CCAA (MFWP and USFWS 2005) program includes a provision for the NRCS to conduct a comprehensive investigation of existing attributes of water rights on the enrolled lands by considering factors such as water holding capacity of the soils, the water requirement of the crops, variability in environmental conditions, and cooperative use with adjacent landowners. This investigation will enable the NRCS to determine the suitable irrigation diversion amount needed for production of crops. This investigation will occur within 30 months of participant enrollment. Following determination of the CCAA diversion amount, enrolled landowners will have flexibility to upgrade their irrigation systems using one or several of the listed recommended options above.

The CCAA applies only to enrolled landowners in the upper Big Hole River planning area. However, the Big Hole Watershed Committee (BHWC), in conjunction with the NRCS and DNRC, will work with interested landowners throughout the upper basin to upgrade their systems and alter cropping and irrigation practices. These potential water savings will add to in channel flows, reduce summer water temperatures, and benefit Arctic grayling, the native fish assemblage, and associated aquatic life. Priority stream sites include stream segments lacking channel definition below diversions, on nutrient and temperature listed streams, where increased flows may assist in nutrient and thermal load dilution and increase the streams' assimilative capacity.

Ground water and surface water are connected. Irrigation plays a role in the amount of ground water in many areas of the Big Hole River Watershed. The most limiting timeframe in the Big Hole River for both irrigators and aquatic life occurs during the heat of the summer (July-early September). Irrigation efficiencies are only called for during hot weather periods for the temperature TMDLs. The timeframe it takes ground water to return to streams is not easily understood without specific study. The temperature TMDL uses general knowledge about irrigation and ground water influences within the project area. This is because of the scale of the project and difficulty in determining spatially and temporally specific groundwater return timeframes from irrigated areas. Therefore, further study should occur to determine time it takes ground water to travel to surface water within specific areas before large scale irrigation efficiency efforts are implemented. Further study should include any consideration of pivots or sprinklers, which may have a large affect upon ground water recharge rates and time of water use associated with water rights. Pivots are not always appropriate for preserving cool stream temperatures, yet may be appropriate in some areas if groundwater return from the irrigated area to streams is naturally delayed until cool weather timeframes when irrigation and evapotranspiration is not occurring.

Early season irrigation should consider both 1) stream flows which are necessary for channel formation and also 2) the ability for irrigation during this timeframe to recharge local aquifers. Spring time aquifer recharge has the potential to increase cool groundwater return flow during the heat of the summer. Irrigation efficiencies during the spring timeframe should not be implemented, unless bank full flood events are needed to scour stream channels and sort sediment within the channel. These two early season irrigation considerations should be balanced in concurrence with each other. Fertilizer application timeframes should also be considered for reducing nutrient runoff if excess water application occurs during high water.

10.4.3 Nutrient Management Planning

Nutrient management is managing the amount, source, placement, form, and timing of plant nutrients and soil amendments. Nutrient management components of the conservation plan should include the following information (NRCS MT 590-1):

- Field maps and soil maps
- Planned crop rotation or sequence
- Results of soil, water, plant, and organic materials sample analysis
- Realistic expected yields
- Sources of all nutrients to be applied
- Nutrient budget, including credits of nutrients available
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns
- Location of designated sensitive areas
- Guidelines for operation and maintenance.

Nutrient management is most effective when used with other agronomic practices, such as cover or green manure crops, residue management, conservation buffers, water management, pest management, and crop rotation. More information about nutrient management techniques can be found at your local NRCS office or in the NRCS publication MT 590-1.

10.4.4 Unpaved Roads BMPs

The road sediment reduction represents the estimated sediment load that would remain once all contributing road treads, cut slopes, and fill slopes were reduced to the maximum of 500 feet in mountainous settings and 100 feet in valley settings. These measurements were selected as an example to illustrate the potential for sediment reduction through BMP application and are not a formal goal at every crossing. For example many road crossings in mountainous settings can easily have a smaller contributing length than 500 ft, while others may not be able to meet a 500ft milestone. The best practical BMPs should be assessed and constructed starting with the most problematic road segments. Achieving the reductions in sediment loading called for in the TMDLs from the road system may occur through a variety of methods at the discretion of local land managers and restoration specialists. Undersized culverts should be replaced to pass at least a 50-100 year flood event if they fail.

Assessments should occur for roads within watersheds that experience timber harvest or other major land management operations. The information gathered during these assessments will allow for timely feedback to land managers about the impact their activities could have on water quality and achievement of TMDL targets and allocations. This feedback mechanism is intended to keep sediment load calculations current and avoid new road impacts that go undetected for an extended period of time.

