Water Quality Assessment for the Tongue River Watershed, Montana

August 2, 2007

FINAL DRAFT

Prepared by:
U.S. Environmental Protection Agency
Montana Operations Office and Tetra Tech, Inc.

Project Manager: Ron Steg

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Acronyms

ARM	Administrative Rules of Montana
BEHI	Bank erosion hazard index
BLM	Bureau of Land Management
CBM	Coal bed methane
CFS	Cubic feet per second
CWA	Clean Water Act
DNRC	Montana Department of Natural Resources and Conservation
DO	Dissolved oxygen
EC	Electrical conductivity
EIS	Environmental Impact Statement
GIS	Geographic information system
HII	Human Influence Index
MDEQ	Montana Department of Environmental Quality
MFWP	Montana Fish, Wildlife, and Parks
mg/L	Milligrams per liter
MLRA	Major land resource area
MRLC	Multi-Resolution Land Characterization
NASS	National Agricultural Statistics Service
NCEPD	Northern Cheyenne Environmental Protection Department
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NTU	Nephelometric turbidity units
NWIS	National Water Information System
RBC	Riparian and bank condition
RBS	Relative bed stability
REMAP	Regional Environmental Monitoring and Assessment Program
SAR	Sodium adsorption ratio
SC	Specific conductance
TDS	Total dissolved solids
TMDL	Total maximum daily load
TN	Total nitrogen
TP	Total phosphorus
TR	Total Recoverable
TRR	Tongue River Reservoir
TRWU	Tongue River Water Users
TSI	Trophic state index
TSS	Total suspended solids
T&Y	Tongue and Yellowstone Irrigation District
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
USDI	United States Department of Interior
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
WDEQ	Wyoming Department of Environmental Quality
WQ	Water quality
WRCC	Western Regional Climate Center
WWDC	Wyoming Water Development Commission

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EXECUTIVE SUMMARY

This document presents an assessment of water quality in the Tongue River, Tongue River Reservoir, and Hanging Woman, Otter, and Pumpkin Creeks. This assessment is based on data and information through September 2006 (this varies on a case-by-case basis depending upon data availability) and the focus is on the listed pollutants and impaired beneficial uses from the 1996 and 2006 Montana Clean Water Act Section 303(d) lists. Pollutants addressed included salinity, sodium adsorption ratio (SAR), metals, sulfates, sediment, nutrients, dissolved oxygen, and temperature. The primary purpose of this assessment was to compare the available water quality data to the applicable Montana water quality standards and, in cases where exceedances of Montana's standards are observed, provide insight into the cause (i.e., natural, anthropogenic, or a combination of both) based on the results of modeling and other analyses. This assessment has been conducted for informational purposes, outside of any regulatory context, to provide watershed stakeholders and decision makers with baseline information regarding the current condition of the waters in the Tongue River Watershed. Formal interpretation of Montana's water quality standards and 303(d) impairment decisions are beyond the scope of these analyses and are not provided.

A list of the waters and pollutants that have been addressed and qualitative, summary assessment results are presented in Table 1. The results in this table are not provided as conclusions regarding water quality impairment status under Clean Water Act Section 303(d). Rather, these summary results are intended to identify where exceedances of Montana's water quality standards have been observed based on the data considered in this assessment. The circumstances around the exceedances reported in Table 1 and details regarding the magnitude, duration and frequency of the exceedances are presented in the document. Water quality impairment status will be determined by the Montana Department of Environmental Quality based on their interpretation of their water quality standards and application of their assessment protocols.

Table 1. Summary listing of the waters and pollutants addressed and qualitative results.

Waterbody	Waterbody ID	Pollutants Addressed	Has the Standard or Indicator Value Been Exceeded?
Tongue River – WY Border to Tongue River Reservoir	MT42B001-001	Salinity	Yes
		SAR	No
		Metals	Yes
		Sulfate	Requires interpretation of Montana's narrative standards
Tongue River – TRR Dam to the Confluence with Hanging Woman Creek	MT42B001-020	Salinity	No
		SAR	No
		Sulfate	Requires interpretation of Montana's narrative standards
		Sediment	Requires interpretation of Montana's narrative standards
Tongue River – Hanging Woman Creek to T&Y Diversion Dam	(MT42C001-001) MT42C001-012	Salinity	Yes
		SAR	No
		Metals	Yes
		Sediment	Requires interpretation of Montana's narrative standards
Tongue River – T&Y Diversion dam to Mouth	(MT42C001-001) MT42C001-011	Salinity	Yes
		SAR	No
		Metals	Yes
		Sediment	Requires interpretation of Montana's narrative standards
Tongue River Reservoir	MT42B003-010	Salinity	No
		SAR	No
		Nutrients	Requires interpretation of Montana's narrative standards
		Dissolved oxygen	Yes
		Sediment	Requires interpretation of Montana's narrative standards
Hanging Woman Creek	(MT42B002-003) MT42B002-031	Salinity	Yes
		SAR	Yes
		Metals	Yes
		Sediment	Requires interpretation of Montana's narrative standards
Otter Creek	MT42C002-020	Salinity	Yes
		SAR	Yes
		Metals	Yes
		Sediment	Requires interpretation of Montana's narrative standards
Pumpkin Creek	MT42C002-060	Salinity	Yes
		SAR	Yes
		Temperature	Requires interpretation of Montana's narrative standards

1.0 INTRODUCTION

This document presents an assessment of water quality in the Tongue River and includes a summary and evaluation of available chemical, physical, and biological data for the water bodies in the Tongue River Watershed that have previously appeared on Montana's 303(d) lists. The analyses presented in this report specifically focus on the listed pollutants and impaired beneficial uses from the 1996[a] and 2006 Montana 303(d) lists (see Section 1.1). Salinity and sodium adsorption ratio (SAR) are also considered in each of the subject streams to provide a watershed-scale perspective for these two pollutants, whether they appeared on the 303(d) lists for these pollutants or not. The main stem Tongue River, the Tongue River Reservoir, Hanging Woman Creek, Otter Creek, and Pumpkin Creek are addressed (Figure 1-1) and the water quality characteristics of these water bodies within both Wyoming and Montana are considered.

This document compares the available water quality data to the applicable Montana water quality standards and, where exceedances are observed, provides insight regarding the potential cause of the exceedances (i.e., natural versus anthropogenic). Montana's water quality standards are used as a point of reference. Formal interpretation of Montana's water quality standards and 303(d) impairment decisions are outside the scope of these analyses and are not provided.

This document first presents the 303(d) list status of waters within the Tongue River watershed. This is followed by a water body-by-water body review of the available chemical and physical data for each listed water body.

The document entitled "Modeling Report for the Tongue River Watershed" (hereafter referred to as the "Modeling Report") is a companion to this document and is incorporated by reference (USEPA, 2007). The following detailed information and supporting technical analyses are presented in appendices:

- Appendix A – Montana Narrative Water Quality Standards
- Appendix B – Methodology for Applying Montana's Water Quality Standards
- Appendix C – Coefficients for Calculating Montana's Metals Standards
- Appendix D – Wyoming and Northern Cheyenne Water Quality Standards
- Appendix E – Monthly SC Analysis
- Appendix F – Monthly SAR analysis
- Appendix G – Groundwater Concentrations in Hanging Woman Creek, Otter Creek, and Pumpkin Creek
- Appendix H – Hydrology of the Tongue River Watershed
- Appendix I – Biological Assemblages and Application of the Multi-Metric Index (MMI) and the River Invertebrate Prediction and Classification System (RIVPACS) in the Tongue River Watershed
- Appendix J – Tongue River Model Scenarios
- Appendix K – Comparison of Great Plains Streams Water Chemistry Data
- Appendix L – 2003 Water Quality Sampling Data

[a] At this point in time, Montana is compelled by a Settlement Agreement between the Montana Department of Environmental Quality, U.S. Environmental Protection Agency, and Friends of the Wild Swan et. al to address waters appearing on the 1996 303(d) list even though a more recent 303(d) list has been completed and approved.

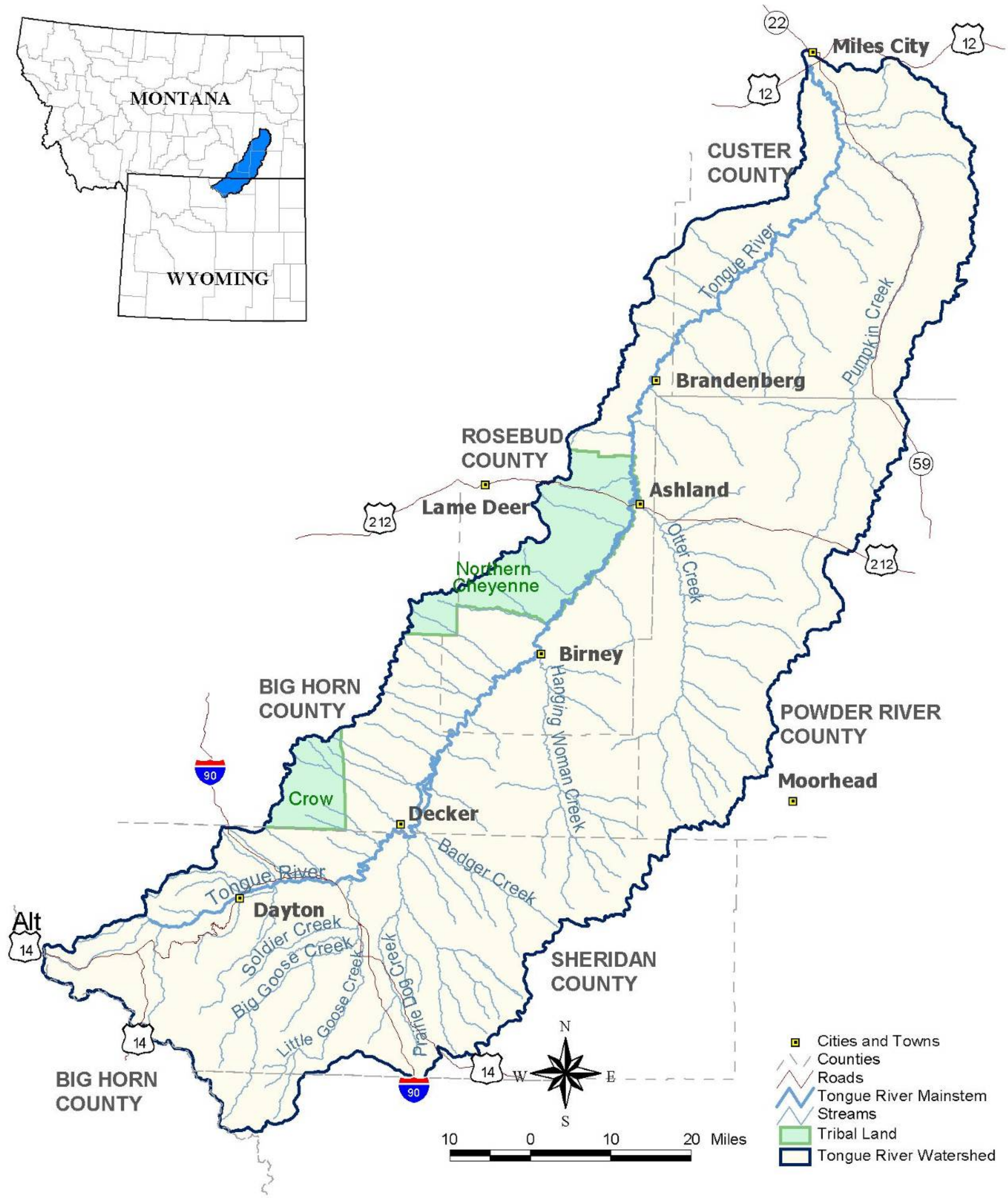


Figure 1-1. Location of the Tongue River watershed.

1.1 Montana 303(d) List Status

A summary of the Montana 1996 and 2006 303(d) lists is provided in Table 1-1 and Table 1-2. Figure 1-2 shows the locations of probable impaired and threatened segments within the Tongue River watershed, as identified in the 1996 to 2006 303(d) lists. The Montana 1996 303(d) list reported that the Tongue River, Tongue River Reservoir, Hanging Woman Creek, Otter Creek, and Pumpkin Creek were impaired (MDEQ, 1996). In 2006, the Montana 303(d) list reported that the Tongue River, Tongue River Reservoir, and Hanging Woman Creek were impaired (MDEQ, 2006a). Combined, the listed probable causes of impairment for these waterbodies included flow alteration, nutrients, organic enrichment/low dissolved oxygen, algal growth/chlorophyll-a, suspended solids/siltation, metals, other inorganics (sulfate), salinity, total dissolved solids, chlorides, other habitat alterations, and thermal modifications. The most common impaired beneficial uses appearing on the 303(d) lists were fisheries and aquatic life.

USEPA has made a determination that some categories of water quality impairment are not considered pollutants subject to regulation under the Clean Water Act (Dodson, 2001). Causes of impairment, including habitat alterations, fish habitat degradation, channel incisement, bank erosion, riparian degradation, stream dewatering, and flow alterations have all been placed in a general category of "pollution" for which TMDLs are not required. On the other hand, TMDLs are required to address impairments caused by discrete "pollutants", such as heavy metals, nutrients, and sediment (Dodson, 2001). This document focuses on this latter impairment cause category, but attempts to understand the relationships between general pollution problems (e.g., bank erosion) and those caused by specific pollutants (e.g., sediment).

Table 1-1. Streams and impaired beneficial uses listed on the Montana 1996 and 2006 303(d) lists for the Tongue River watershed.

Waterbody & Stream Description	Waterbody #	Use Class	Year	Aquatic Life	Fisheries	Drinking Water	Swimmable/ (Recreation)	Agriculture	Industry
Tongue River – WY Border to Tongue River Reservoir	MT42B001-001	B2	1996	P	P			N	
			2006	X	X	X	X	X	X
Tongue River Reservoir	MT42B003-010	B2	1996	P	P		P		
			2006	P	X	X	P	F	F
Tongue River – TRR Dam to the Confluence with Hanging Woman Creek	MT42B001-020	B3	1996	P	P				
			2006	X	X	X	X	X	X
Tongue River – Hanging Woman Creek to T&Y Diversion Dam	(MT42C001-001) MT42C001-012	B3	1996	P	P			P	
			2006	X	X	X	X	X	X
Tongue River – T&Y Diversion Dam to Mouth	(MT42C001-001) MT42C001-011	B3	1996	P	P			P	
			2006	P	P	X	P	F	F
Hanging Woman Creek	(MT42B002-003) MT42B002-031	C3	1996	P	P			P	
			2006	P	P	X	X	X	X
Otter Creek	MT42C002-020	C3	1996	P	P			P	
			2006	X	X	X	X	X	X
Pumpkin Creek	MT42C002-060	C3	1996	P	P			P	
			2006	X	X	X	X	X	X

__F__= Full Support; __P__= Partial Support; __N__= Not Supported; __T__= Threatened; __X__= Not Assessed (Insufficient Credible Data).

Table 1-2. Probable causes of water quality impairment in the Tongue River watershed identified in the 1996 and 2006 Montana 303(d) lists.

Waterbody	1996 Causes[1]	2006 Causes[1]
Tongue River – WY Border to Tongue River Reservoir	*Flow alteration*	Not Assessed
Tongue River Reservoir	Nutrients Organic enrichment/ dissolved oxygen Suspended solids	Chlorophyll-a
Tongue River – TRR Dam to the confluence with Hanging Woman Creek	*Flow alteration*	Not Assessed
Tongue River – Hanging Woman Creek to T&Y Diversion Dam	*Flow alteration* Metals Other inorganics Salinity/TDS/chlorides Suspended solids	Not Assessed
Tongue River – T&Y Diversion Dam to Mouth	*Flow alteration* Metals Other inorganics Salinity/TDS/chlorides Suspended solids	*Low Flow Alterations*
Hanging Woman Creek	*Flow alteration* Metals Salinity/TDS/chlorides	Siltation
Otter Creek	Metals *Other habitat alterations* Salinity/TDS/chlorides Suspended solids	Not Assessed
Pumpkin Creek	*Flow alteration* Salinity/TDS/chlorides Thermal modifications	Not Assessed

[1]Nonpollutants for which TMDLs are not required are italicized.

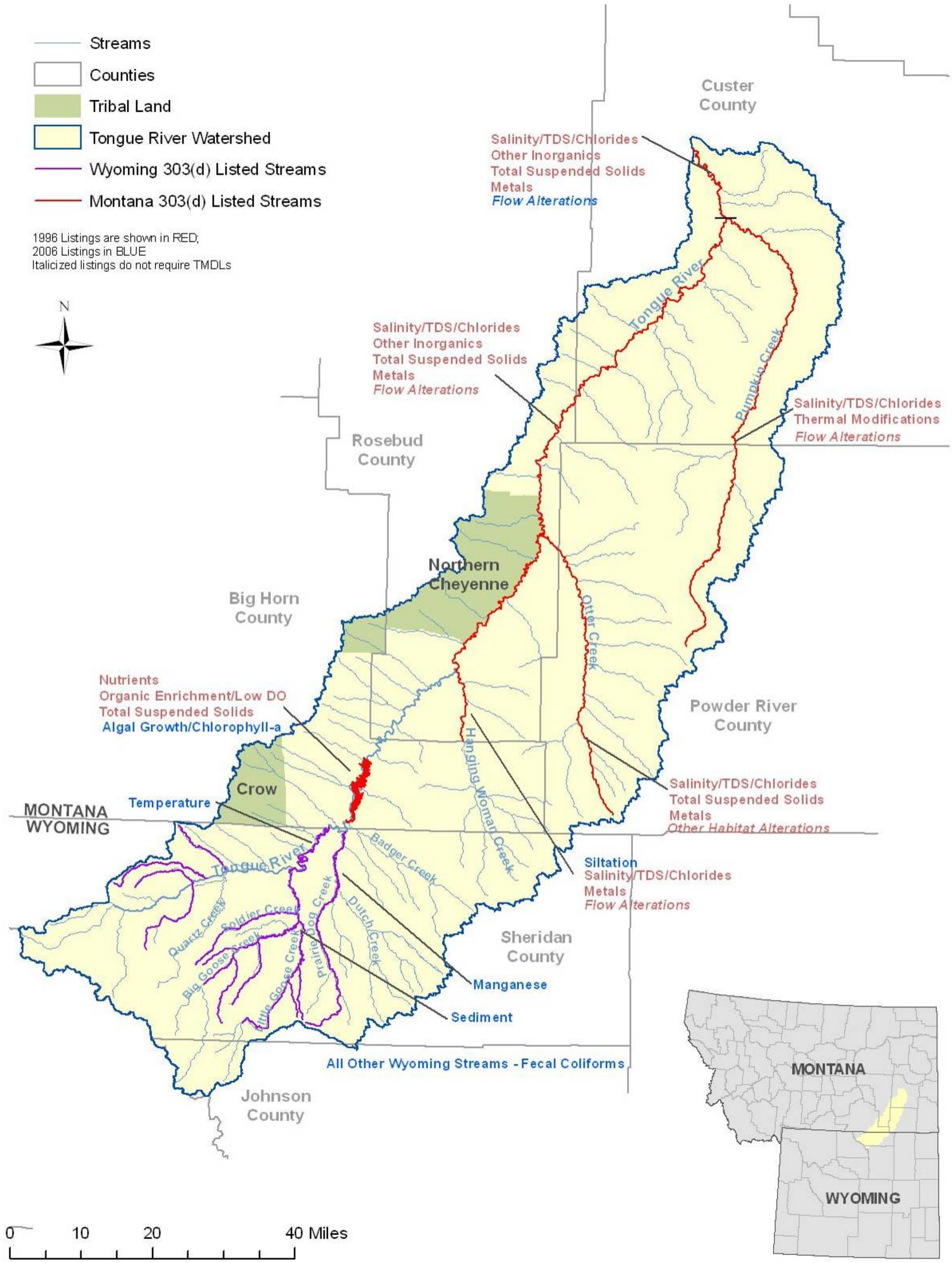


Figure 1-2. Location of the Tongue River watershed and the 303(d) listed streams.