10.4.5 Road Sanding

Application of sand to highways during winter months has the potential to increase loading of fine sediment (< 2 mm in diameter) to surface waters in the upper Big Hole River planning area. Source assessments for this category of fine sediment delivery included spatial evaluations of roads adjacent to streams, and a study commissioned by the Montana Department of Transportation (MDT) to evaluate contributions to select streams in the basin (Hydrometrics 2005). Essentially, this study provides many components of the TMDL with respect to this potential source of fine sediment. This includes a source assessment, evaluation of the relative contribution, and a basis to allocate an allowable load from this source.

Field reconnaissance investigations indicated stream crossings and stream adjacent reaches of highway were the features associated with potential delivery of road traction sand to surface waters (Hydrometrics 2005). Sand entered highway adjacent reaches after being thrown or washed down embankments; however, presence of a flat, vegetated drainage bottom between the embankment and stream impeded most of the delivery to streams. Observers identified ten reaches presenting a sediment delivery risk (**Table 10-3**) and rated these according to their potential to deliver sediment based on a questionnaire that evaluated distance from road to stream, percent vegetative cover, slope of the embankment, observed presence of sand, and evidence of conveyance.

Table10-3: Field reconnaissance results for Trail Creek stream segments proximal to Highway 43 (Hydrometrics 2005).

Stream Reach ID	Relative Road Sand Loading Potential (field inspection score)*	Stream Length Adjacent to Road Embankment	Average Distance Road Shoulder to Stream
TC-1	Low (10.0)	250	20
TC-2	Low (9.5)	300	30
TC-3	High (14.0)	300	15
TC-4	Low (9.0)	150	20
TC-5	High (12.5)	100	25
TC-6	High (12.5)	100	20
TC-7	High (12.5)	40	30
TC-8	Medium (12.0)	100	30
TC-9	Medium (12.0)	100	20
TC-10	Medium (12.0)	700	25

* Relative road sanding loading potential based on GIS analysis and field reconnaissance. Ratings are relative.

Stream crossings also presented risks for sediment loading along Highway 43 with 11 crossings identified as having moderate to high loading potential (**Table 10-4**). Factors contributing to delivery potential included distance of road to the stream, vegetative cover between road and stream, presence of road sand, and evidence of delivery of road sand to the stream. Road sand was attributable for a sharp contrast in substrate composition at several crossings. Sand comprised a majority of observed size fractions at these locations.

Table 10-4: Stream crossings with identified potential to deliver traction sand to surface waters in the Trail Creek drainage (Hydrometrics 2005).

Site	Stream Name	Crossing Type	Relative Loading Potential
TCX-1	Trail Creek	Bridge	High
TCX-2	Sheep Creek	Culvert	Moderate
TCX-3	Trail Creek	Bridge	High
TCX-4	May Creek	Culvert	Moderate
TCX-5	Trail Creek	Bridge	High
TCX-6	Canyon Creek	Culvert	Moderate
TCX-7	Cascade Creek	Culvert	Moderate
TCX-8	Sage Creek	Culvert	Moderate
TCX-9	Runaway Creek	Culvert	Moderate
TCX-10	Placer Creek	Culvert	Moderate
TCX-11	Trail Creek	Bridge	High

* Relative loading potential based on GIS analysis and field reconnaissance.

The Hydrometrics study (2005) also assessed loads from the different source areas. Roadside embankments delivered 0.54 tons of sand to streams, and delivery at road crossings totaled 0.90

tons of sand, for 1.44 tons/year in the 2004-2005 winter season. Although road traction sanding and fill erosion are a small proportion of the overall sediment loads, allocations are provided. Allocations for sediment contributed from road traction sanding are based on BMPs presented in **Table 10-5**.

Table 10-5: Road traction sanding BMPs on Highway 43 (MDT 2005).

Number	Description
1	Increasing salt concentration in the sand stockpile, which causes snowpack on the roadway to break up faster so fewer sand applications are necessary
2	Pre-wetting of sand/ salt with liquid magnesium chloride, which causes more of the road sand to stay on the roadway longer, instead of being blown off by traffic
3	Pre-application of liquid magnesium chloride, which, under proper conditions, keeps snowpack from forming a tight bond to the road surface
4	Recovering sand from the roadway, shoulders, ditches, and around guardrails, so the sand does not wash farther down slope
5	not applicable along this section of road.
6	Installation and monitoring of silt fences, especially in areas below the fill slopes where sand is being transported from the toe of the fill slope toward a stream
7	Redirecting the snow blower onto fill slopes, which allows the sand that lands on the fill slope with the snow to be captured and stabilized by fill slope vegetation
8	Accurate record keeping to track sand application and recovery rates and inform road maintenance management through the adaptive management approach

10.5 Recent Restoration Activities

A high level of restoration activities have occurred since the initiation of the TMDLs in this planning area or are currently underway due to Fluvial Arctic Grayling CCAA (candidate conservation agreement with assurances) restoration efforts. Generally, most of these restoration efforts promote reductions in sediment, heat and nutrient loads or help to alleviate current loads through increased buffering capacities of the streams in the Upper Big Hole Valley. **Table 10-6** identifies the differing types of restoration projects which include of irrigation and stock water efficiencies, riparian vegetation restoration, stream bank restoration, moving corrals off of streams, and livestock fencing for improving riparian grazing management.

Table 10-6. Fluvial Arctic Grayling CCAA Restoration Projects

CCAA Segment	TMDL Reach (Appendix K-4)	Project Title	Year Completed	Restoration (miles)	Fence (miles)	Headgates	Diversions	Fish ladder	Measuring Devices	Fish screens	Stockwater well
above Miner Cr. bridge	BH13, BH14	Jackson Reach Restoration	2007	0.75	1	0	0	0	0	0	0
above Miner Cr. bridge	BH14, BH15	Schindler Restoration	2008	0	1	0	0	0	0	0	0
above Miner Cr. bridge	BH14	Schindler Feedlot	2006	0	0	0	0	0	0	0	1
above Miner Cr. bridge		Dooling Livestock Well	2007	0	0	0	0	0	0	0	1
above Miner Cr. bridge	GC09, GC10	Governor Creek Culvert Replacement	On-Going	0.25	0	0	0	0	0	0	0
above Miner Cr. bridge		Mitchell Fish Ladder	2007	0	0	0	0	1	0	0	0
above Miner Cr. bridge		M Jackson Diversions/Fish Ladders	2006	0	0	2	2	2	0	0	0
Segment Subtotal				***1***	***2***	***2***	***2***	***3***	***0***	***0***	***2***
Miner Cr. to Little Lake Cr. bridge	WS12, WS13, WS14	Warm Springs Fence/Finch	2008	0	3	0	0	0	2	0	0
Miner Cr. to Little Lake Cr. bridge		Warm Springs Stock Water/Lapham	2008	0	0	0	0	0	0	0	1
Miner Cr. to Little Lake Cr. bridge		Johnson Headgates	2005	0	0	2	0	0	2	0	0
Miner Cr. to Little Lake Cr. bridge	WS09	Warm Springs Fence/ Lapham	2009	0	0.7	0	0	0	0	0	0
Miner Cr. to Little Lake Cr. bridge	BH16	Big Hole - Lapham Riparian Fence	2008	0	0.6	0	0	0	0	0	0
Miner Cr. to Little Lake Cr. bridge		John Jackson Wetland Restoration	2007	0	0	0	0	0	0	0	0
Miner Cr. to Little Lake Cr. bridge		Johnson Riparian Fence	2009	0							
Miner Cr. to Little Lake Cr. bridge		Husted/Hirschy Diversions	2006	0	0	3	1	0	2	0	0
Miner Cr. to Little Lake Cr. bridge		John Jackson Riparian Fence	2008								
Segment Subtotal				***0***	***4.3***	***5***	***1***	***0***	***6***	***0***	***1***
Little Lake Cr. to Wisdom bridge	RO05, RO06	Rock Creek Restoration	2007	2.5	5	1	1	1	0	0	0
Little Lake Cr. to Mudd Cr. bridge	BH25, BH26	Wisdom Reach Restoration	2007	1.75	3.5	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge	BH19	Big Hole/Little Lake Creek	2008	2	4.5	0	0	0	0	0	0