1.2 Wyoming 303(d) List Status

A summary of the 2006 Wyoming 303(d) list is provided in Table 1-3. Figure 1-2 shows the locations of impaired and threatened segments within the Tongue River watershed, as identified in the most recent approved Wyoming 303(d) list (WDEQ, 2006). While this document does not specifically address the water body/pollutant combinations appearing on Wyoming's 303(d) list, this information is presented to provide a watershed scale perspective of potential water quality issues.

Table 1-3. Impaired streams within the Tongue River watershed on the 2006 Wyoming 303(d) list.

Waterbody & Stream Description	Use Class	Aquatic Life	Fisheries	Drinking Water	Contact Recreation	Cause of Impairment
Tongue River – Goose Creek downstream	2AB		N			Temperature
Beaver Creek – Big Goose Creek to upstream	2AB				N	Fecal Coliform
Big Goose Creek – Sheridan to above Beckton	2AB				N	Fecal Coliform
Columbus Creek – Confluence with Tongue River to above Highway 14	2AB				N	Fecal Coliform
Five Mile Creek – Confluence with Tongue River to above Ranchester	3B				N	Fecal Coliform
Goose Creek – Confluence of Big and Little Goose Creeks to downstream	2AB				N	Fecal Coliform
Goose Creek – Within City of Sheridan	2AB	N	N			Sediment
Jackson Creek – Little Goose Creek to upstream	2AB				N	Fecal Coliform
Kruse Creek – Little Goose Creek to upstream	2AB				N	Fecal Coliform
Little Goose Creek – Sheridan upstream to above Big Horn	2AB				N	Fecal Coliform
Little Goose Creek – Within City of Sheridan	2AB	N	N			Sediment
Little Tongue River – Confluence with Tongue River to above Dayton	2AB				N	Fecal Coliform
McCormick Creek – Little Goose Creek to upstream	2AB				N	Fecal Coliform
North Tongue River – Confluence of Bull Creek upstream to above Hwy 14A	1				N	Fecal Coliform
Park Creek – Big Goose Creek to upstream	2AB				N	Fecal Coliform
Prairie Dog Creek – Entire Prairie Dog Creek Drainage	2AB				N	Fecal Coliform
Prairie Dog Creek – Tongue River to upstream	2AB			N		Manganese
Rapid Creek – Big Goose Creek to upstream	2AB				N	Fecal Coliform
Sacket Creek – Little Goose Creek to upstream	2AB				N	Fecal Coliform
Smith Creek – Confluence with Tongue River to above Dayton	2AB				N	Fecal Coliform
Soldier Creek – Goose Creek to upstream	2AB				N	Fecal Coliform

__F__= Full Support; __P__= Partial Support; __N__= Not Supported; __T__= Threatened; __X__= Not Assessed (Insufficient Credible Data).

2.0 APPLICABLE WATER QUALITY STANDARDS

The following pollutants have been considered in this analysis: electrical conductivity (EC), sodium adsorption ratio (SAR), sediment, nutrients, dissolved oxygen, metals, and temperature. The Tongue River watershed is encompassed by four jurisdictional entities that have, or could have, applicable water quality standards. These entities are the State of Montana, the State of Wyoming, the Northern Cheyenne Tribe, and the Crow Tribe. The States of Wyoming and Montana have adopted water quality standards under Section 303 of the Clean Water Act for water bodies within each State's respective jurisdiction. The Northern Cheyenne Tribe has received Treatment as a State for Clean Water Act water quality standards purposes but has not yet submitted standards to EPA for approval for Clean Water Act purposes. The Northern Cheyenne Tribe has tribally-adopted water quality standards. The Crow Tribe has not received Clean Water Act Treatment as a State for Clean Water Act purposes and does not have tribally-adopted water quality standards. This assessment focuses on Montana's water quality standards.

Montana has numeric water quality standards for EC, SAR, dissolved oxygen, and metals. Sediment, nutrients and temperature are addressed in Montana with narrative standards. Montana’s numeric standards are summarized in Table 2-1 to Table 2-4 and the narrative standards are presented in Appendix A. Details regarding how both the numeric and narrative standards have been applied to facilitate a comparison to the available water quality data are provided in Appendix B. The Wyoming and Northern Cheyenne Tribal water quality standards are presented in Appendix D. The Crow Tribe does not, at this time, have approved or adopted water quality standards.

Throughout this document, Montana’s numeric water quality standards for EC and SAR are used as a watershed-wide, common point of reference for purposes of characterizing current water quality conditions in both Montana and Wyoming. This is not intended to imply that Montana’s water quality standards are directly applicable within the jurisdictional boundaries of Wyoming. Montana’s values are used only to provide a single watershed-scale point of reference.

Table 2-1. Montana’s numeric salinity (measured as electrical conductivity (EC)) criteria fort the Tongue River watershed.

Waterbody	Season	Monthly Average EC (µS/cm)	Maximum EC (µS/cm)
Tongue River	Nov 1 – Mar 1	1,500	2,500
	Mar 2 – Oct 31	1,000	1,500
Tongue River Tributaries	Nov 1 – Mar 1	500	500
	Mar 2 – Oct 31	500	500
Tongue River Reservoir	Nov 1 – Mar 1	1,000	1,500
	Mar 2 – Oct 31	1,000	1,500

MDEQ, 2006b

Table 2-2. Montana’s numeric SAR criteria for the Tongue River watershed.

Waterbody	Season	Monthly Average SAR	Maximum SAR
Tongue River	Nov 1 – Mar 1	5.0	7.5
	Mar 2 – Oct 31	3.0	4.5
Tongue River Tributaries	Nov 1 – Mar 1	5.0	7.5
	Mar 2 – Oct 31	3.0	4.5
Tongue River Reservoir	Nov 1 – Mar 1	3.0	4.5
	Mar 2 – Oct 31	3.0	4.5

MDEQ, 2006b

Table 2-3. Aquatic life standards for dissolved oxygen (mg/L).

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

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

Table 2-4. Montana numeric criteria for metals.

Parameter	Aquatic Life (acute) (µg/L)[a]	Aquatic Life (chronic) (µg/L)[b]	Human Health (µg/L)[a]
Arsenic (TR)	340	150	10
Cadmium (TR)	6.74 @ 310 mg/L hardness[c]	0.63 @ 310 mg/L hardness[c]	5
Chromium (III) (TR)	4,554 @ 310 mg/L hardness[c]	218 @ 310 mg/L hardness[c]	—
Copper (TR)	41 @ 310 mg/L hardness[c]	25 @ 310 mg/L hardness[c]	1,300
Iron (TR)	—	1,000	—
Lead (TR)	345 @ 310 mg/L hardness[c]	13 @ 310 mg/L hardness[c]	15
Nickel (TR)	1,222 @ 310 mg/L hardness[c]	136 @ 310 mg/L hardness[c]	100
Selenium (TR)	20	5	50
Silver (TR)	28 @ 310 mg/L hardness[c]	—	100
Zinc (TR)	312 @ 310 mg/L hardness[c]	312 @ 310 mg/L hardness[c]	2,000

[a]Maximum allowable concentration.
[b]No four-day (96-hour) or longer period average concentration shall exceed these values.
[c]Standard is dependent on the hardness of the water, measured as the concentration of total hardness at the time of sampling ($CaCO_3$) (mg/L). The average hardness of the Tongue River (310 mg/L) is presented in this table for an example.
TR – Total Recoverable.

3.0 TONGUE RIVER

The Tongue River flows 286 miles from its origin in the Big Horn Mountains in Wyoming to the confluence with the Yellowstone River near Miles City, Montana (see Figure 1-1). The total watershed covers roughly 5,400 square miles. In 1996, Montana DEQ included four segments of the Tongue River on the 303(d) list of impaired waters – Tongue River from the Wyoming border to the Tongue River Reservoir (MT42B001-001); Tongue River from the Tongue River Reservoir Dam to the confluence with Hanging Woman Creek (MT42B001-020); Tongue River from the confluence with Hanging Woman Creek to the T&Y Diversion Dam (MT42C001-012); and Tongue River from the diversion dam to the mouth (MT42C001-011) (see Table 1-1) (MDEQ, 1996). However, the basis for the 1996 listings is unknown. A revised listing for each segment appeared on Montana's 2006 303(d) list, and only the Tongue River from the T&Y Diversion Dam to the mouth was listed as impaired, and only due to flow alterations (see Table 1-1 and Table 1-2) (MDEQ, 2006a).

Tongue River near Ashland, Montana (Photo by NRCS)

This analysis specifically addresses the listed pollutants and impaired beneficial uses from the Montana 1996 and 2006 303(d) lists (i.e., impairments to the agriculture, warm-water fishery, and aquatic life beneficial uses associated with salinity/TDS/chlorides, suspended solids, sulfates, and metals). Sodium adsorption ratio (SAR) is also addressed given its potential importance related to future Coal Bed Methane development in the watershed. The purpose of this analysis is to determine if Montana's water quality standards are currently exceeded in the Tongue River, and, if so, provide insight into the potential cause of the exceedance (i.e., natural versus anthropogenic).

Tongue River near the Montana-Wyoming state line (Photo by Tetra Tech, Inc.)

The remainder of this section includes summaries and evaluations of available data, and comparisons between the available data and the applicable Montana water quality standards for salinity, sulfates, chlorides, suspended solids, and metals. Biological data for the Tongue River are discussed in Appendix I, and Appendix H provides a general overview of the hydrologic characteristics of the Tongue River watershed. The Tongue River Reservoir is discussed in Section 7.0.

3.1 Salinity

Salinity in the Tongue River is measured primarily as specific conductance (SC), with units of microSiemens per centimeter. SC data for the Tongue River are available from the late 1950's to the present, and include both grab and continuous samples. Grab samples are available from over 100 stations in the Tongue River in Montana and Wyoming, dating from 1959 to 2006, and collected by multiple governmental agencies and private organizations. USGS also collected continuous flow and salinity data at the Tongue River at Monarch, WY (06299980), State Line (06306300), below the Tongue River Reservoir (06307500), Birney Day School Bridge (06307616), Brandenberg Bridge (06307830), above the T&Y Diversion Dam (06307990), and Miles City (06308500) for various years between 1980 and the present. The available data are listed in Table 3-1 and the sample site locations are shown in Figure 3-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only salinity grab samples are used so that the continuous data do not bias the results.[b]

Table 3-1. Specific conductance (SC) data for the main stem Tongue River.[1]

Segment	Station ID	Station Name	Agency	River Mile	n	Period of Record
Headwaters to the MT-WY Border	**06298000**	**Tongue River Near Dayton, WY**	**USGS**	**271.3**	**216**	**1966-1981; 1998-2002**
	06299980	**Tongue River at Monarch, WY**	**USGS**	**246.3**	**744**	**1974-1983; 2004-2006**
MT-WY Border to the Tongue River Reservoir	**06306300**	**Tongue River at State Line Near Decker, MT**	**USGS**	**215.4**	**3,703**	**1985-2006**
	1975TO02	Tongue River just upstream of the Tongue River Reservoir	MDEQ	212.1	11	1974-1977
Tongue River Reservoir Dam to the T&Y Diversion Dam	2075TO04	Tongue River just downstream of the Tongue River Reservoir Dam	MDEQ	201.2	13	1974-1977
	06307500	**Tongue River at Tongue River Dam Near Decker, MT**	**USGS**	**201.0**	**3,126**	**1975-2006**
	2277TO01	Tongue River at confluence with Hanging Woman Creek	MDEQ	179.5	27	1975-1979; 1990
	2278TO01	Tongue River downstream of Hanging Woman Creek	MDEQ	165.2	19	1974-1977
	06307610	Tongue River Below Hanging Woman Creek Near Birney, MT	USGS	164.9	66	1974-1979
	06307616	**Tongue River at Birney Day School Bridge Near Birney, MT**	**USGS**	**154.3**	**961**	**1979-2006**
	2579TO02	Tongue River near Ashland, MT	MDEQ	125.8	13	1975-1977
	06307830	**Tongue River Below Brandenberg Bridge Near Ashland, MT**	**USGS**	**88.1**	**1699**	**1974-1985; 2000-2006**
	06307990	**Tongue River Above T&Y Diversion Dam Near Miles City, MT**	**USGS**	**28.0**	**410**	**2004-2006**
T&Y Diversion Dam to the Mouth	3582TO01	Tongue River downstream of the T&Y Dam	MDEQ	8.2	25	1973-1980
	06308500	**Tongue River at Miles City, MT**	**USGS**	**2.5**	**1178**	**1959; 1962-2006**

[1]Stations with 10 or more samples are included in this table. Entire period of record is shown. Highlighted stations are used in the analyses presented in the following sections.

[b] Continuous salinity data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

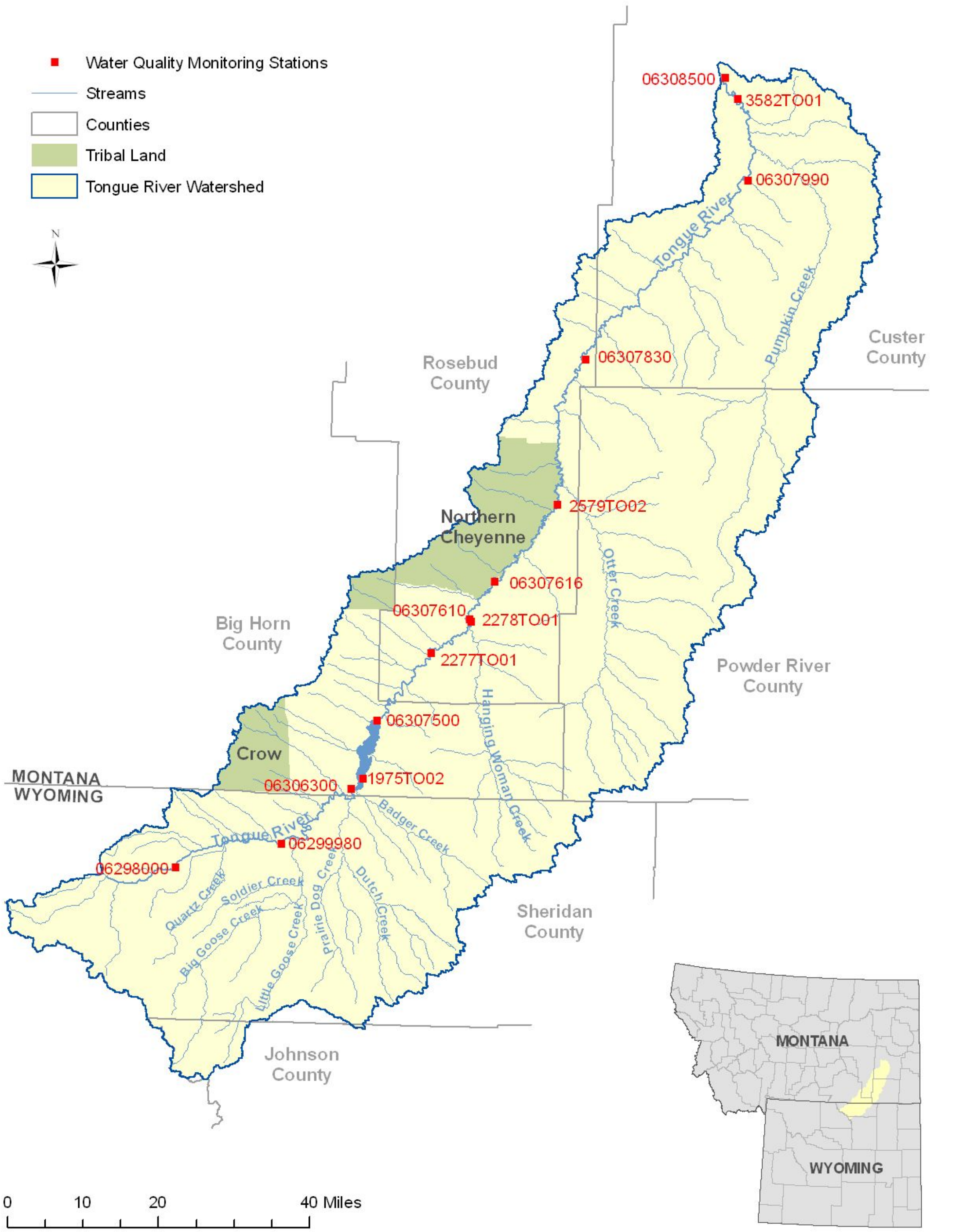


Figure 3-1. **Tongue River watershed and location of the main stem Tongue River surface water salinity monitoring stations (stations with 10 or more sample dates are shown).**

3.1.1 Spatial Characterization

The USGS sample stations highlighted above in Table 3-1 have been used to provide a general spatial characterization of SC in the Tongue River. As shown in Figure 3-2 and Table 3-2, specific conductance increases in a downstream direction, from a mean of 238 µS/cm at Dayton, Wyoming, to 589 µS/cm at the Stateline, and 831 µS/cm at Miles City. The largest increase in mean salinity per river mile occurs between Dayton, Wyoming and Monarch, Wyoming, where there is an average increase of 7.0 µS/cm per river mile. The next highest increase in average salinity occurs between Monarch, Wyoming and the Montana-Wyoming Stateline (5.7 µS/cm increase per river mile). The increase in average salinity per river mile is relatively low downstream of the Tongue River Reservoir, with a maximum increase of 1.8 µS/cm occurring between the Birney Day School Bridge and the Brandenberg Bridge.