Table 10-6. Fluvial Arctic Grayling CCAA Restoration Projects

CCAA Segment	TMDL Reach (Appendix K-4)	Project Title	Year Completed	Restoration (miles)	Fence (miles)	Headgates	Diversions	Fish ladder	Measuring Devices	Fish screens	Stockwater well
		Restoration									
Little Lake Cr. to Wisdom bridge	BH24	McDowell Reach Restoration	2008	6	12	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge	BH24	Spokane Diversion - Fish Ladder	2003	0	0	0	0	1	0	0	0
Little Lake Cr. to Wisdom bridge		Huntley Headgates	2008	0	0	4	3	0	2	0	0
Little Lake Cr. to Wisdom bridge		Maverick Headgate	2006	0	0	1	0	0	0	0	0
Little Lake Cr. to Wisdom bridge	BH24	Hirschy Diversion	2006	0	0	1	2	0	0	0	0
Little Lake Cr. to Wisdom bridge		Peterson Feedlot	2007	0.2	0.5	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge		Big Hole Grazing Association Well	2008	0	0	0	0	0	0	0	1
Little Lake Cr. to Wisdom bridge		Nelson Fish Ladders (Rock,Big Lake Cr)	2008	0	0	0	0	2	0	0	0
Little Lake Cr. to Wisdom bridge		Hirschy Bank Restoration	2008	0.1	0	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge		Huntley Pasture/Riparian Fence	2008	0	3	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge		HHirschy Little Lake Stock Well	2008	0	0	0	0	0	0	0	1
Little Lake Cr. to Wisdom bridge		HHirschy Ruby Wells	2008	0	0	0	0	0	0	0	2
Little Lake Cr. to Wisdom bridge		HHirschy Headgate and Diversion	2008	0	0	1	1	0	1	0	0
Little Lake Cr. to Wisdom bridge		Nelson Rock Creek Fence	2008	0	0.75	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge		Nelson Stock Wells	2009	0	0	0	0	0	0	0	2
Little Lake Cr. to Wisdom bridge		Huntley Fish Ladder	2006	0	0	0	0	1	0	0	0
Little Lake Cr. to Wisdom bridge		Wisdom River Fence (Upper Rock Creek)	2008	0	1	0	0	0	0	0	0
Little Lake Cr. to Wisdom bridge		Rock Creek Fish Ladder (Erb)	2007	0	0	0	0	1	0	0	0
Segment Subtotal				***12.55***	***30.25***	***8***	***7***	***6***	***3***	***0***	***6***
Wisdom to Mudd Cr. bridge	NF09, NF10	North Fork Fish Screens	2008	0	0	0	0	0	0	2	0
Wisdom to Mudd Cr. bridge	SW08, SW09, SW10	Swamp Creek Riparian Fence	2008	0	12	0	0	0	0	0	0
Wisdom to Mudd Cr. bridge	BH26, BH27	Big Hole - Harrington Riparian Fence	2008	0	5	0	0	0	0	0	0

Table 10-6. Fluvial Arctic Grayling CCAA Restoration Projects

CCAA Segment	TMDL Reach (Appendix K-4)	Project Title	Year Completed	Restoration (miles)	Fence (miles)	Headgates	Diversions	Fish ladder	Measuring Devices	Fish screens	Stockwater well
Wisdom to Mudd Cr. bridge		Steel Creek Diversions	2008	0	0	1	1	0	0	0	0
Wisdom to Mudd Cr. bridge	SC06, SC07	Steel Creek Riparian Fence	2003	0	3	0	0	0			
Wisdom to Mudd Cr. bridge		York Gulch Riparian Fence	2008	0	3.5	0	0	0	0	0	0
Wisdom to Mudd Cr. bridge		Quarter Circle 3T Stock Well	2008	0	0	0	0	0	0	0	1
Wisdom to Mudd Cr. bridge		York Gulch Diversions	2008	0	0	5	5	5	5	0	0
Segment Subtotal				***0***	***23.5***	***6***	***6***	***5***	***5***	***2***	***1***
Mudd Cr. to Dickie bridge		Big Hole - Christiansen Riparian Fence	2008	0	2.85	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Ralston Big Hole Riparian Fence	2007	0	3.2	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Fishtrap Riparian Fence	2007	0	1	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Lamarche Creek Stock Water	2008	0	0	0	0	0	0	0	2
Mudd Cr. to Dickie bridge		Fishtrap Habitat Enhancement	2005	0.5	0	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Lamarche Creek Habitat Enhancement	2006	1	0	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Lamarche Creek Riparian Fence	2004	0	2.5	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Deep Creek Riparian Fence	2006	0	1	0	0	0	0	0	0
Mudd Cr. to Dickie bridge		Fishtrap Creek - Ernie Bacon Stock Wells	2008	0	0	0	0	0	0	0	2
Mudd Cr. to Dickie bridge		Reinhardt Stock Water Wells	2007	0	0	0	0	0	0	0	3
Mudd Cr. to Dickie bridge		Ralston Big Hole Stock Well	2008	0	0	0	0	0	0	0	1
Mudd Cr. to Dickie bridge		Ralston Deep Creek Stock Well	2008	0	0	0	0	0	0	0	1
Mudd Cr. to Dickie bridge		Fishtrap Luckey Stock Water	2008	0	0	0	0	1	0	0	0
Segment Subtotal				***1.5***	***10.55***	***0***	***0***	***1***	***0***	***0***	***9***
Totals				**15.05**	**70.6**	**21**	**16**	**15**	**14**	**2**	**19**

10.6 Watershed Restoration Summary

The most important restoration efforts for implementation in the upper and North Fork Big Hole Watersheds will be to restore and protect riparian vegetation. Restoring riparian areas will provide the most sediment, nutrient, and thermal load reductions. A tiered approach for restoring stream channels and adjacent riparian vegetation should consider the existing conditions of the stream channel and adjacent vegetation. In non-conifer dominated areas, the restoration goals should focus on restoring natural shrub cover on streambanks to reference levels which are provided by the sediment, nutrient and temperature TMDL riparian vegetation targets. In areas with little to no shrub vegetation exists in non-conifer dominated riparian zones, active natural shrub reintroduction should occur, especially where CCAA and TMDL objectives overlap. In areas where stream channels are unnaturally stable or streambanks are eroding excessively, active restoration approaches such as channel design, bank sloping, seeding and shrub planting may be needed.

All riparian areas should be protected against excessive hoof sheer, over grazing, and especially over browsing. In many cases where riparian areas are heavily impacted, protection may need a number of years rest with careful deferment or rotation schedules thereafter. In areas meeting riparian, stream channel, and other targets, these protections should continue with active grazing and hay management. Active riparian grazing management is important for long term health of riparian zones. When actively managing these zones after restoration when shrub health has increased, browse should be kept to a minimum. These areas should be utilized during specific seasons that promote grazing and not browsing. Grazing use of riparian areas should also occur quickly and only when sufficient forage is available. Grazing systems should be dynamic and based upon measures of browse, hoof sheer and stubble height only after sufficient shrubs have been allowed to recover. Weed management should also be a dynamic component of managing riparian areas as they recover.

Other restoration activities called for by the TMDLs include nutrient management on irrigated areas, unpaved road BMPs, and road sanding BMPs on Lost Trail Pass.

SECTION 11.0
MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

11.1 Introduction

This section provides a monitoring strategy to strengthen the TMDLs presented in this report, assess water quality issues on water bodies that are not currently listed but may be impaired, and determine the effectiveness of restoration activities recommended in Section 10.0 once they are implemented. Funding for future monitoring is uncertain and variable due to economic and political change. Prioritization of monitoring activities depends on stakeholder priorities for restoration activities and funding opportunities.

11.2 Future Monitoring Guidance

A number of future monitoring objectives are identified in the Upper and North Fork Big Hole Watershed. A portion of the monitoring identified in this section is proposed to observe how sediment, temperature and nutrient conditions change over time as restoration activities occur. Another goal of future monitoring will be to strengthen current TMDL source assessments in limited areas before well-informed restoration can occur. A third objective of monitoring identified in this section identifies streams and pollutants that should be investigated further because there are indications that TMDLs may be needed.

11.2.1 Strengthening Source Assessment Prior to Restoration Work

11.2.1.1 Hydrology

A water balance and irrigation efficiency study should be conducted for the upper Big Hole valley. Additionally, the study should determine if the irrigation infrastructure or management can be modified to reduce/retain more instream flow during environmentally sensitive timeframes. Once feasible irrigation improvements are identified and planned, additional monitoring should be conducted to quantify irrigation effects to ground water conditions and ultimately surface water as improvements are implemented. As irrigation efficiency projects are implemented, effectiveness monitoring should occur to see how much water is saved by each project. An economic analysis of each irrigation efficiency project should also occur to determine the cost of the saved water. See the recently completed report for the Upper Jefferson River for an example approach to determining the most cost effective saving water alternatives. This effort would need local initiation. Funding would likely come from both local match and also federal and state sources.

11.2.1.2 Nutrients

Steel and Francis Creek nutrient TMDLs were completed during this TMDL development effort. Controllable human caused sources in these watersheds are agricultural based and restoration approaches involve riparian and upland grazing management along with fertilizer management. These restoration approaches are very reasonably implemented and clearly identified by the

TMDL source assessment and allocation approach. No further water quality nutrient monitoring is necessary before restoration activities begin. Prioritizing areas for riparian restoration could be based upon further riparian vegetation monitoring efforts, but local knowledge and professional judgment are acceptable approaches to prioritizing riparian restoration projects in both watersheds.

11.2.1.3 Sediment

If there is stakeholder interest to do so, future TMDL reviews could refine the allocation approach to include allocations specific to road ownerships such as BLM, county, private and USFS areas. Sediment allocations to roads and unpaved road restoration activities would likely benefit from this effort.

A sediment TMDL was written for Miner Creek even though very little restoration work can occur in this watershed. A more robust spatial sampling of stream bottom content and eroding bank monitoring in Miner Creek may be warranted before restoration work is completed. The results could indicate if future restoration work is necessary.