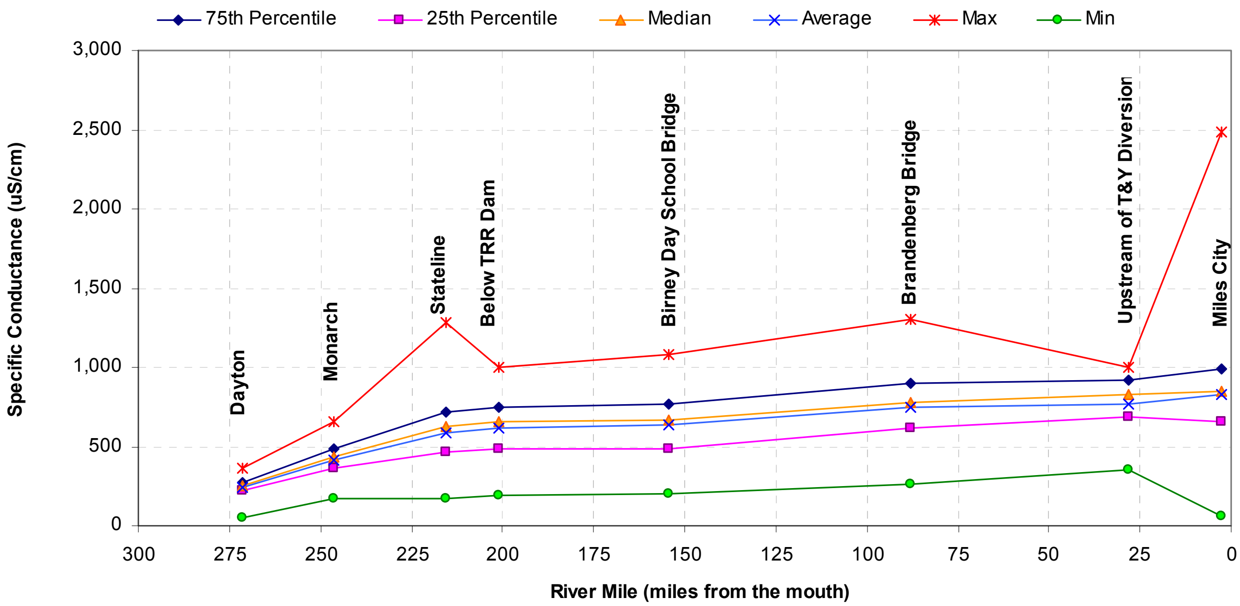


Figure 3-2. Specific conductance statistics for USGS stations with 10 or more samples in the main stem Tongue River. The entire period of record is shown for each station; grab samples only.

Table 3-2. Specific conductance statistics for various time periods, flows, and stations on the mainstem Tongue River, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Tongue River at Dayton, WY (USGS Gage 06298000)	n	216	1	58	54	104
	Min	50	222	200	121	50
	Max	360	222	340	260	360
	Mean	238	222	269	178	252
	Median	250	222	268	172	255
Tongue River at Monarch, WY (USGS Gage 06299980)	n	135	44	33	33	67
	Min	170	193	393	170	272
	Max	660	535	560	520	660
	Mean	413	384	469	288	445
	Median	432	404	460	263	450
Tongue River at State Line Near Decker, MT (USGS Gage 06306300)	n	241	95	60	60	120
	Min	175	186	495	175	232
	Max	1,280	990	1,280	991	862
	Mean	589	624	747	325	640
	Median	630	636	730	265	635
Tongue River at Tongue River Dam Near Decker, MT (USGS Gage 06307500)	n	299	67	75	74	150
	Min	190	282	430	190	289
	Max	996	800	931	947	996
	Mean	617	620	718	411	669
	Median	658	653	728	369	681
Tongue River at Birney Day School Bridge Near Birney, MT (USGS Gage 06307616)	n	227	66	57	57	113
	Min	198	319	476	229	198
	Max	1,080	807	990	785	1,080
	Mean	632	634	749	420	680
	Median	662	663	756	390	681
Tongue River Below Brandenberg Bridge Near Ashland, MT (USGS Gage 06307830)	n	198	82	49	49	99
	Min	260	337	640	260	408
	Max	1,300	1,070	1,300	1,150	1,260
	Mean	751	730	865	560	788
	Median	780	759	859	490	780
Tongue River Above T&Y Diversion Dam Near Miles City, MT (USGS Gage 06307990)	n	37	37	9	9	19
	Min	351	351	830	351	579
	Max	1,000	1,000	1,000	772	963
	Mean	764	764	939	518	798
	Median	830	830	947	455	831
Tongue River at Miles City, MT (USGS Gage 06308500)	n	610	66	145	145	288
	Min	60	60	60	252	420
	Max	2,480	2,280	2,280	1,500	2,480
	Mean	831	918	1,017	620	863
	Median	850	968	1,030	617	867

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SC data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

3.1.2 Relationship between Specific Conductance and Discharge

As evidenced in Figure 3-3, SC in the Tongue River increases with decreasing flow. The relationship between SC and flow is strongest upstream of the Tongue River Reservoir Dam, as exemplified at the Dayton, Monarch, and Stateline stations in Figure 3-3. Downstream of the Tongue River Reservoir Dam, the relationship weakens, with the weakest relationship (R^2 = 0.3821) occurring at the Miles City gage.

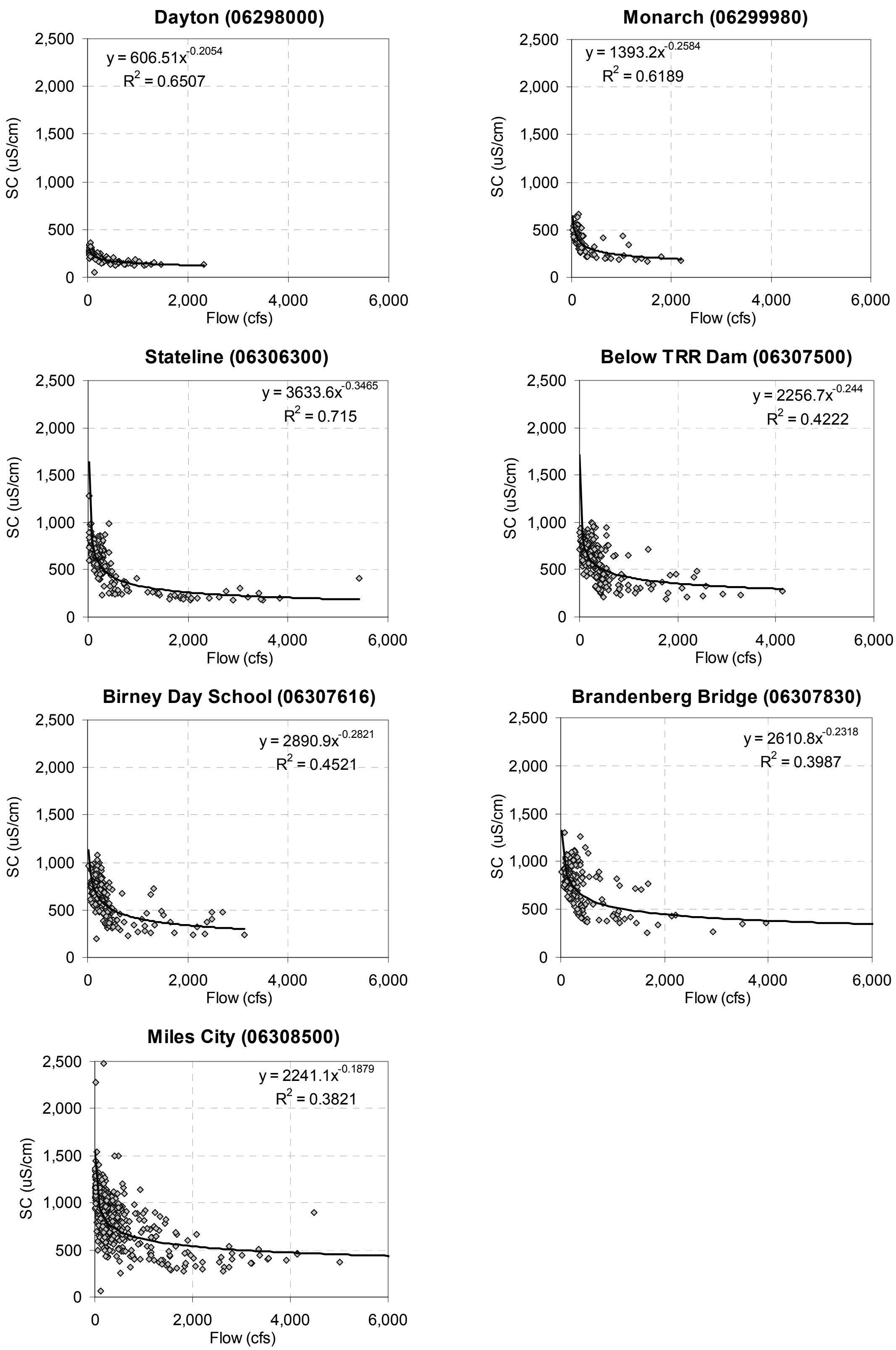


Figure 3-3. Relationship between flow and SC at selected USGS stations on the main stem Tongue River. Entire period of record is shown; grab samples only.

3.1.3 Comparison to Applicable Standards

Of the three jurisdictions that border the Tongue River (Wyoming, Montana, and the Northern Cheyenne Tribe), only Montana has approved numeric water quality standards for salinity. Wyoming's salinity standards are narrative, and while the Northern Cheyenne Tribe has adopted standards, they have not yet been approved by USEPA. As a result, this analysis focuses on Montana's salinity standards (described in Appendix B). The USGS sample stations (highlighted in Table 3-1) have been used to compare measured data to the salinity standards in the Tongue River.

Since there is no guidance in the Administrative Rules of Montana (ARM), it is assumed that the "electrical conductivity" standard can be applied to "specific conductance" (SC) data, which is simply electrical conductivity that has been corrected to a temperature of 25º Celsius. The standards are seasonal, with separate criteria for the growing season (March 2 – October 31) and non-growing season (November 1 – March 1) and include monthly average criteria as well as instantaneous maximum criteria. To facilitate comparison to Montana's standards, the available data have been stratified by the growing season and non-growing season.

3.1.3.1 Instantaneous Maximum Standard

The instantaneous maximum salinity criteria for the main stem Tongue River are 1,500 µS/cm for the growing season and 2,500 µS/cm for the non-growing season. These criteria have only been exceeded in the Tongue River at Miles City, only during the growing season, and only once. The single exceedance occurred during a low flow period in October 2001 at which time an SC of 2,280 µS/cm was measured in the river. SC values of 1,500 µS/cm were observed twice, once in 1979 and once in 1986 during relatively high flow conditions (78th and 75th flow percentiles – see Figure 3-4).

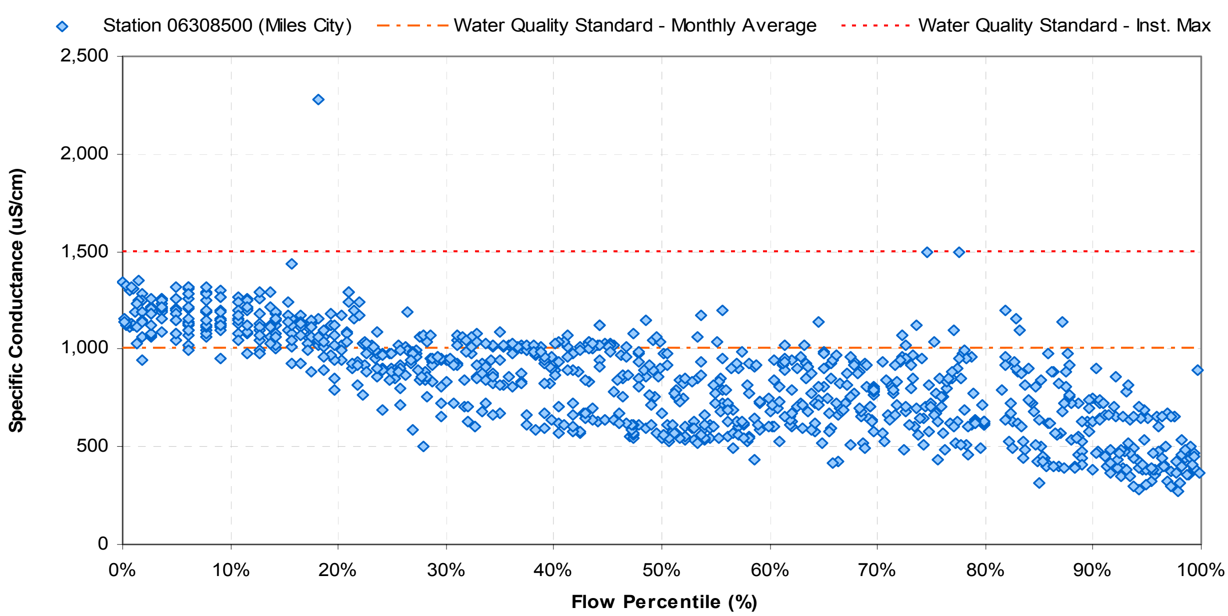


Figure 3-4. Specific conductance versus flow percentile (growing season only) for the Tongue River at Miles City, Montana (USGS Gage 06308500). Entire period of record is shown; continuous data and grab samples.

3.1.3.2 Monthly Average Standards

The monthly average salinity standards for the Tongue River are 1,000 µS/cm for the growing season and 1,500 µS/cm for the non-growing season. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis (i.e., 1, 2, 3, ≥4 data points per month) and whether or not the available data represent the full range of flow conditions and the current time period. Since the quantity of available data varies on a station-by-station basis, this screening analysis was conducted for each of the USGS stations. This analysis is presented in Appendix E and shows that, in general:

- The period of record varies from a maximum of approximately 47 years at Miles City, Montana to a minimum of approximately two years above the T&Y Diversion Dam, Montana.
- There is considerably less data during the non-growing season when compared to the growing season.
- In most cases, with the exception of the last five years when USGS began continuous SC data collection, there are few months with greater than one sample per month.
- Given the variability in SC on a monthly basis (maximum measured change in one month of 801 µS/cm at Miles City, July 1963), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.
- Even though there are only ≥ 4 samples per month for a relatively small proportion of the period of record, those months generally represent the current time period (i.e., the last 5 years) and also represent the full range of flow conditions (high flows, low flows, average flows).

Therefore, for the purposes of providing a comparison of the available data to the monthly average criteria, only the last five years have been considered and monthly average SC was only calculated in cases were at least four monthly samples were available[c]. The frequency of exceedances for each USGS station is shown in Table 3-3. Exceedances have only been observed at two locations; the Tongue River at the Birney Day School Bridge – USGS Gage 06307616, and the Tongue River at Miles City – USGS Gage 06308500. All of the exceedances occurred during low flow conditions (i.e., < 20th flow percentile) and during the growing season (Figure 3-5 and Figure 3-6). It should be noted, however, that data are limited for the non-growing season at all stations except the Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300 and only one sample has been collected in the Tongue River at Dayton, Wyoming in the last five years. The ability to reach conclusions during the non-growing season, therefore, may be restricted by limited data.

[c] The monthly average salinity standard was exceeded in August 2001, when the monthly average SC reached 1,331 us/cm in the Tongue River at Montana-Wyoming State Line (USGS Gage 06306300). 31 average daily SC samples are available for August 1 to August 31 from the USGS continuous SC sampler, and also one grab sample for a total of 32 samples. August 2001 had the second lowest recorded volume of water on record at the State Line gage (803 acre-feet of water), and all of the average daily flows were in the bottom one percent of the measured average daily flows on record (flows ranged from 7 to 25 cfs in August 2001).

Table 3-3. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River for the last five years assuming ≥ four grab and/or continuous samples per month.[1]

Station	Season	Numeric Standard	# Months with ≥ 4 Samples	# Months Exceeding	% Months Exceeding
Tongue River at Dayton – USGS Gage 06298000	Growing Season	< 1000 µS/cm	0	NA	NA
	Nongrowing Season	< 1500 µS/cm	0	NA	NA
Tongue River at Monarch – USGS Gage 06299980	Growing Season	< 1000 µS/cm	21	0	0.00%
	Nongrowing Season	< 1500 µS/cm	0	NA	NA
Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300	Growing Season	< 1000 µS/cm	39	0	0.00%
	Nongrowing Season	< 1500 µS/cm	16	0	0.00%
Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500	Growing Season	< 1000 µS/cm	21	0	0.00%
	Nongrowing Season	< 1500 µS/cm	7	0	0.00%
Tongue River at the Birney Day School Bridge – USGS Gage 06307616	Growing Season	< 1000 µS/cm	22	1	**4.45%**
	Nongrowing Season	< 1500 µS/cm	5	0	0.00%
Tongue River at the Brandenberg Bridge – USGS Gage 06307830	Growing Season	< 1000 µS/cm	37	0	0.00%
	Nongrowing Season	< 1500 µS/cm	6	0	0.00%
Tongue River above the T&Y Diversion Dam – USGS Gage 06307990	Growing Season	< 1000 µS/cm	15	0	0.00%
	Nongrowing Season	< 1500 µS/cm	1	0	0.00%
Tongue River at Miles City – USGS Gage 06308500	Growing Season	< 1000 µS/cm	22	10	**45.45%**
	Nongrowing Season	< 1500 µS/cm	0	NA	NA

[1]Montana's numeric water quality standards for EC are used as a watershed-wide, common point of reference for purposes of characterizing current water quality conditions in both Montana and Wyoming. This is not intended to imply that Montana's water quality standards are directly applicable within the jurisdictional boundaries of Wyoming. Montana's values are used only to provide a single watershed-scale point of reference.

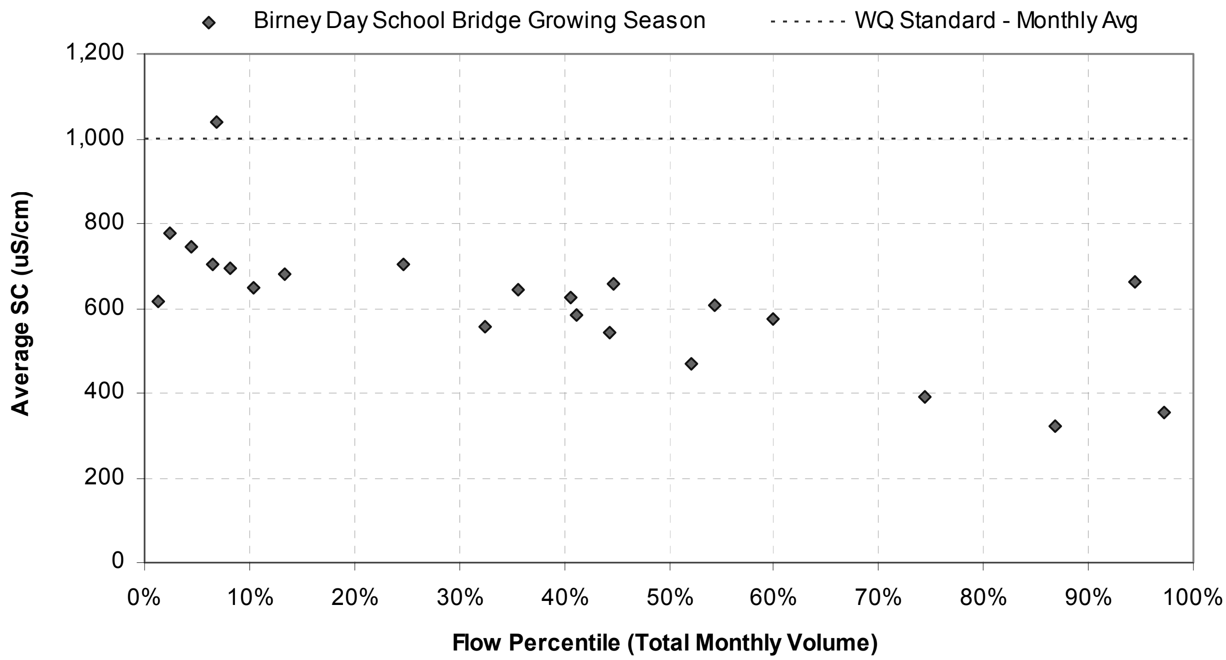


Figure 3-5. Average monthly growing season SC values at the Birney Day School Bridge (past five years with 4 or more samples per month) versus flow percentile.

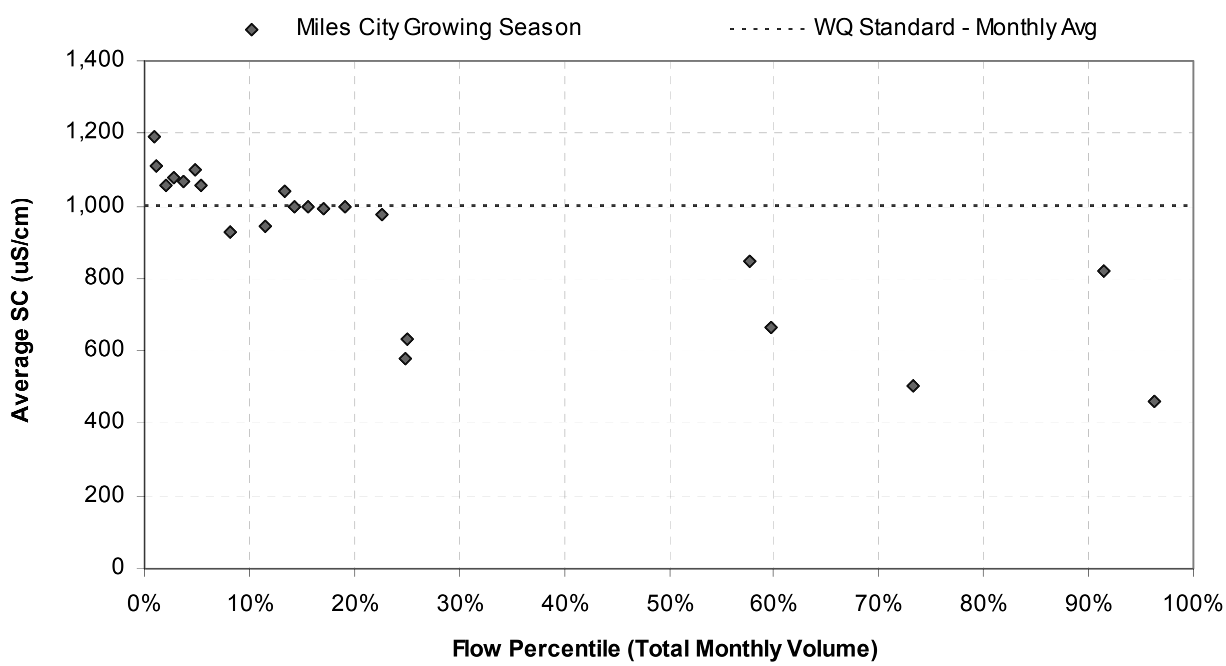


Figure 3-6. Average monthly growing season SC values at Miles City (past five years with 4 or more samples per month) versus flow percentile.

3.1.3.3 Nondegradation

Nondegradation is designed to maintain the existing quality of water when that existing quality is better than the minimum requirements specified in the water quality standards. Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[d]. This is illustrated for SC in the Tongue River mainstem in Figure 3-7. Increases larger than 10 percent are deemed significant. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SC to the nondegradation threshold is presented in Figure 3-8 and Figure 3-9. The nondegradation threshold is exceeded at least some of the time during all months at all of the evaluated Montana USGS gages from Monarch downstream to Miles City.

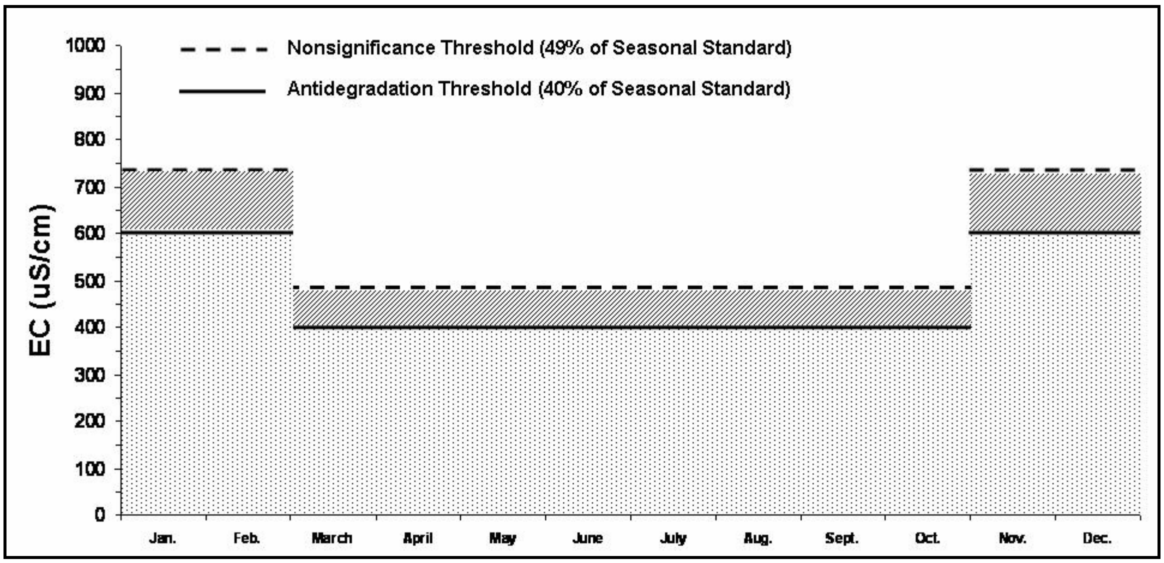


Figure 3-7. Application of Montana's nondegradation policy to electrical conductivity (EC) in the main stem Tongue River (MDEQ, 2007).

[d] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

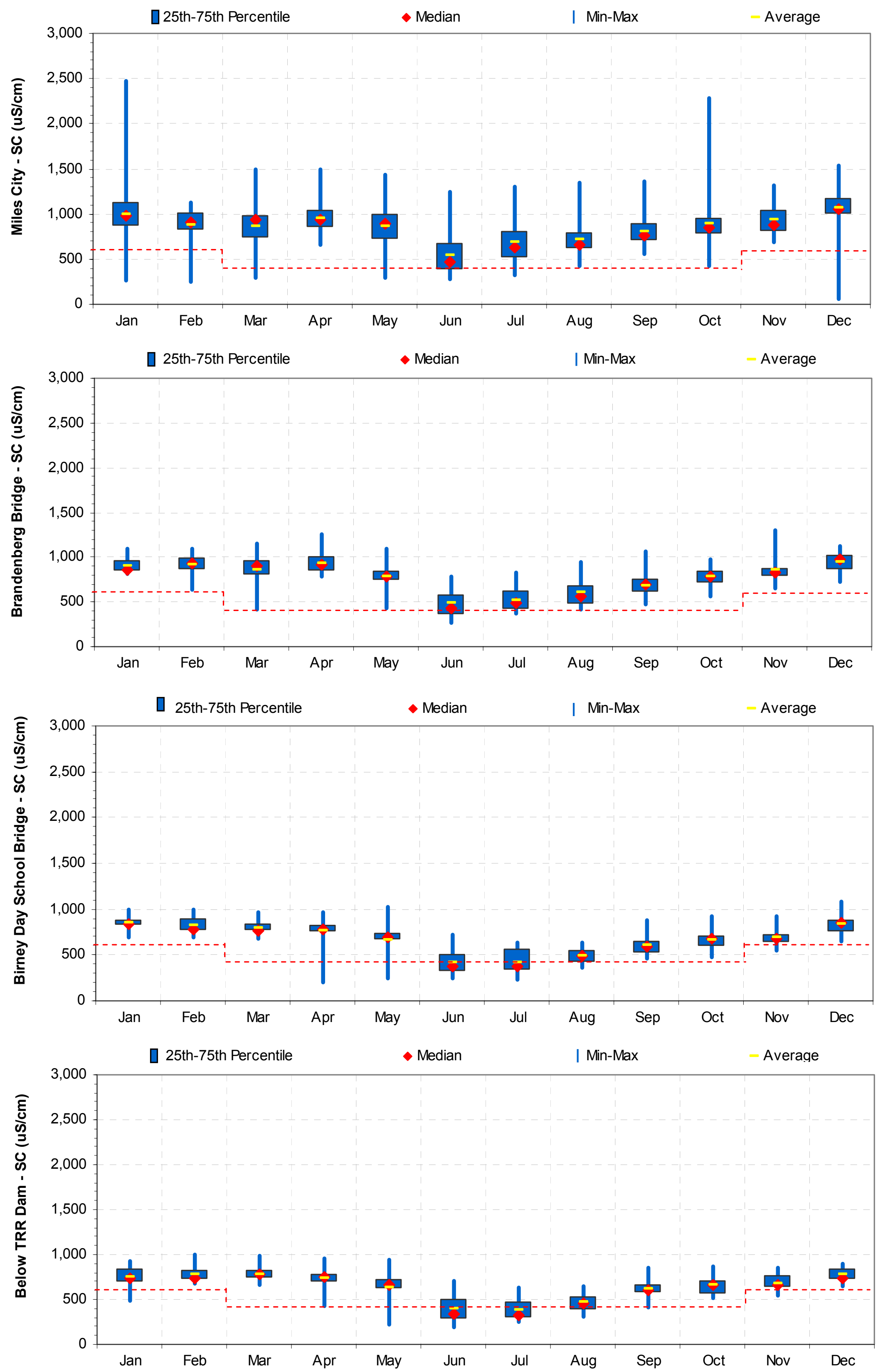


Figure 3-8. SC data and nondegradation thresholds for USGS gages downstream of the Tongue River Reservoir. Entire period of record is shown; grab samples only.

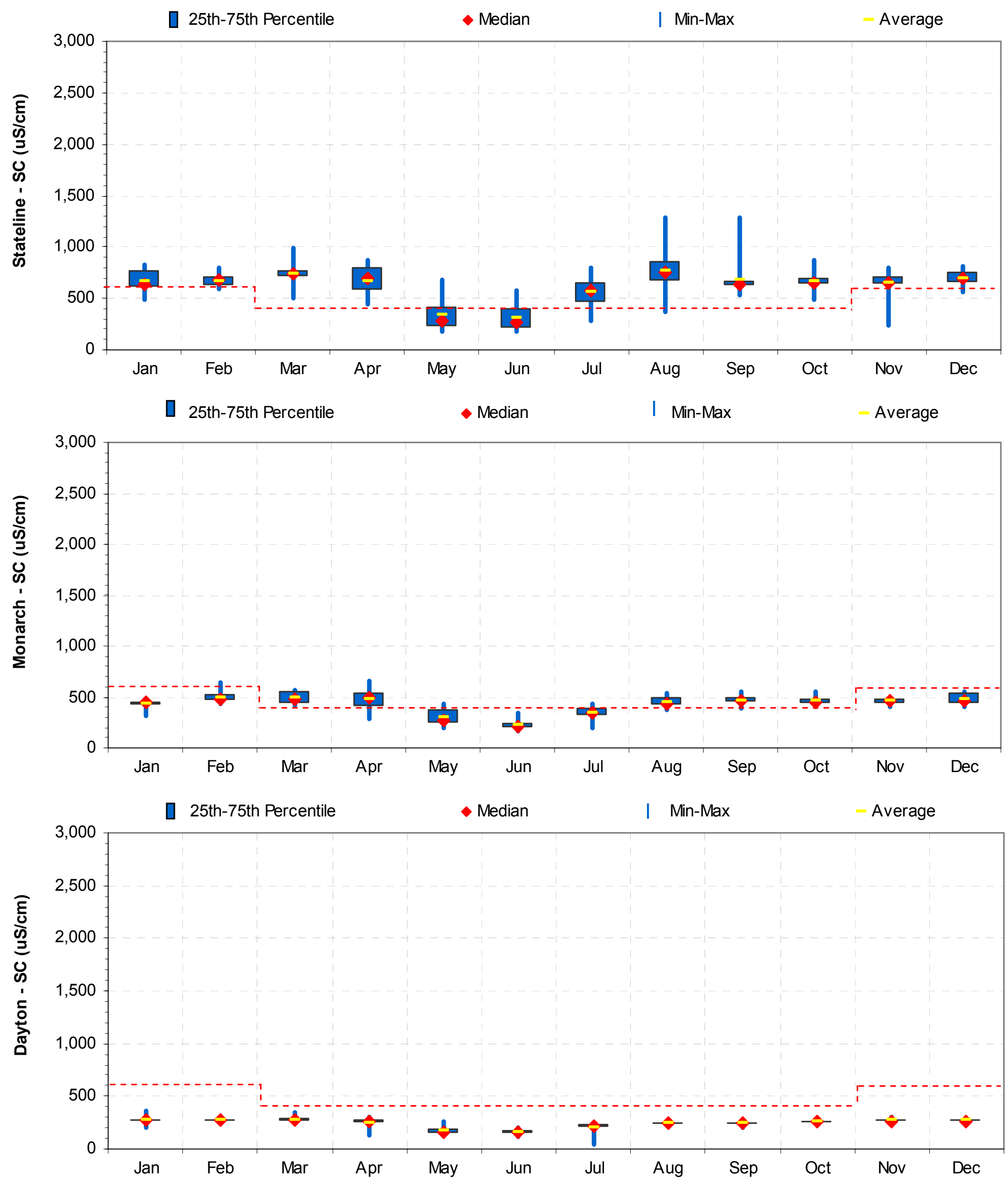


Figure 3-9. SC data and nondegradation thresholds for USGS gages upstream of the Tongue River Reservoir. Entire period of record is shown; grab samples only.[e]

[e] Montana's numeric water quality standards for EC are used as a watershed-wide, common point of reference for purposes of characterizing current water quality conditions in both Montana and Wyoming. This is not intended to imply that Montana's water quality standards are directly applicable within the jurisdictional boundaries of Wyoming. Montana's values are used only to provide a single watershed-scale point of reference.

3.1.4 Sources of Salinity and Their Influence on the Tongue River

As described above, exceedances of Montana's salinity standards (predominantly the monthly average criterion) have been observed in the Tongue River. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both). Factors that potentially influence SC levels in the Tongue River include:

- Stock ponds
- Irrigation
    - High altitude reservoirs
    - High altitude diversions
    - Interbasin transfers
    - Irrigation withdrawal
    - Irrigation return
- Agriculture
    - Irrigated
    - Non-irrigated
- CBM
    - Direct discharge
    - Discharge to pond
    - On-channel
    - Off-channel
- Coal mining
- Municipal WWTP
- Tongue River Reservoir and Dam operations
- Soils/geology

All of these factors except for soils and geology are human caused. A modeling analysis was conducted to estimate the salinity levels that may have occurred in the absence of human influence (see the Modeling Report; USEPA, 2007). To accomplish this, two model scenarios were developed – the "existing" condition and "natural" condition (see Appendix J). In the natural scenario, all of the anthropogenic sources listed above were removed from the model except for the Tongue River Reservoir and high altitude reservoirs (e.g., Dome Lake, Park Reservoir), which remained but were modeled as though they were not managed. The existing scenario simulated the anthropogenic sources as they existed as of September 2006.

As shown in Figure 3-10, simulated salinity in the natural scenario is significantly less than the existing scenario in the main stem Tongue River at State Line and Miles City. The difference in mean SC was 167.0 µS/cm and 200.5 µS/cm at State Line and Miles City, respectively. The mean, median, minimum, maximum, 25^{th} percentile and 75^{th} percentile values are reported in Appendix J. Model uncertainty is discussed in Section 7.0 of the Modeling Report.

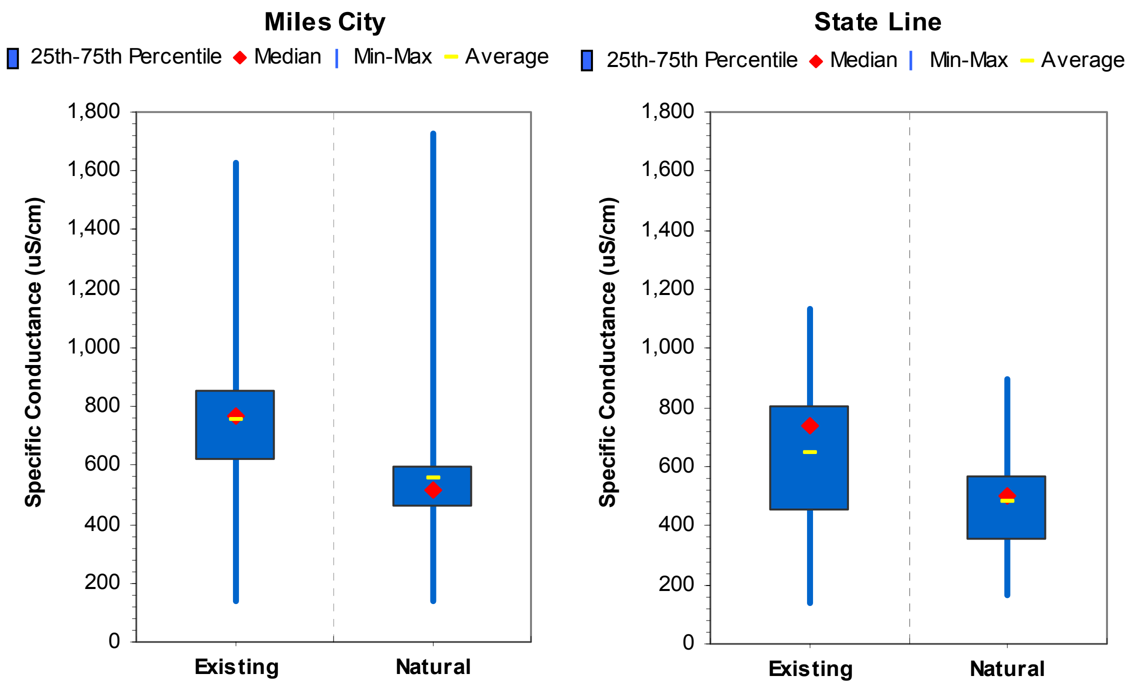


Figure 3-10. Modeled existing versus natural salinity (SC) in the Tongue River at State Line (USGS Gage 06306300) and Miles City (USGS Gage 06308500).

Additional model scenarios were evaluated to assess the relative importance of two of the anthropogenic sources of salinity – discharge of CBM wastewater and irrigation. These two scenarios were evaluated because it was hypothesized that they are the most significant sources. Additional modeling and analysis would be necessary to test this hypothesis and to determine the relative importance of each of the anthropogenic factors that influence salinity levels in the Tongue River. Details regarding the model inputs for these scenarios are included in Appendix J.

Mean SC values for the existing condition scenario and the two scenarios where CBM discharge ("No CBM") and irrigation ("No Irrigation") were removed from the model input files are presented in Table 3-4). The percent difference between each of these scenarios and the existing condition scenario are also presented in Table 3-4.