Additional monitoring is recommended to gain a better understanding of streambank retreat rates. Streambank retreat rates are part of the equation for calculating sediment loading from near-stream sediment sources for sediment TMDLs and allocation. The current sediment TMDLs are calculated using literature values for streambank retreat rates. Measuring streambank retreat rates on water bodies within the Upper and North Fork Big Hole TPA would be useful to verify or revise the bank retreat rates used in this effort and would also be useful for completing or revising sediment TMDLs in other watersheds throughout southwest Montana and other areas with similar settings. Bank retreat rates can be determined by installing a series of bank pins at different positions on the streambank at several transects in sites placed in a range of landscape settings and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions.

Conditions relative to sediment production at unpaved road crossings should be monitored prior to and post restoration efforts. Pre and post restoration information should be applied to the same unpaved road model used for the TMDL sediment assessments. This approach would estimate sediment reduction from unpaved road erosion reduction projects.

11.2.1.4 Temperature

Irrigation returns can contribute heat to the water bodies to which they drain. Irrigation withdrawals can cause increases in stream temperature and reduce the efficiency of sediment routing. The irrigation network in the Upper Big Hole Valley is extensive and could not be fully assessed during this TMDL assessment. Irrigation also has a large influence on ground water in the upper Big Hole Valley, which in turn, influences surface water conditions. A more thorough assessment of irrigation water use above Wisdom would be useful for irrigation water management restoration activities. See the hydrology monitoring Section 11.2.1.1 for more guidance about hydrological assessment.

An aerial assessment of temperature trends of the upper Big Hole River using Forward-Looking Infrared (FLIR) technology would be useful for identifying influences of irrigation and groundwater on the temperature of the upper Big Hole River. Future efforts should identify all significant irrigation withdrawals and returns. A subset of these should be monitored for pollutant impacts to streams.

11.2.2 Impairment Status Monitoring

The Montana Department of Environmental Quality (DEQ) is the lead agency for developing and conducting impairment status monitoring. Other agencies or entities may work closely with the DEQ to provide compatible data if interest arises. Impairment determinations are conducted by the State of Montana but can use data from other collection sources. The following section provides general guidance for future impairment status monitoring.

11.2.2.1 Sediment

A sediment TMDL was not completed in Warms Springs Creek even though significant controllable human caused sources were present because sediment conditions in the stream could not be clearly linked to aquatic life impacts. Further stream bottom content and pool measurements should occur to verify this is the case. This monitoring would likely occur by the DEQ or via funding from the DEQ.

The DEQ is currently considering overall biological health and also sediment related metrics for periphyton assessments. These new metrics may provide additional relevant information relating to beneficial uses should be considered during future TMDL reviews.

11.2.2.2 Metals

Further copper monitoring and follow up 303d assessments should occur to determine if a TMDL or site specific standards are needed for Governor Creek. Further lead and copper monitoring and a follow up 303d assessment should occur to determine if a TMDL or site specific standards are needed for Joseph Creek. Lead should continue to be monitored in Mussigbrod Creek to determine if site specific standards are needed. Further cadmium and copper monitoring and a follow up 303d assessment should occur to determine if a TMDL or site specific standards are needed for Steel Creek.

11.2.2.3 Nutrients

A number of nutrient TMDLs were not pursued at this time. Some were not pursued due to their recent inclusion in Montana’s 303(d) List. Others were not pursued because of the lacking knowledge about their extensive irrigation network which heavily influence stream flow and nutrient load. Future stream flow and nutrient monitoring should occur in Rock, McVey, Swamp, Fox, Pine and Warm Spring Creek watersheds prior to TMDL development to increase knowledge about nutrient conditions in each of these watersheds. Irrigation water management should also be investigated further in these watersheds during future TMDL development.

Future nutrient monitoring at or below Wisdom on the upper Big Hole River is warranted. Large algae mats are observed during summer low flow timeframes during a number of recent years. Little to no nutrient data are available to assess nutrient conditions in this reach of the Big Hole River. Part of the algae growth may be caused by increased sunlight due to over wide stream and warmed conditions from low stream flow in this area.

11.2.2.4 Temperature

A temperature TMDL for Pintlar Creek was not pursued at this time. Monitoring information produced from this effort did not provide enough information to determine if a TMDL was needed. Further monitoring of irrigation system water use is recommended. A more robust aerial photo assessment and associated riparian vegetation shade monitoring may be necessary.

11.2.3 Effectiveness Monitoring for Restoration Activities

The following recommendations are categorized by the type of restoration practice to which they apply.

11.2.3.1 Road BMPs

Monitoring road sediment delivery is necessary to determine if BMPs are effective, to determine which are most effective, and to determine which practices or sites require modification to achieve water quality goals. Effectiveness monitoring should be initiated prior to implementing BMPs at treatment sites.