Based on model results, both the discharge of CBM wastewater and irrigation are contributing to elevated salinity levels in the Tongue River. Given the conservative nature of the components that make up salinity (Thomann and Mueller, 1987; Wang and Periera, 1987), the effects of CBM carry downstream to Miles City even though there are no discharges of CBM downstream of the confluence with Hanging Woman Creek. Irrigation occurs throughout the entire watershed. The estimated contribution from irrigation ranges from 20 to 21 percent while the contribution from CBM discharge ranges from 4 to 5 percent Table 3-4.

Table 3-4. Simulated mean SC under three modeled scenarios and percent change from the existing condition scenario.

Location	Existing	No CBM		No Irrigation	
	µS/cm	µS/cm	% Δ	µS/cm	% Δ
Stateline	647	613	-5%	510	-21%
Above T&Y Diversion	728	696	-4%	585	-20%
Miles City	754	725	-4%	595	-21%

3.2 Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) is the ratio of sodium to calcium plus magnesium concentrations expressed as milliequivalents. SAR data for the Tongue River are available from the late 1950's to the present, and include both grab and continuous samples. Grab samples are available from 54 stations in the Tongue River in Montana and Wyoming, dating from 1959 to 2006, and collected by multiple governmental agencies and private organizations. USGS also collected continuous flow and SAR data at the Tongue River at Monarch, WY (06299980), State Line (06306300), Brandenberg Bridge (06307830), and Miles City (06308500) between 2004 and the present. The available data are listed in Table 3-5 and the sample site locations are shown in Figure 3-11. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only SAR grab samples are used so that the continuous data do not bias the results.[f]

Table 3-5. SAR data for the main stem Tongue River.[1]

Segment	Station ID	Station Name	Agency	River Mile	n	Period of Record
Headwaters to the MT-WY Border	**06298000**	**Tongue River Near Dayton, WY**	**USGS**	**271.3**	**220**	**1966-1981; 1999-2002**
	06299980	**Tongue River at Monarch, WY**	**USGS**	**246.3**	**733**	**1974-1980; 2004-2006**
MT-WY Border to the Tongue River Reservoir	**06306300**	**Tongue River at State Line Near Decker, MT**	**USGS**	**215.4**	**2,071**	**1985-1986; 1991-2006**
Tongue River Reservoir Dam to the T&Y Diversion Dam	2075TO04	Tongue River just downstream of the Tongue River Reservoir Dam	MDEQ	201.2	10	1975-1977
	06307500	**Tongue River at Tongue River Dam Near Decker, MT**	**USGS**	**201.0**	**236**	**1975-2006**
	2277TO01	Tongue River at confluence with Hanging Woman Creek	MDEQ	179.5	13	1975-1979; 1990
	6307610	Tongue River Below Hanging Woman Creek Near Birney, MT	USGS	164.9	63	1974-1979
	06307616	**Tongue River at Birney Day School Bridge Near Birney, MT**	**USGS**	**154.3**	**144**	**1979-1993; 2004-2006**
	06307830	**Tongue River Below Brandenberg Bridge Near Ashland, MT**	**USGS**	**88.1**	**759**	**1974-1981; 2000-2006**
	06307990	**Tongue River Above T&Y Diversion Dam Near Miles City, MT**	**USGS**	**28.0**	**35**	**2004-2006**
T&Y Diversion Dam to the Mouth	3582TO01	Tongue River downstream of the T&Y Dam	MDEQ	8.2	20	1973-1980
	06308500	**Tongue River at Miles City, MT**	**USGS**	**2.5**	**1,034**	**1959; 1962-2006**

[1]Stations with 10 or more samples are included in this table. Entire period of record is shown. Highlighted stations are used in the analyses presented in the following sections.

[f] Continuous SAR data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

Figure 3-11. Tongue River watershed and location of the mainstem Tongue River surface water SAR monitoring stations (stations with 10 or more sample dates are shown).

3.2.1 Spatial Characterization

The USGS sample stations highlighted above in Table 3-5 have been used to provide a general spatial characterization of SAR in the mainstem Tongue River. As shown in Figure 3-12 and Table 3-6, SAR increases in a downstream direction (indicating an increasing fraction of sodium in the total salinity load), from a mean of 0.07 at Dayton, Wyoming, to 0.85 at the Stateline, and 1.55 at Miles City. The largest increase in mean SAR per river mile occurs between Dayton, Wyoming and Monarch, Wyoming, where there is an average SAR increase of 0.02 per river mile. The next highest increase in average SAR occurs between Monarch, Wyoming and the Montana-Wyoming Stateline (0.01 per river mile). Downstream of the Tongue River Reservoir, the maximum increase in SAR per river mile occurs between the station just upstream of the T&Y Diversion Dam and Miles City (increase of 0.004 per river mile).

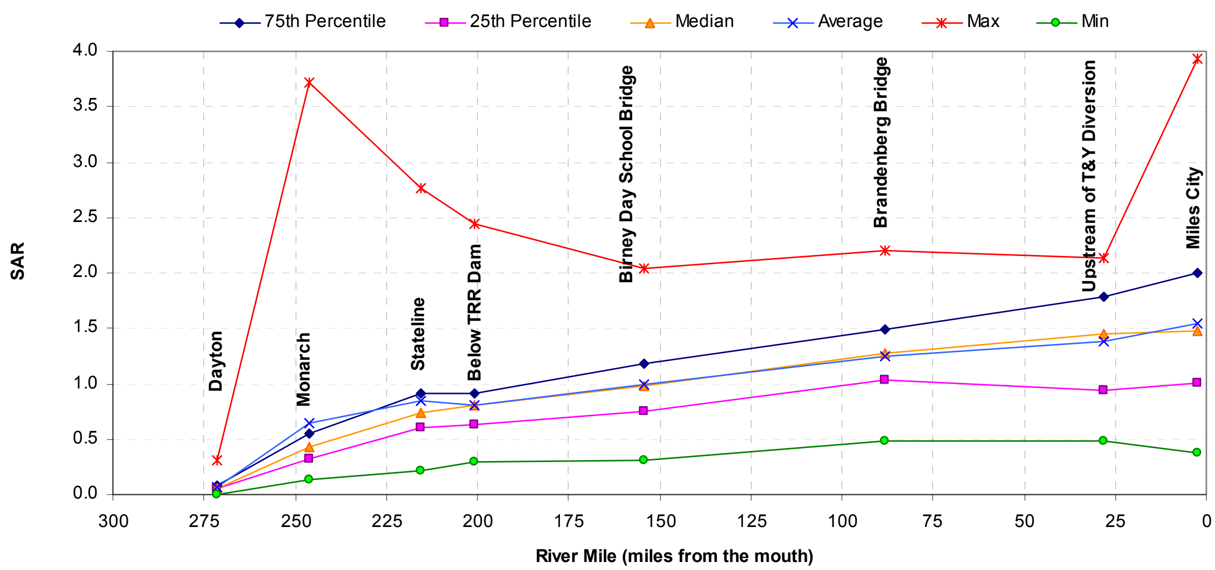


Figure 3-12. SAR statistics for USGS stations with 10 or more samples in the main stem Tongue River. The entire period of record is shown for each station; grab samples only.

Table 3-6. SAR statistics for various time periods, flows, and stations on the mainstem Tongue River, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Tongue River at Dayton, WY (USGS Gage 06298000)	n	220	1	60	55	105
	Min	0.00	0.06	0.03	0.02	0.00
	Max	0.31	0.06	0.15	0.14	0.31
	Mean	0.07	0.06	0.06	0.07	0.07
	Median	0.06	0.06	0.06	0.07	0.06
Tongue River at Monarch, WY (USGS Gage 06299980)	n	122	43	30	61	31
	Min	0.13	0.16	0.27	0.20	0.13
	Max	3.72	3.72	3.01	2.98	3.72
	Mean	0.65	0.99	0.73	0.64	0.59
	Median	0.43	0.37	0.46	0.46	0.30
Tongue River at State Line Near Decker, MT (USGS Gage 06306300)	n	134	90	34	34	66
	Min	0.21	0.28	0.47	0.21	0.50
	Max	2.77	2.73	2.77	2.73	2.64
	Mean	0.85	0.94	1.16	0.53	0.86
	Median	0.74	0.79	0.96	0.38	0.74
Tongue River at Tongue River Dam Near Decker, MT (USGS Gage 06307500)	n	236	51	59	59	118
	Min	0.30	0.36	0.70	0.30	0.39
	Max	2.44	2.44	1.42	1.14	2.44
	Mean	0.81	1.10	0.94	0.55	0.87
	Median	0.81	1.04	0.91	0.50	0.81
Tongue River at Birney Day School Bridge Near Birney, MT (USGS Gage 06307616)	n	144	51	36	36	72
	Min	0.31	0.43	0.66	0.31	0.63
	Max	2.03	2.03	2.03	1.18	2.00
	Mean	1.00	1.18	1.25	0.61	1.06
	Median	0.99	1.18	1.24	0.57	0.99
Tongue River Below Brandenberg Bridge Near Ashland, MT (USGS Gage 06307830)	n	165	78	41	41	83
	Min	0.48	0.48	0.82	0.48	0.71
	Max	2.20	2.13	2.20	1.88	2.13
	Mean	1.25	1.32	1.52	0.88	1.29
	Median	1.28	1.32	1.52	0.78	1.30
Tongue River Above T&Y Diversion Dam Near Miles City, MT (USGS Gage 06307990)	n	35	35	9	9	17
	Min	0.49	0.49	1.76	0.54	0.49
	Max	2.13	2.13	2.13	1.42	1.80
	Mean	1.38	1.38	1.88	0.88	1.38
	Median	1.46	1.46	1.83	0.81	1.46
Tongue River at Miles City, MT (USGS Gage 06308500)	n	466	54	117	117	232
	Min	0.37	0.37	1.00	0.45	0.37
	Max	3.93	3.74	3.74	3.70	3.93
	Mean	1.55	1.80	1.98	1.20	1.51
	Median	1.48	1.55	2.00	1.00	1.48

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SAR data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

3.2.2 Relationship between SAR and Discharge

As evidenced by Figure 3-13, SAR tends to increase with decreasing flow. The relationship between SAR and flow is strongest at the Stateline gage (R^2 of 0.8044). However, the relationship grows weaker towards the Bighorn Mountains, where there is almost no relationship between SAR and flow (Dayton gage R^2 of 0.0016). Downstream of the Tongue River Reservoir Dam, the relationship between the two parameters is fairly constant, with R^2 values between 0.4002 and 0.5738.

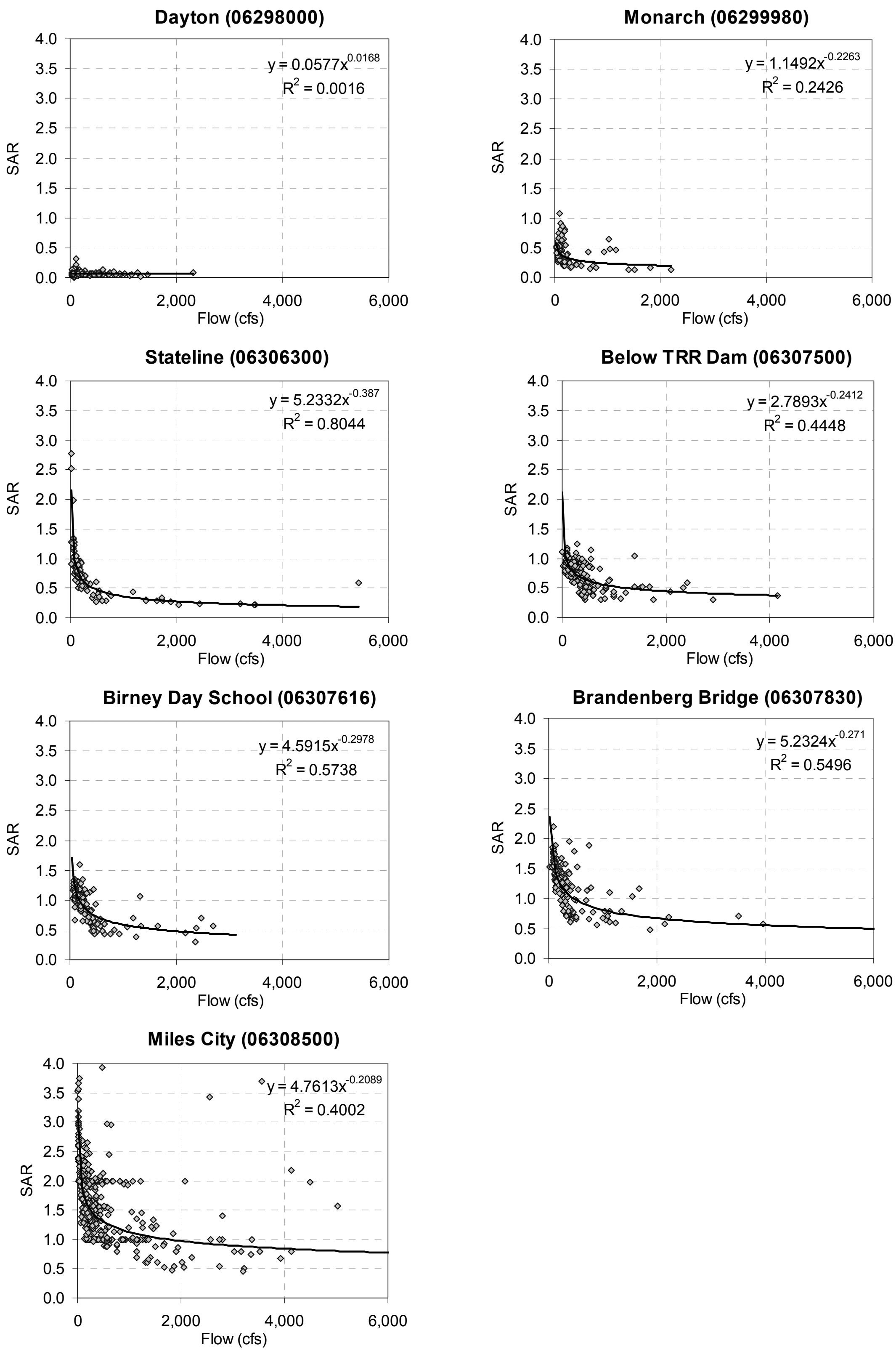


Figure 3-13. Relationship between flow and SAR at selected USGS stations on the main stem Tongue River. Entire period of record is shown; grab samples only.

3.2.3 Comparison to Applicable Standards

Of the three jurisdictions that border the Tongue River (Wyoming, Montana, and the Northern Cheyenne Tribe), only Montana has approved numeric water quality standards for SAR. Wyoming's SAR standards are narrative, and while the Northern Cheyenne Tribe has adopted standards, they have not yet been approved by USEPA. As a result, this analysis focuses on Montana's SAR standards (described in Appendix B). The standards are seasonal, with separate criteria for the growing season (March 2 – October 31) and non-growing season (November 1 – March 1) and include monthly average criteria as well as instantaneous maximum criteria.

3.2.3.1 Instantaneous Maximum SAR Standards

The instantaneous maximum SAR criteria for the mainstem Tongue River are 4.5 for the growing season and 7.5 for the non-growing season. None of the available SAR data for the mainstem Tongue River has ever exceeded these criteria.

3.2.3.2 Monthly Average SAR Standards

The monthly average SAR standards for the Tongue River are 3.0 for the growing season and 5.0 for the non-growing season. However, as with salinity, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis (i.e., 1, 2, 3, ≥4 data points per month) and whether or not the available data represent the full range of flow conditions and the current time period. Since the quantity of available data varies on a station-by-station basis, this screening analysis was conducted for each of the mainstem USGS stations with 10 or more samples. This analysis is presented in Appendix F and shows that, in general:

- The period of record varies from a maximum of approximately 47 years at Miles City, Montana to a minimum of approximately two years above the T&Y Diversion Dam, Montana.
- There is considerably less data during the non-growing season when compared to the growing season.
- In most cases, with the exception of the last five years when USGS began continuous SAR data collection, there are few months with greater than one sample per month.
- Given the variability in SAR on a monthly basis (maximum measured change in one month of 3.54 at Monarch, Wyoming, June 2006), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.
- Even though there are only ≥ 4 samples per month for a relatively small proportion of the period of record, those months generally represent the current time period (i.e., the last 5 years) and also represent the full range of flow conditions (high flows, low flows, average flows).

Therefore, for the purposes of providing a comparison of the available data to the monthly average SAR criteria, only the last five years have been considered and monthly average SAR was only calculated in cases where at least four monthly samples were available. The frequency of exceedances for each USGS station is shown in Table 3-7. In the past 5 years, no exceedances of the average monthly criteria have been observed. It should be noted, however, that data are limited for the non-growing season at all stations except the Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300. The ability to reach conclusions during the non-growing season, therefore, may restricted by limited data.

Table 3-7. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River for the last five years assuming ≥ four samples per month.[1]

Station	Season	Numeric Standard	# Months with ≥ 4 Samples	# Months Exceeding	% Months Exceeding
Tongue River at Dayton – USGS Gage 06298000	Growing Season	< 3	0	NA	NA
	Nongrowing Season	< 5	0	NA	NA
Tongue River at Monarch – USGS Gage 06299980	Growing Season	< 3	21	0	0.00%
	Nongrowing Season	< 5	0	NA	NA
Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300	Growing Season	< 3	39	0	0.00%
	Nongrowing Season	< 5	16	0	0.00%
Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500	Growing Season	< 3	5	0	0.00%
	Nongrowing Season	< 5	0	NA	NA
Tongue River at the Birney Day School Bridge – USGS Gage 06307616	Growing Season	< 3	5	0	0.00%
	Nongrowing Season	< 5	0	NA	NA
Tongue River at the Brandenberg Bridge – USGS Gage 06307830	Growing Season	< 3	23	0	0.00%
	Nongrowing Season	< 5	1	0	0.00%
Tongue River above the T&Y Diversion Dam – USGS Gage 06307990	Growing Season	< 3	5	0	0.00%
	Nongrowing Season	< 5	0	NA	NA
Tongue River at Miles City – USGS Gage 06308500	Growing Season	< 3	22	0	0.00%
	Nongrowing Season	< 5	0	NA	NA

[1]Montana's numeric water quality standards for SAR are used as a watershed-wide, common point of reference for purposes of characterizing current water quality conditions in both Montana and Wyoming. This is not intended to imply that Montana's water quality standards are directly applicable within the jurisdictional boundaries of Wyoming. Montana's values are used only to provide a single watershed-scale point of reference.

3.2.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[g]. This is illustrated for SC in Figure 3-7 in Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SAR to the nondegradation threshold is presented in Figure 3-14 and Figure 3-15. The nondegradation threshold is rarely exceeded during the nongrowing season. Some exceedances have been observed at all of the evaluated stations except Dayton, Wyoming during the growing season. The greatest frequency of exceedance occurs at Miles City, where it is exceeded approximately 50 percent of the time during the growing season.

[g] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

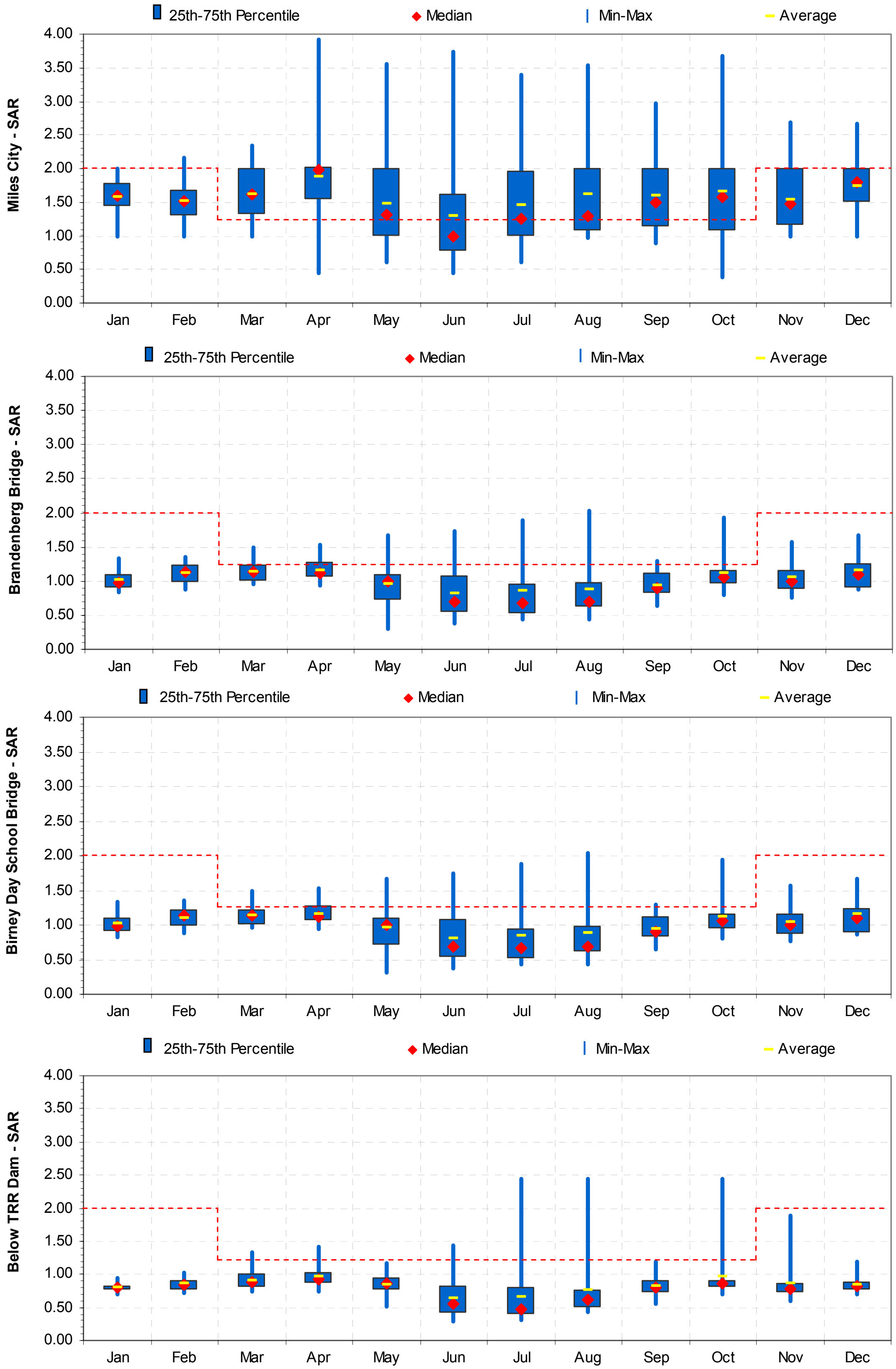


Figure 3-14. SAR data and nondegradation thresholds for the Tongue River downstream of the Tongue River Reservoir Dam. Entire period of record is shown; grab samples only.

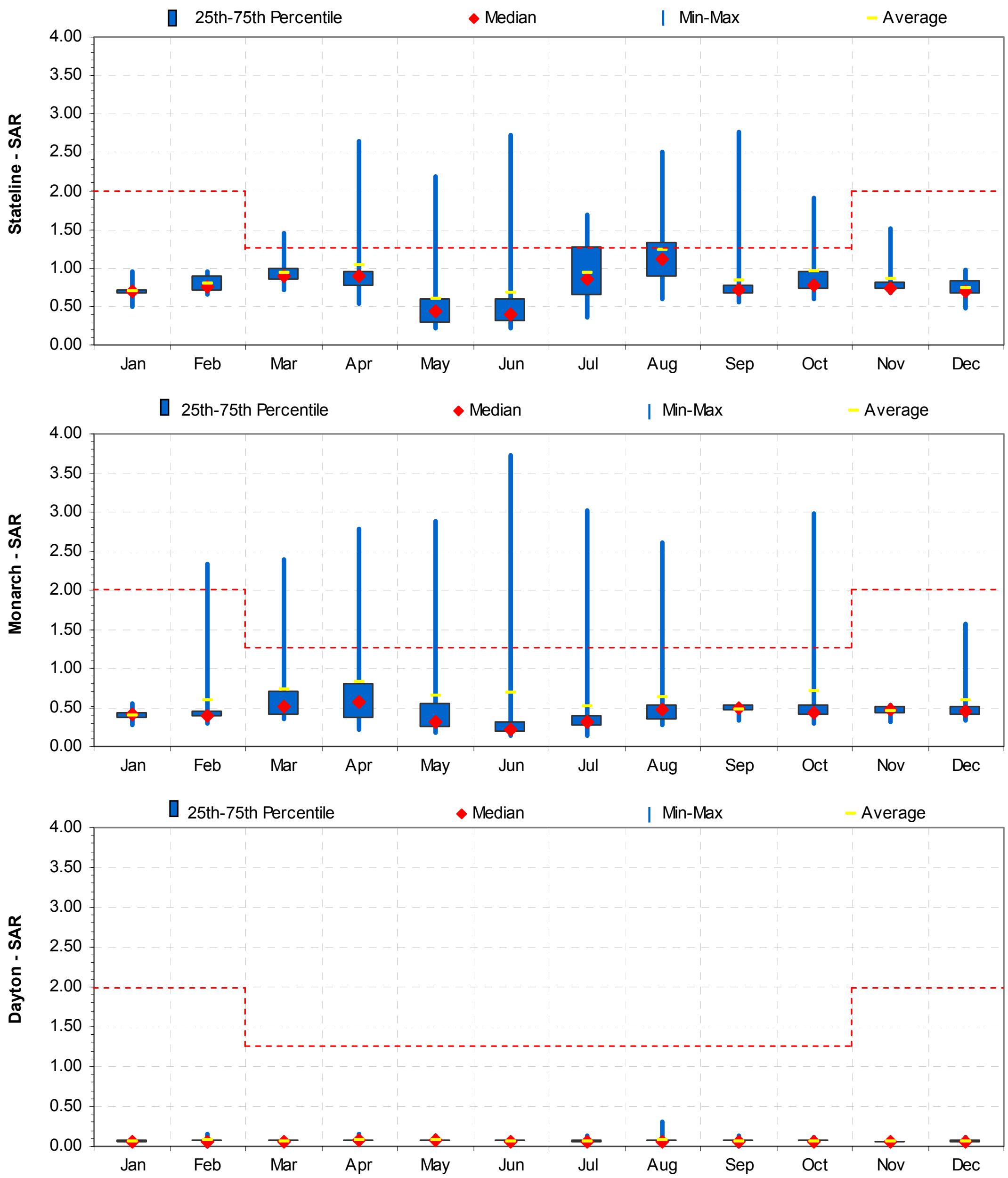


Figure 3-15. SAR data and nondegradation thresholds for the Tongue River upstream of the Tongue River Reservoir Dam. Entire period of record is shown; grab samples only.[h]

[h] Montana's numeric water quality standards for SAR are used as a watershed-wide, common point of reference for purposes of characterizing current water quality conditions in both Montana and Wyoming. This is not intended to imply that Montana's water quality standards are directly applicable within the jurisdictional boundaries of Wyoming. Montana's values are used only to provide a single watershed-scale point of reference.

3.2.4 Sources of SAR and Their Influence on the Tongue River

Since there have been no observed exceedances of the instantaneous maximum or average monthly SAR standards in the main stem Tongue River, no source analysis has been conducted.

3.3 Metals

Aquatic life and fishery beneficial uses in the Tongue River (confluence with Hanging Woman Creek to the mouth) were listed as impaired because of metals on the Montana 1996 303(d) list (Segments MT42C001_012 and MT42C001_011). No specific metals were listed as the cause of impairment, but the metals listing on the 1996 list applies to one or more of the following parameters – arsenic, cadmium, chromium, copper, iron, lead, nickel, selenium, silver, and zinc (Personal communications, Montana DEQ, 2002). Metals were not listed as a cause of impairment on the 2006 303(d) list.

As described in Appendix B, metals data for the following analysis consist only of USGS, USEPA, and Montana DEQ data collected between January 1, 1997 and the present. Data were compared to the Montana total recoverable metals standards, but both "total" and "total recoverable" data were used in the assessment. Where no hardness data were available, the average values shown in Table 3-8 were used to calculate hardness dependent criteria.

Table 3-8. Summary of hardness data in the Tongue River.

Station Name	Station Number	Count	Average (mg/L)	Minimum (mg/L)	Maximum (mg/L)
Tongue River near the State Line	06306300	151	264	81	417
Tongue River below the Tongue River Reservoir Dam	06307500	253	280	86	450
Tongue River at the Birney Day School Bridge	06307616	161	282	110	450
Tongue River near the Brandenberg Bridge	06307830	181	308	140	490
Tongue River at Miles City	06308500	483	322	56	590

Metals data were analyzed for the entire Tongue River in Montana. The river was divided into three segments for the analysis – Wyoming border to the Tongue River Reservoir (Segment MT42B001_010); Tongue River Reservoir Dam to the T&Y Diversion Dam (Segments MT42B001_020 and MT42C001_012); and T&Y Diversion Dam to the Mouth (Segment MT42C001_011). These segments correspond to the 1996 303(d) listed segments. The two 303(d) segments between the Tongue River Reservoir Dam and the T&Y Diversion Dam were combined for the purpose of this analysis. The following sections summarize the metals data for each segment of the Tongue River.

3.3.1 State Line to the Tongue River Reservoir

Table 3-9 presents a summary of the available metals data obtained in the Tongue River between the Montana-Wyoming border and the Tongue River Reservoir. In general, 53 samples were obtained for each parameter. Data were available between May 15, 2001 and May 15, 2006, and all of the samples were obtained at USGS gage 06306300 (Tongue River at the Stateline).

Table 3-9. Summary of metals data in the Tongue River between the MT-WY border and the Tongue River Reservoir.

Parameter	Count	Average (µg/L)	Min (µg/L)	Max (µg/L)	Period of Record
Arsenic (Total) (µg/L as As)	53	1.13	0.44	3.00	5/15/01-5/15/06
Cadmium (Total) (µg/L as Cd)	53	0.03	0.02	0.35	5/15/01-5/15/06
Chromium (Total) (µg/L as Cr)	53	0.99	0.40	7.00	5/15/01-5/15/06
Copper (Total) (µg/L as Cu)	53	2.47	0.80	15.20	5/15/01-5/15/06
Iron, (Total), (µg/L as Fe)	54	590	66	7,530	5/15/01-5/15/06
Lead (Total) (µg/L as Pb)	53	0.68	0.04	10.80	5/15/01-5/15/06
Nickel (Total) (µg/L as Ni)	53	2.93	0.75	12.10	5/15/01-5/15/06
Selenium (Total) (µg/L as Se)	53	0.47	0.20	1.60	5/15/01-5/15/06
Zinc (Total) (µg/L as Zn)	53	5.53	1.00	44.00	5/15/01-5/15/06

Seven iron samples (13 percent) exceeded the chronic criterion of 1,000 µg/L. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-10. At most, iron samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. No other metals samples exceeded the metals standards in this segment.

Table 3-10. Summary of the iron exceedances in the Tongue River between the MT-WY border and the Tongue River Reservoir.

Station	Date of the Exceedance	Chronic Standard	Value	% Increase from the Standard
06306300	5/15/2001	1,000 µg/L	1,680 µg/L	68%
06306300	6/19/2001	1,000 µg/L	1,090 µg/L	9%
06306300	6/5/2002	1,000 µg/L	1,020 µg/L	2%
06306300	7/10/2002	1,000 µg/L	1,090 µg/L	9%
06306300	5/6/2003	1,000 µg/L	1,120 µg/L	12%
06306300	6/4/2003	1,000 µg/L	1,050 µg/L	5%
06306300	5/12/2005	1,000 µg/L	7,530 µg/L	653%

3.3.2 Tongue River Reservoir Dam to the T&Y Diversion Dam

Metals data were available at eight stations between the Tongue River Reservoir Dam and the T&Y Diversion Dam (Table 3-11). The frequency, number, and type of samples obtained at each station varied at each station. The number of samples per parameter varied between 6 and 89. Data were available between March 27, 2002 and May 16, 2006. Table 3-12 presents a summary of the available metals data for this segment.

Table 3-11. Stations with metals data – Tongue River Reservoir Dam to the T&Y Diversion Dam.

Station Name	Station ID	Agency	RM Miles
Tongue River at Tongue River Reservoir Dam near Decker MT	06307500	USGS	201.0
Tongue River below Hanging Woman Creek near Birney, MT	Y16TNGR01	MDEQ	164.9
Tongue River at Birney Day School Bridge near Birney MT	06307616	USGS	154.3
Tongue River near Birney at the Birney Day School, MT	Y16TNGR02	MDEQ	153.9
Tongue River below Brandenberg Bridge near Ashland MT	06307830	USGS	88.1
Tongue River near Brandenberg	Y16TONGR01	MDEQ	87.4
Tongue River above T&Y Diversion Dam near Miles City, MT	06307990	USGS	28.0
Tongue River at the T&Y Dam	Y16TR80	MDEQ	21.1

Table 3-12. Summary of metals data in the Tongue River between the Tongue River Reservoir Dam and the T&Y Diversion Dam.

Parameter	Count	Average (µg/L)	Min (µg/L)	Max (µg/L)	Period of Record
Arsenic (Total) (µg/L as As)	74	1.28	0.80	5.00	3/27/02-5/16/06
Cadmium (Total) (µg/L as Cd)	81	0.04	0.02	0.22	4/26/03-5/16/06
Chromium (Total) (µg/L as Cr)	73	2.05	0.50	10.00	3/27/02-5/16/06
Copper (Total) (µg/L as Cu)	85	3.13	0.38	15.90	3/27/02-5/16/06
Iron, (Total), (µg/L as Fe)	89	731	22	8,480	3/27/02-5/16/06
Lead (Total) (µg/L as Pb)	82	0.81	0.03	9.33	3/27/02-5/16/06
Nickel (Total) (µg/L as Ni)	80	3.39	0.01	13.40	3/27/02-5/16/06
Selenium (Total) (µg/L as Se)	80	0.53	0.20	2.00	4/26/03-5/16/06
Silver (Total) (µg/L as Ag)	6	0.43	0.25	1.50	4/26/03-10/02/03
Zinc (Total) (µg/L as Zn)	84	4.20	0.01	34.00	4/18/02-5/16/06

Fourteen iron samples (16 percent) exceeded the chronic criterion of 1,000 µg/L. The date of the exceedance, the concentration, and the percent increase from the standard are presented in Table 3-13. At most, iron samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. No other metals samples exceeded the metals standards in this segment.

Table 3-13. Summary of the iron exceedances in the Tongue River between the Tongue River Reservoir Dam and the T&Y Diversion Dam.

Station	Date of the Exceedance	Standard	Value	% Increase from the Standard
Y16TR80	3/27/2002	1,000 µg/L	4,860 µg/L	386%
Y16TNGR01	4/26/2003	1,000 µg/L	1,180 µg/L	18%
Y16TONGR01	6/21/2004	1,000 µg/L	1,010 µg/L	1%
6307616	8/23/2004	1,000 µg/L	4,300 µg/L	330%
6307830	8/23/2004	1,000 µg/L	1,000 µg/L	0%
6307830	5/16/2005	1,000 µg/L	6,880 µg/L	588%
6307616	5/16/2005	1,000 µg/L	1,300 µg/L	30%
6307990	5/18/2005	1,000 µg/L	8,480 µg/L	748%
6307990	6/7/2005	1,000 µg/L	2,760 µg/L	176%
6307990	6/21/2005	1,000 µg/L	5,310 µg/L	431%
Y16TONGR01	7/13/2005	1,000 µg/L	1,170 µg/L	17%
6307990	10/4/2005	1,000 µg/L	5,290 µg/L	429%
6307990	3/6/2006	1,000 µg/L	1,070 µg/L	7%
6307990	4/5/2006	1,000 µg/L	2,820 µg/L	182%

3.3.3 T&Y Diversion Dam to the Mouth

Table 3-14 presents a summary of the available metals data obtained in the Tongue River between the T&Y Diversion Dam and the mouth. In general, 22 to 34 samples were obtained for each parameter. Data were available between June 15, 1999 and May 17, 2006, and all of the samples were obtained at USGS gage 06308500 (Tongue River at Miles City).

Table 3-14. Summary of metals data in the Tongue River between the T&Y Diversion Dam and the mouth.

Parameter	Count	Average (µg/L)	Min (µg/L)	Max (µg/L)	Period of Record
Arsenic (Total) (µg/L as As)	33	2.45	0.69	8.00	6/15/99-5/17/06
Cadmium (Total) (µg/L as Cd)	32	0.24	0.02	1.85	6/15/99-5/17/06
Chromium (Total) (µg/L as Cr)	30	8.46	0.40	51.00	6/15/99-5/17/06
Copper (Total) (µg/L as Cu)	33	15.42	1.60	120.00	6/15/99-5/17/06
Iron, (Total), (µg/L as Fe)	24	8,125	86	46,900	4/18/02-5/17/06
Lead (Total) (µg/L as Pb)	32	10.53	0.06	90.20	6/15/99-5/17/06
Nickel (Total) (µg/L as Ni)	32	16.44	1.30	123.00	6/15/99-5/17/06
Selenium (Total) (µg/L as Se)	22	0.73	0.24	2.50	2/04/04-5/17/06
Zinc (Total) (µg/L as Zn)	32	39.38	1.00	337.00	6/15/99-5/17/06

Cadmium, copper, iron, lead, nickel, and zinc concentrations exceeded the metals standards in the Tongue River between the T&Y Diversion Dam and the mouth. No other metals exceeded standards. The following sections summarize the individual exceedances.

3.3.3.1 Iron

Ten iron samples (42 percent) exceeded the chronic criterion of 1,000 µg/L. The date of the exceedance, the concentration, and the percent increase from the standard are presented in Table 3-15. At most, iron samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values.