Monitoring actual sediment routing is difficult or prohibitively expensive. It is likely that budget constraints will influence the number of monitored sites. A detailed monitoring study design should be developed once specific restoration projects are identified. Monitoring at specific locations should continue for a period of 2-3 years after BMPs are initiated to overcome environmental variances.

Specific types of monitoring for separate issues and improvements are listed in **Table 11-1**.

Table 11-1: Monitoring Recommendations for Road BMPs.

Road Issue from Section 10.0 (Restoration)	Restoration Recommendations	Monitoring Recommendation	Recommended Methodology
Ditch Relief Combined with Stream Crossings	• Re-engineer & rebuild roads to completely disconnect inboard ditches from stream crossings. Techniques may include: o Ditch relief culverts o Rolling dips o Water Bars o Outsloped roads o Catch basins o Raised road grade near stream crossing	• Place silt trap directly upslope of tributary crossing to determine mass of sediment routed to that point • Rapid inventory to document improvements and condition	• Sediment yield monitoring based on existing literature/USFS methods • Revised Washington Forest Practices Board methodology
Ditch Relief Culverts	• Consider eliminating the inboard ditch and outsloping the road or provide rolling dips • When maintaining/ cleaning ditch, do not disturb toe of cutslope • Install culverts with proper slope and angle following Montana road BMPs • Armor culvert outlets • Construct stable catch basins • Vegetate cutslopes above ditch • Increase vegetation or install slash filters, provide infiltration galleries where culvert outlets are near a stream	• Rapid inventory to document improvements and condition • Silt traps below any ditch relief culvert outlets close to stream	• Revised Washington Forest Practices Board methodology • Sediment yield monitoring based on existing literature/USFS methods
Stream Crossings	• Place culverts at streambed grade and at base of road fill • Armor and/or vegetate inlets and outlets • Use proper length and diameter of culvert to allow for flood flows and to extend beyond road fill	• Repeat road crossing inventory after implementation • Fish passage and culvert condition inventory	• Revised Washington Forest Practices Board methodology • Montana State (DNRC) culvert inventory methods

Table 11-1: Monitoring Recommendations for Road BMPs.

Road Issue from Section 10.0 (Restoration)	Restoration Recommendations	Monitoring Recommendation	Recommended Methodology
Road Maintenance	• Avoid casting graded materials down the fill slope & grade soil to center of road, compact to re-crown • Avoid removing toe of cut slope • In some cases (primarily Ramshorn Creek Road) graded soil may have to be removed or road may have to be moved	• Repeat road inventory after implementation • Monitor streambed fine sediment (grid or McNeil core) and sediment routing to stream (silt traps) below specific problem areas	• Revised Washington Forest Practices Board methodology • Standard sediment monitoring methods in literature
Oversteepened Slopes/General Water Management	• Where possible outslope road and eliminate inboard ditch • Place rolling dips and other water diverting techniques to improve drainage following Montana road BMPs • Avoid other disturbance to road, such as poor maintenance practices and grazing	• Rapid inventory to document improvements and condition	• Revised Washington Forest Practices Board methodology

11.2.3.2 Agricultural BMPs

Management improvements related to grazing, irrigation, and crop production have been implemented in many areas throughout the Upper and North Fork Big Hole River TPA. These projects have been implemented through NRCS, State, other federal, or private funds, and often include monitoring specific to those projects. Additional monitoring is recommended below for future improvements and projects.

Grazing BMPs function to reduce grazing pressure along streambanks and riparian areas. Recovery resulting from implementing BMPs may be reflected in improved water quality, channel narrowing, cleaner substrates, and recovery of vegetation along streambanks and riparian areas. Effectiveness monitoring for grazing BMPs should be conducted over several years, making sure to start monitoring prior to BMP implementation. If possible, monitoring reaches should be established in pastures keeping the same management as well as in those that have changed. Where grazing management includes moving livestock according to riparian use level guidelines, it is important to monitor changes within the growing season as well as over several years. Monitoring recommendations to determine seasonal and longer-term changes resulting from implementing grazing BMPs are outlined below in **Table 11-2**.

Table 11-2: Effectiveness Monitoring Recommendations for Grazing BMPs by Restoration Concern.