Table 3-15. Summary of the iron exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard	Value	% Increase from the Standard
6308500	March 11, 2004	1,000 µg/L	2,770 µg/L	177%
6308500	May 25, 2004	1,000 µg/L	46,900 µg/L	4590%
6308500	June 23, 2004	1,000 µg/L	1,080 µg/L	8%
6308500	October 13, 2004	1,000 µg/L	1,010 µg/L	1%
6308500	May 17, 2005	1,000 µg/L	12,500 µg/L	1150%
6308500	June 9, 2005	1,000 µg/L	42,400 µg/L	4140%
6308500	August 23, 2005	1,000 µg/L	18,600 µg/L	1760%
6308500	October 5, 2005	1,000 µg/L	35,200 µg/L	3420%
6308500	March 6, 2006	1,000 µg/L	2,590 µg/L	159%
6308500	April 5, 2006	1,000 µg/L	25,600 µg/L	2460%

3.3.3.2 Copper

Seven copper samples (21 percent) exceeded the chronic copper criterion. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-16. At most, copper samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. Six of the seven copper samples also exceeded the acute criterion.

Table 3-16. Summary of the copper exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard[1]	Value	% Increase from the Standard
06308500	June 5, 2001	Acute: 30.5 µg/L Chronic: 18.9 µg/L Human Health: 1,300 µg/L	32.6 µg/L	Acute: 7% Chronic: 72% Human Health: NA
06308500	May 25, 2004	Acute: 22.5 µg/L Chronic: 14.4 µg/L Human Health: 1,300 µg/L	79.3 µg/L	Acute: 252% Chronic: 451% Human Health: NA
06308500	May 17, 2005	Acute: 33.7 µg/L Chronic: 22.9 µg/L Human Health: 1,300 µg/L	23.6 µg/L	Acute: NA Chronic: 3% Human Health: NA
06308500	June 9, 2005	Acute: 8.2 µg/L Chronic: 5.8 µg/L Human Health: 1,300 µg/L	120.0 µg/L	Acute: 1,356% Chronic: 1,979% Human Health: NA
06308500	August 23, 2005	Acute: 22.5 µg/L Chronic: 14.3 µg/L Human Health: 1,300 µg/L	30.8 µg/L	Acute: 37% Chronic: 115% Human Health: NA
06308500	October 5, 2005	Acute: 42.1 µg/L Chronic: 25.3 µg/L Human Health: 1,300 µg/L	69.5 µg/L	Acute: 65% Chronic: 174% Human Health: NA
06308500	April 5, 2006	Acute: 42.1 µg/L Chronic: 25.3 µg/L Human Health: 1,300 µg/L	44.7 µg/L	Acute: 6% Chronic: 76% Human Health: NA

[1]Acute and chronic criteria are hardness dependant. See Appendix C for the methodology for calculating the criteria.

3.3.3.3 Lead

Eight lead samples (25 percent) exceeded the chronic lead criterion. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-17. At most, lead samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. One of the eight lead samples also exceeded the acute criterion, and six of the samples exceeded the human health criterion of 15 µg/L.

Table 3-17. Summary of the lead exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard[1]	Value	% Increase from the Standard
06308500	June 15, 1999	Acute: 109.2 µg/L Chronic: 4.3 µg/L Human Health: 15 µg/L	8.1 µg/L	Acute: NA Chronic: 90% Human Health: NA
06308500	June 5, 2001	Acute: 233.9 µg/L Chronic: 9.1 µg/L Human Health: 15 µg/L	29.4 µg/L	Acute: NA Chronic: 223% Human Health: 96%
06308500	May 25, 2004	Acute: 155.2 µg/L Chronic: 6.0 µg/L Human Health: 15 µg/L	79.8 µg/L	Acute: NA Chronic: 1,220% Human Health: 432%
06308500	May 17, 2005	Acute: 311.6 µg/L Chronic: 12.1 µg/L Human Health: 15 µg/L	15.0 µg/L	Acute: NA Chronic: 24% Human Health: NA
06308500	June 9, 2005	Acute: 39.9 µg/L Chronic: 1.6 µg/L Human Health: 15 µg/L	90.2 µg/L	Acute: 126% Chronic: 5,699% Human Health: 501%
06308500	August 23, 2005	Acute: 154.9 µg/L Chronic: 6.0 µg/L Human Health: 15 µg/L	23.2 µg/L	Acute: NA Chronic: 284% Human Health: 55%
06308500	October 5, 2005	Acute: 361.8 µg/L Chronic: 14.1 µg/L Human Health: 15 µg/L	41.7 µg/L	Acute: NA Chronic: 196% Human Health: 178%
06308500	April 5, 2006	Acute: 361.8 µg/L Chronic: 14.1 µg/L Human Health: 15 µg/L	38.4 µg/L	Acute: NA Chronic: 172% Human Health: 156%

[1]Acute and chronic criteria are hardness dependant. See Appendix C for the methodology for calculating the criteria.

3.3.3.4 Cadmium

Five cadmium samples (16 percent) exceeded the chronic cadmium criterion. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-18. At most, cadmium samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. One of the five cadmium samples also exceeded the acute criterion.

Table 3-18. Summary of the cadmium exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard[1]	Value	% Increase from the Standard
06308500	June 15, 1999	Acute: 2.69 µg/L Chronic: 0.32 µg/L Human Health: 5 µg/L	0.50 µg/L	Acute: NA Chronic: 56% Human Health: NA
06308500	May 25, 2004	Acute: 3.56 µg/L Chronic: 0.39 µg/L Human Health: 5 µg/L	1.21 µg/L	Acute: NA Chronic: 208% Human Health: NA
06308500	June 9, 2005	Acute: 1.20 µg/L Chronic: 0.18 µg/L Human Health: 5 µg/L	1.85 µg/L	Acute: 54% Chronic: 937% Human Health: NA
06308500	August 23, 2005	Acute: 3.56 µg/L Chronic: 0.39 µg/L Human Health: 5 µg/L	0.42 µg/L	Acute: NA Chronic: 7% Human Health: NA
06308500	October 5, 2005	Acute: 7.00 µg/L Chronic: 0.64 µg/L Human Health: 5 µg/L	0.84 µg/L	Acute: NA Chronic: 31% Human Health: NA

[1]Acute and chronic criteria are hardness dependant. See Appendix C for the methodology for calculating the criteria.

3.3.3.5 Zinc

Two zinc samples (6 percent) exceeded the chronic zinc criterion. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-19. At most, zinc samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. Both of the zinc samples also exceeded the acute criterion.

Table 3-19. Summary of the zinc exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard[1]	Value	% Increase from the Standard
06308500	May 25, 2004	Acute: 184 µg/L Chronic: 184 µg/L Human Health: 2,000 µg/L	247 µg/L	Acute: 34% Chronic: 34% Human Health: NA
06308500	June 9, 2005	Acute: 74 µg/L Chronic: 74 µg/L Human Health: 2,000 µg/L	337 µg/L	Acute: 352% Chronic: 352% Human Health: NA

[1]Acute and chronic criteria are hardness dependant. See Appendix C for the methodology for calculating the criteria.

3.3.3.6 Nickel

Two nickel samples (6 percent) exceeded the chronic nickel criterion. The date of the exceedances, the concentrations, and the percent increase from the standard are presented in Table 3-20. At most, nickel samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. One of the nickel samples also exceeded the human health criterion.

Table 3-20. Summary of the zinc exceedances in the Tongue River between the T&Y Diversion Dam and the Mouth.

Station	Date of the Exceedance	Standard[1]	Value	% Increase from the Standard
06308500	May 25, 2004	Acute: 719 µg/L Chronic: 80 µg/L Human Health: 100 µg/L	85 µg/L	Acute: NA Chronic: 6% Human Health: NA
06308500	June 9, 2005	Acute: 292 µg/L Chronic: 32 µg/L Human Health: 100 µg/L	123 µg/L	Acute: NA Chronic: 279% Human Health: 23%

[1]Acute and chronic criteria are hardness dependant. See Appendix C for the methodology for calculating the criteria.

3.3.4 Metals and Sediment

The Tongue River has a naturally high sediment load (see Section 3.4). Metals are bound to sediment in varying degrees, depending on the local geology and sources. Both total recoverable and total metals laboratory analyses measure the sediment-bound metals in the sample, in addition to the dissolved water column metals. Therefore, when a water sample has more sediment, it is likely that the total or total recoverable metals sample will have higher metals concentrations. This phenomenon is demonstrated in Figure 3-16 below, which shows that total cadmium, copper, iron, lead, nickel, and zinc concentrations are all highly correlated with suspended solids at USGS station 06308500 (Tongue River at Miles City). These data indicate that the Tongue River may naturally exceed the various metals standards at times due to high sediment loads.

To support this theory, dissolved metals concentrations were analyzed to determine if the majority of the metals concentrations were in the dissolved or suspended form when standards were exceeded. Table 3-21 shows that the paired dissolved and total metals data collected in the Tongue River at Miles City mostly consisted of suspended metals, with very little dissolved concentrations. This is significant because it is primarily the dissolved form that causes aquatic toxicity, and USEPA has recommended that criteria for metals be re-expressed as dissolved concentrations (USEPA, 1996).

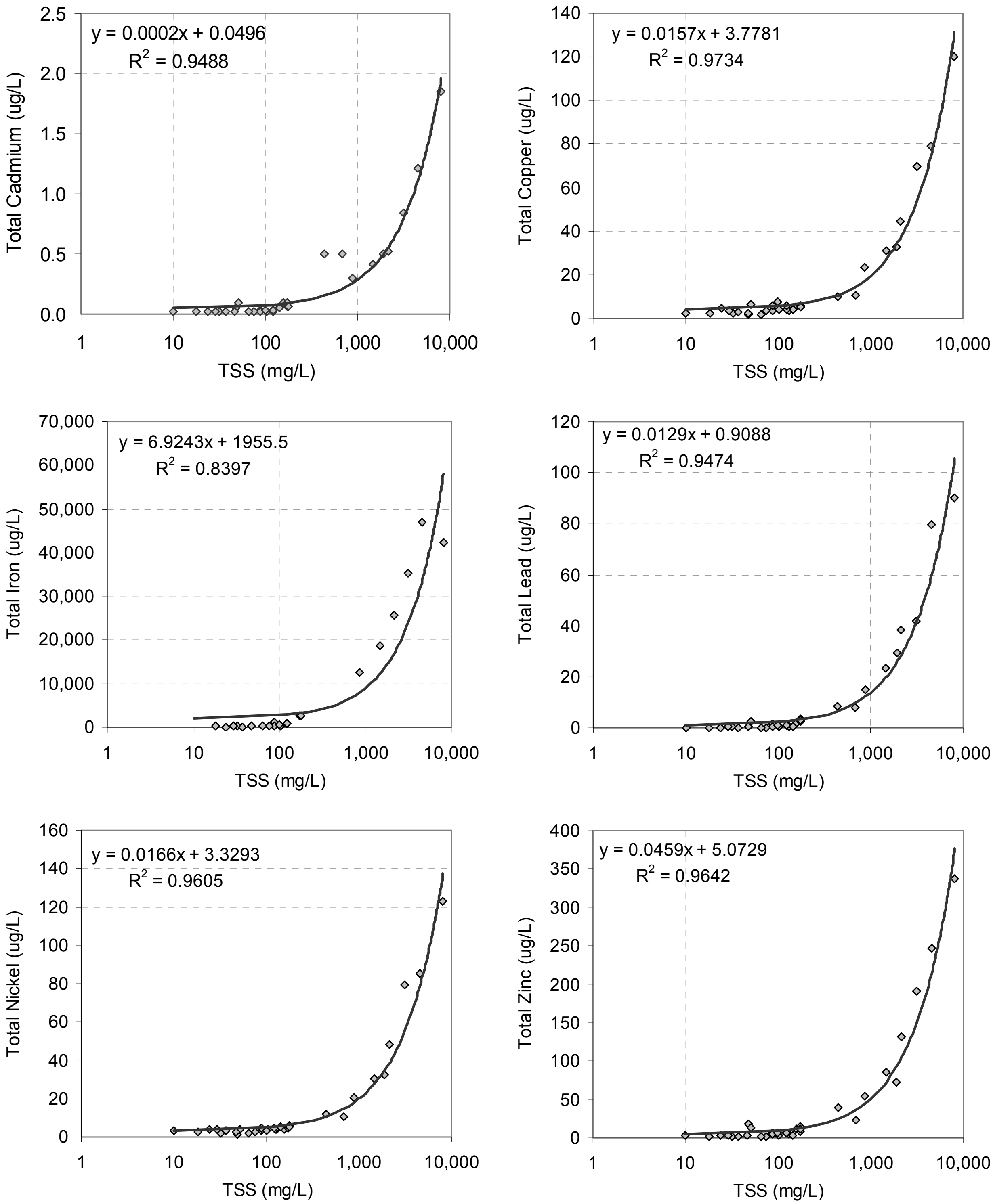


Figure 3-16. Total metals concentrations versus TSS/SSC data in the Tongue River at Miles City (USGS Gage 06308500). Period of Record June 1999 to August 2006.

Table 3-21. Paired total and dissolved metals concentrations in the Tongue River at Miles City, Montana.

Station	Parameter	Date	Total Concentration	Dissolved Concentration	% Suspended	% Dissolved
6308500	Copper	5/5/04	79.3 µg/L	3.2 µg/L	96.1%	3.9%
6308500	Copper	6/9/05	120 µg/L	4.6 µg/L	96.3%	3.7%
6308500	Copper	8/23/05	30.8 µg/L	5 µg/L	86.0%	14.0%
6308500	Copper	10/5/05	69.5 µg/L	3.1 µg/L	95.7%	4.3%
6308500	Copper	4/5/06	44.7 µg/L	5.1 µg/L	89.7%	10.3%
6308500	Cadmium	5/25/04	1.21 µg/L	0.02 µg/L	98.4%	1.6%
6308500	Cadmium	6/9/05	1.85 µg/L	0.02 µg/L	98.9%	1.1%
6308500	Cadmium	10/5/05	0.84 µg/L	0.02 µg/L	97.7%	2.3%
6308500	Zinc	6/9/05	337 µg/L	6 µg/L	98.2%	1.8%
6308500	Lead	5/25/04	79.8 µg/L	0.10 µg/L	99.8%	0.2%
6308500	Lead	5/17/05	15 µg/L	0.04 µg/L	99.8%	0.2%
6308500	Lead	6/9/05	90.2 µg/L	0.23 µg/L	99.8%	0.2%
6308500	Lead	8/23/05	23.2 µg/L	0.14 µg/L	99.4%	0.6%
6308500	Lead	10/5/05	41.7 µg/L	0.04 µg/L	100%	0%
6308500	Lead	4/5/06	38.4 µg/L	0.04 µg/L	99.9%	0.1%
6308500	Iron	3/11/04	2,770 µg/L	3 µg/L	99.9%	0.1%
6308500	Iron	5/25/04	46,900 µg/L	6 µg/L	100%	0%
6308500	Iron	6/23/04	1,080 µg/L	3 µg/L	99.8%	0.2%
6308500	Iron	10/13/04	1,010 µg/L	3 µg/L	99.7%	0.3%
6308500	Iron	5/17/05	12,500 µg/L	3 µg/L	100%	0%
6308500	Iron	6/9/05	42,400 µg/L	15 µg/L	100%	0%
6308500	Iron	8/23/05	18,600 µg/L	5 µg/L	100%	0%
6308500	Iron	10/5/05	35,200 µg/L	4 µg/L	100%	0%
6308500	Iron	3/6/06	2,590 µg/L	5 µg/L	99.9%	0.1%
6308500	Iron	4/5/06	25,600 µg/L	6 µg/L	100%	0%

3.3.5 Sources of Metals

Potential anthropogenic metals sources (e.g., coal mines, CBM, oil and gas fields) in the Tongue River watershed are located upstream of the Tongue River Reservoir Dam. However, most exceedances were not observed in this reach. Rather, exceedances (other than iron) were only observed at the most downstream sampling location at Miles City. Total metals concentrations tend to increase in a downstream direction, corresponding to increases in the sediment load. This is verified in the synoptic sampling conducted by USGS in the Tongue River between May 24 and May 26, 2004 (Figure 3-17). Dissolved concentrations of copper, lead, and iron do not show the same pattern, and do not indicate any localized impacts from downstream sources.

It is possible that unknown sources (other than in-stream sediment) are causing the increases in total metals concentrations in a downstream direction. However, a detailed source assessment would be needed to determine the amount and impact from the unknown sources.

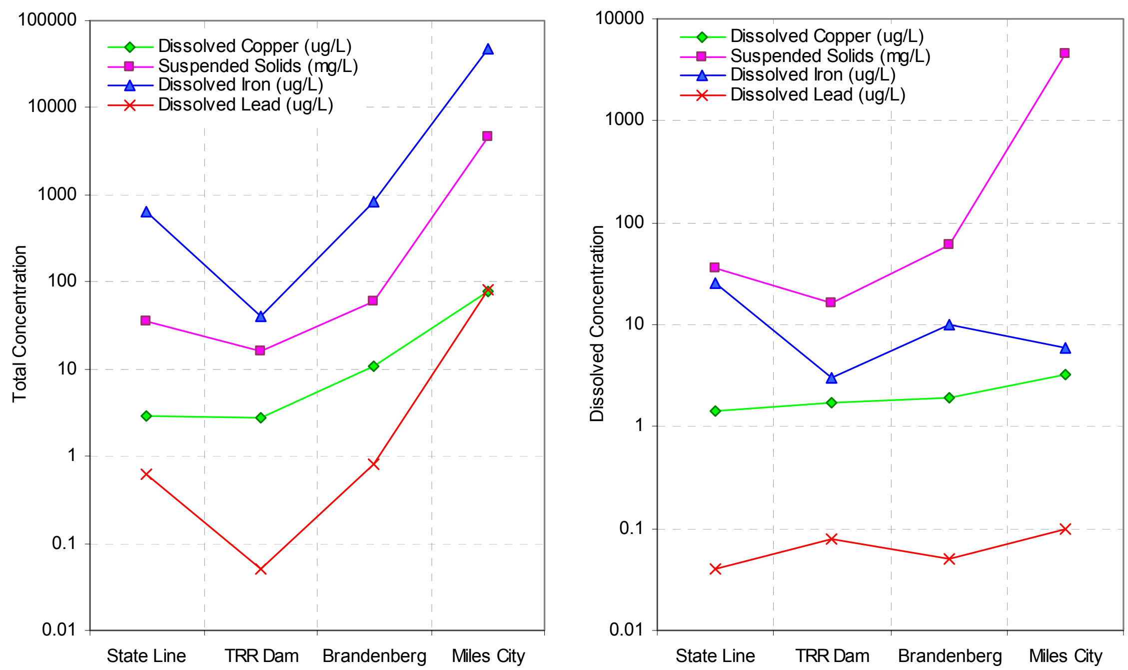


Figure 3-17. Synoptic sampling results for total and dissolved metals concentrations at various sites in the Tongue River, Montana (May 24-26, 2004).

3.4 Total Suspended Solids

The Tongue River from the confluence with Hanging Woman Creek to the mouth was listed on the Montana 1996 303(d) list as impaired because of suspended solids (MDEQ, 1996). Suspended solids were not listed as a cause of impairment on the 2006 303(d) list. The following sections present the suspended solids data for the mainstem Tongue River.

As described in Appendix B, both total suspended solids (TSS) and suspended sediment concentration (SSC) data were collected in the Tongue River watershed. Where available, both SSC and TSS data are presented in the following sections to increase the total number and temporal range of samples in the Tongue River. Summary tables and figures denote where data are SSC, TSS, or a combination of both.