Recovery Concern	Monitoring Recommendations	Methodology or Source
Seasonal impacts on riparian area and streambanks	Seasonal monitoring during grazing season using riparian grazing use indicators • Streambank alteration • Riparian browse • Riparian stubble height at bank and "key area"	BDNF/BLM riparian standards (Bengeyfield and Svoboda, 1998)
Long-term riparian area recovery	• Photo points • PFC/NRCS Riparian Assessment (every 5-10 yrs) • Vegetation Survey (transects perpendicular to stream and spanning immediate floodplain) every 5-10 years o Strip transects- Daubenmire 20cm x 50cm grid or point line transects	Harrelson et al., 1994; Bauer and Burton, 1993; NRCS, 2001 Stream Assessment Protocols
Streambank stability	Greenline including bare ground, bank stability, woody species regeneration (every 3-5 years)	Modified from Winward, 2000
Channel stability	Cross-sectional area, with % fines/ embeddedness • Channel cross-section survey • Wolman pebble count • Grid or McNeil core sample	Rosgen, 1996; Harrelson et al., 1994
Aquatic habitat condition	• Aquatic macroinvertebrate sampling • Pool quality • R1/R4 aquatic habitat survey	DEQ biomonitoring protocols; Hankin and Reeves, 1988; USFS 1997 R1R4 protocols
General stream corridor condition	EMAP/Riparian Assessment (every 5-10 yrs)	NRCS 2001 Stream Assessment Protocols; U.S. EPA 2003.

11.2.3.4 Other Restoration Activities

This TMDL assessment has revealed the importance of beaver to stream systems within the Upper and North Fork Big Hole River TPA. Beavers are important for managing water and sediment runoff and allowing recovery of riparian zones. Re-establishing populations in some areas may be an important tool for restoring natural channel dynamics and healthy riparian zones. Alternatively, beavers may cause problems by moving into irrigation networks and may need to be managed closely because of this issue. Monitoring is needed to identify areas that can support beaver populations, define habitat requirements to be able to assess likelihood of reintroduction success in potential sites, and determine positive and negative influences of beaver reintroduction on channel stability, fish habitat, water quality and quantity, riparian habitat, and aquatic and terrestrial wildlife. Specific monitoring needs will depend on the nature of reintroduction efforts and site-specific requirements.

11.2.3.5 Watershed-Scale Monitoring

Monitoring should be conducted at a watershed scale over several years to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. It is important to remember that degradation of aquatic resources happens over many decades, and that restoration is also a long-term process. Long-term monitoring should be an understood component of any restoration effort.

Trends in water quality are difficult to define, and even more difficult to relate directly to restoration or other changes in management, due to the natural high variability in water quality conditions. Improvements in water quality or aquatic habitat resulting from restoration activities on listed streams are most likely to be evident in increases in instream flow, changes in communities and distribution of fish and other bioindicators, improvements in bank stability and riparian habitat, changes in channel cumulative width/depths, fine sediment deposition and channel substrate embeddedness. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budgetary and time constraints. Long term water quality assessment should occur at the USGS Wisdom gage station to document long term trends in temperature, nutrients and potentially Total Suspended Solids (TSS).

SECTION 12.0
STAKEHOLDER AND PUBLIC COMMENTS

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. Public comment on the Upper and North Fork Big Hole River TMDLs involved two components. First, stakeholders and a technical advisory group (including private landowners, conservation groups, and agency representatives) were kept abreast of the TMDL process through periodic meetings, and were provided opportunities to review and comment on interim technical documents which ultimately became appendices to the final TMDL document. The stakeholders and a technical advisory group also were allowed a stakeholder draft comment timeframe during which the draft document was posted on the Big Hole Watershed Committee's website until the public comment draft was posted for the public comment period on DEQ's website. In addition, presentations about the draft TMDL document were provided to the following groups:

- Technical Advisory Group – Divide, MT, November, 6th, 2008
- Stakeholder Feedback – Wisdom, MT, November, 11th , 2008

The second component of public involvement was a public comment period. This public review period was initiated on December 15th, 2008 and extended through January 16th, 2009. A public meeting on December 10th, 2008 in Wisdom, Montana provided an overview of the Upper and North Fork Big Hole River TMDLs and Watershed Water Quality Planning Framework document. The meeting provided an opportunity to solicit public input and comments on the plan. This meeting and the opportunity to provide public comment on the draft document were advertised via a press release by DEQ and was included in a number of local newspapers. Copies of the main document were available at the Beaverhead County Conservation District, Wisdom Post Office, Jackson Post Office, the Montana State Library, and via the internet on DEQ's web page or via direct communication with the DEQ project manager.

Appendix L includes a summary of the public comments received and the DEQ response to these comments. The original comment letters are located in the project files at DEQ and may be reviewed upon request.

DEQ also provides an opportunity for public comment during the biennial review of the Montana's Integrated Water Quality Report that includes the 303(d) List. This includes public meetings and opportunities to submit comments either electronically or through traditional mail. DEQ announces the public comment opportunities through several media including press releases and the Internet.

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