TSS and SSC data for the mainstem Tongue River are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 53 stations in the Tongue River in Montana and Wyoming, dating from 1974 to 2006, and were collected by multiple governmental agencies and private organizations. USGS also collected continuous SSC data at the Tongue River at the Stateline (06306300) and at the Brandenberg Bridge (06307830) for various years between 1974 and 1985. The available grab sample data are listed in Table 3-22 and the sample site locations are shown in Figure 3-18.

Table 3-22. Summary of TSS and SSC grab samples in the mainstem Tongue River.[1]

Segment	Station ID	Station Name	Agency	River Mile	Count	Period of Record
Headwaters to the Wyoming Border	**06298000**	**Tongue River Near Dayton, Wyoming**	**USGS**	**271.3**	**78**	**1974-1980; 1999-2001**
	06299980	**Tongue River At Monarch, Wyoming**	**USGS**	**246.3**	**67**	**1974-1977; 2004-2006**
Wyoming Border to the Tongue River Reservoir	**06306300**	**Tongue River at State Line Near Decker MT**	**USGS**	**215.4**	**104**	**2000-2006**
	1975TO02	Tongue River near the Tongue River Reservoir	MDEQ	212.1	10	1975-1977
Tongue River Reservoir Dam to the T&Y Diversion Dam	2075TO04	Tongue River below the Tongue River Reservoir	MDEQ	201.2	12	1975-1977
	06307500	**Tongue River at Tongue River Dam Near Decker, Montana**	**USGS**	**201.0**	**242**	**1974-1995; 2004-2006**
	2277TO01	Tongue River near Birney, MT	MDEQ	179.5	25	1975-1979; 1990
	06307610	Tongue River Below Hanging Woman Creek Near Birney, Montana	USGS	164.9	63	1944-1979
	06307616	**Tongue River at Birney Day School Bridge Near Birney, Montana**	**USGS**	**154.3**	**130**	**1979-1986; 2004-2006**
	06307830	**Tongue River Below Brandenberg Bridge Near Ashland, Montana**	**USGS**	**88.1**	**169**	**1974-1981; 2000-2006**
	06307990	Tongue River Above T&Y Diversion Dam Near Miles City, Montana	USGS	28.0	45	2004-2006
T&Y Diversion Dam to the mouth	3582TO01	Tongue River near the Mouth	MDEQ	8.2	17	1975-1980
	06308500	**Tongue River at Miles City, Montana**	**USGS**	**2.5**	**265**	**1974-2006**

[1]Data shown for stations with 10 or more samples. Highlighted stations are used in the analyses presented in the following sections.

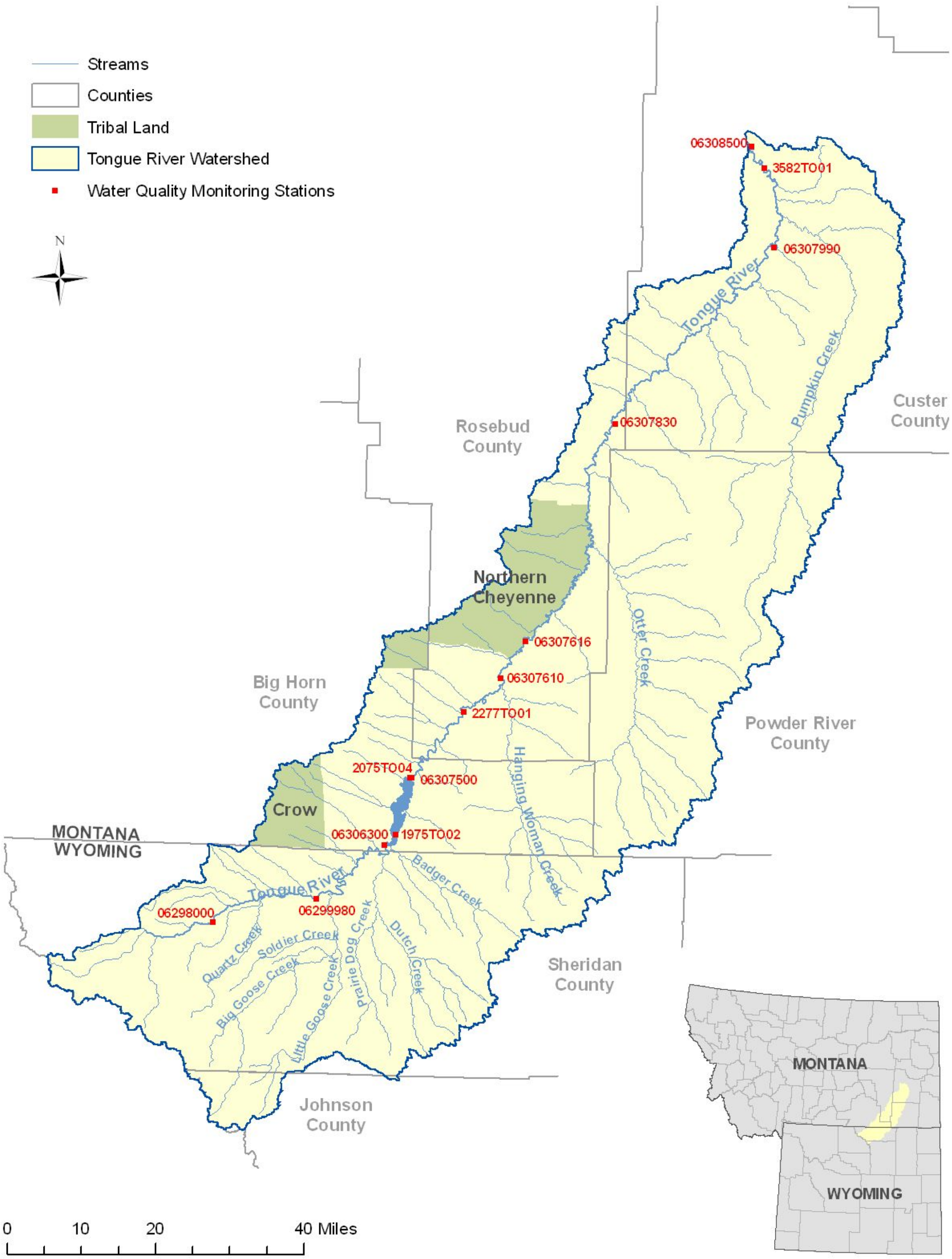


Figure 3-18. Tongue River watershed and location of the TSS/SSC monitoring stations (stations with 10 or more sample dates are shown).

3.4.1 Spatial Characterization

The USGS sample stations highlighted above in Table 3-22 have been used to provide a general spatial characterization of TSS and SSC in the Tongue River. As shown in Figure 3-19 and Table 3-23, concentrations increases in a downstream direction from the headwaters to the Tongue River Reservoir. A decrease is then observed from the Stateline station downstream to the USGS sample station downstream of the Tongue River Reservoir, resulting from settling in the reservoir. Concentrations increase again from the Tongue River Reservoir Dam to the mouth.

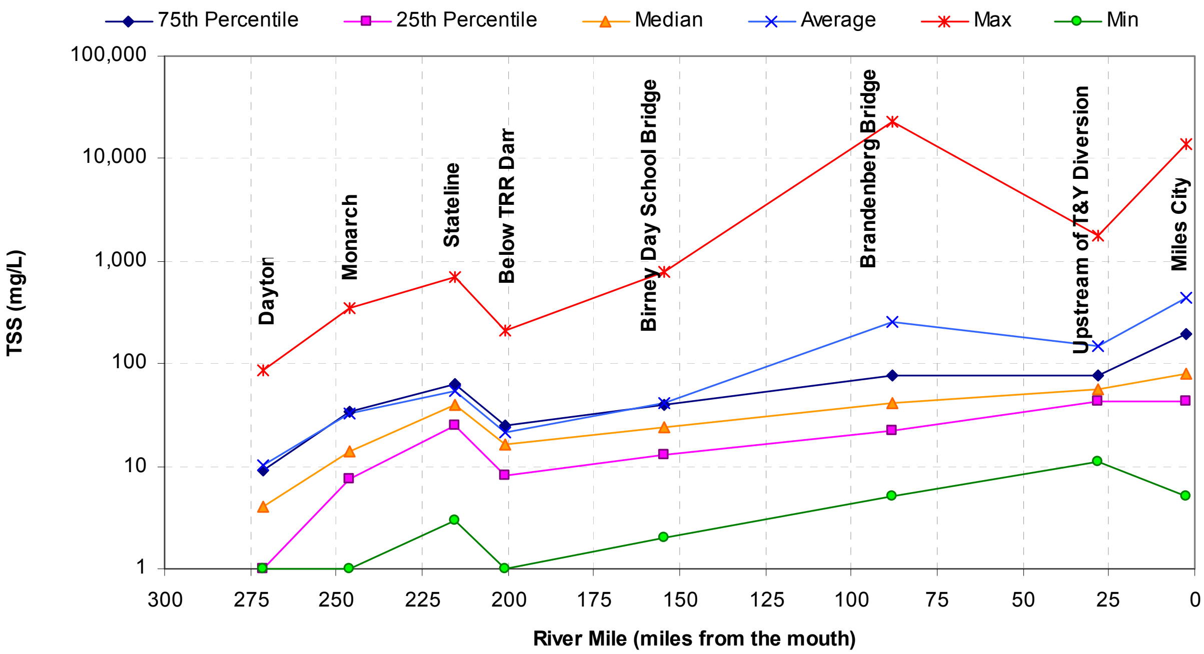


Figure 3-19. TSS/SSC statistics for USGS stations with 10 or more samples in the mainstem Tongue River. The entire period of record is shown for each station; grab samples only.

Table 3-23. TSS/SSC statistics for various time periods and stations on the mainstem Tongue River, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]
Tongue River at Dayton, WY (USGS Gage 06298000)	n	65	0
	Min	1	NA
	Max	86	NA
	Mean	10	NA
	Median	4	NA
Tongue River at Monarch, WY (USGS Gage 06299980)	n	59	43
	Min	1	2
	Max	352	266
	Mean	32	23
	Median	14	13
Tongue River at State Line Near Decker, MT (USGS Gage 06306300)	n	94	78
	Min	3	6
	Max	697	697
	Mean	53	48
	Median	39	36
Tongue River at Tongue River Dam Near Decker, MT (USGS Gage 06307500)	n	232	51
	Min	1	1
	Max	213	43
	Mean	22	12
	Median	16	8
Tongue River at Birney Day School Bridge Near Birney, MT (USGS Gage 06307616)	n	120	51
	Min	2	2
	Max	780	205
	Mean	42	26
	Median	24	20
Tongue River Below Brandenberg Bridge Near Ashland, MT (USGS Gage 06307830)	n	159	78
	Min	5	6
	Max	23,100	513
	Mean	256	69
	Median	42	39
Tongue River Above T&Y Diversion Dam Near Miles City, MT (USGS Gage 06307990)	n	35	35
	Min	11	11
	Max	1,750	1,750
	Mean	146	146
	Median	57	57
Tongue River at Miles City, MT (USGS Gage 06308500)	n	235	58
	Min	5	10
	Max	14,000	8,110
	Mean	439	476
	Median	81	88

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.

3.4.2 Comparison to Other Great Plains Streams

TSS and SSC data from multiple sites in the main stem Tongue River were compared to other similar streams in the Great Plains ecoregion (see Appendix H for further details). Data from 14 streams (25 sites) show that the Tongue River had relatively low TSS and SSC concentrations within the ecoregion. The median concentrations for all sites in the Tongue River, for both the grab sample and continuous data, fall within the lower 25th percentile of the data set.

3.4.3 Sediment Source Identification and Load Quantification

Compared to rivers in some other parts of the country, the Tongue River has naturally high suspended solids due to soils, geology, and topography (see the Tongue River TMDL Status Report – MDEQ, 2003). Historic accounts (early 1800s) state that the Tongue River was very muddy and shallow, with shifting sand bars and quicksand present in the channel near Miles City (as summarized in NRCS, 2002). Furthermore, several species of fish found in the Tongue River are adapted to the high turbidity waters (paddlefish, sturgeon chub, sauger) (MFWP, 2003). However, there are anthropogenic suspended solid sources and sinks in the watershed, and the net effect from the sources and sinks is unknown. The following sections discuss the various suspended solid sources, sinks, and loads throughout the Tongue River watershed.

3.4.3.1 Tongue River Reservoir (Suspended Solids Sink)

Reservoirs can settle out suspended solids due to slow moving currents and long retention times (Tongue River Reservoir = 89 days). To determine the effects of the Tongue River Reservoir on suspended solids, data collected upstream and downstream of the reservoir were evaluated. Data were collected at the Tongue River near the State Line (station 06306300) and the Tongue River downstream of the Tongue River Reservoir Dam (station 06307500). Each site has data collected from January 2004 through September 2006, and has a similar number of suspended solid samples (61). The average concentration upstream of the reservoir was 46 mg/L, and the average concentration downstream of the reservoir was 13 mg/L. On average, the data suggest that 72 percent of the suspended solids entering the Tongue River Reservoir are settled out. This effectively divides the Tongue River into two segments – upstream and downstream of the reservoir. The remainder of this section focuses on the Tongue River downstream of the reservoir because the reservoir settles out 72 percent of the suspended solids from the Tongue River upstream of the reservoir. The potential affects of sediment sources above the reservoir are, therefore, largely inconsequential in the downstream portions of the Tongue River that are the focus of this analysis.

Table 3-24. Summary of suspended solids concentrations collected upstream and downstream of the Tongue River Reservoir, Montana.

Station	Count	Average (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Period of Record
State Line (06306300)	61	46	31	8	697	2004-2006
Below Tongue River Reservoir Dam (06307500)	61	13	8	1	43	2004-2006

3.4.3.2 Upland Sediment Loading (Suspended Solids Source)

The Universal Soil Loss Equation (USLE) was used to evaluate upland sediment loading to two Tongue River tributaries – Hanging Woman Creek and Otter Creek – which comprise 33 percent of the area of the Tongue River watershed downstream of the Tongue River Reservoir (see Sections 4.4 and 5.4). Two scenarios were evaluated in each watershed – existing conditions (i.e., existing grazing and agriculture), and natural conditions (i.e., no grazing or agriculture). The results of the analysis suggest that upland loads associated with grazing and agriculture are only a small percentage of the total load in each watershed (0.4 percent in Hanging Woman Creek, and 0.3 percent in Otter Creek). Using this information, it is conservatively assumed that only a small percentage of the suspended solids load in the Tongue River (downstream of the reservoir) is due to upland anthropogenic sources.

3.4.3.3 Bank Erosion (Suspended Solids Source)

NRCS performed a Rapid Aerial Assessment and a Riparian Analysis of the Tongue River in 2001 and 2002 (NRCS, 2001, 2002). The Tongue River in Big Horn County and Custer County was surveyed. A summary of the results pertaining to bank condition are shown below (NRCS, 2001):

- Total Tongue River Length Surveyed: 104.8 miles
- Total Length of Natural Erosion: 2.1 miles (2.0 percent)
- Total Length of Erosion (Unknown Source): 0.68 miles (0.6 percent)
- Total Length of Bank Erosion Affected by Animal Grazing: 0.14 miles (0.1 percent)

In total, there were 0.82 miles of potential anthropogenic erosion observed by NRCS in the Tongue River in Big Horn and Custer counties. Assuming that erosion occurred at a similar rate in Rosebud County, there would be an estimated total of 1.74 miles of anthropogenic erosion along the main stem Tongue River in Montana.

3.4.3.4 Suspended Solids Mass Balance

Suspended solid loads in the Tongue River were evaluated at four representative stations – State Line (06306300), below Tongue River Reservoir Dam (06307500), Brandenberg Bridge (06307830), and Miles City (06308500) – to estimate sediment load fluxes from upstream to downstream. Since the data were not collected at the same time, it was not possible to directly compare one station to another.

The relationship between suspended solids (measured as suspended sediment concentration, SSC) and flow was evaluated at each station to facilitate calculation of suspended solids loads for comparable time periods at each site.

As shown in Table 3-25 and, Figure 3-20 there was a moderate positive relationship between flow and SSC at three of the four stations. Just downstream of the Tongue River Reservoir Dam, no relationship could be determined, presumably because of the regulating effect of the reservoir. Using the flow-SSC relationships, along with daily flows, daily SSC concentrations were calculated for each station between January 2000 and December 2004. This time period was chosen to represent post construction conditions in the Tongue River Reservoir, and because the most data were available for this period. Daily and yearly loads were then calculated at the State Line, Brandenberg Bridge, and Miles City. Loads were estimated at the Tongue River just downstream of the Tongue River Reservoir Dam using the average reduction in suspended solids discussed above (74 percent reduction in suspended solids). On average, concentrations downstream of the reservoir are 26 percent of the concentrations just upstream of the reservoir.

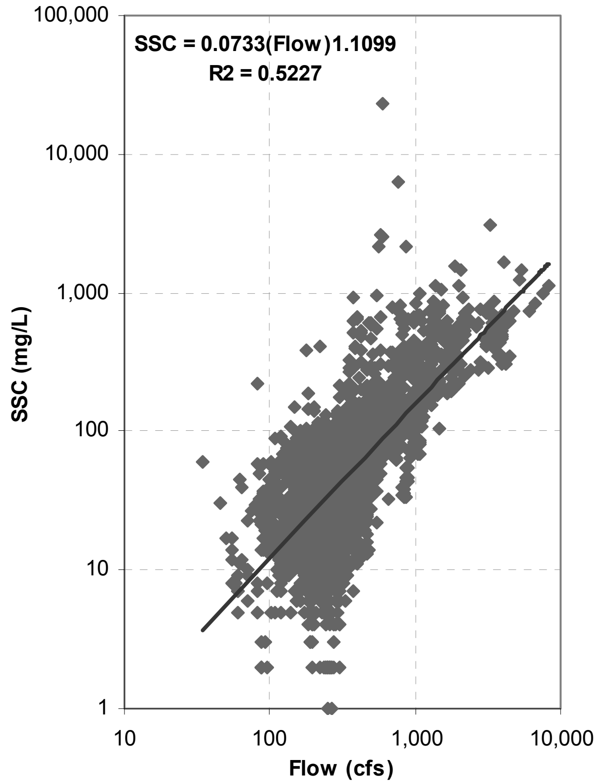


Figure 3-20. Relationship between flow and SSC in the Tongue River near the Brandenberg Bridge, Montana.

The uncertainty associated with the use of regression equations to predict SSC based on flow is acknowledged. However, the general trend of reduced sediment loads downstream of the reservoir is supported by the observed data. This methodology was merely relied upon as a means to estimate the relative significance of the load reductions.

Table 3-26 shows the estimated suspended solids loads in the Tongue River. The Tongue River Reservoir removes an estimated 74 percent of the suspended solids load between the State Line and the Tongue River Reservoir Dam. Loads then increase in a downstream direction up to the Tongue and Yellowstone (T&Y) Diversion Dam. The T&Y Canal diverts an estimated average of 132 cubic feet per second of water from the Tongue River between the months of May and October (DNRC, 2006). Assuming that the suspended solids concentration at the point of diversion is the same as that observed at the closest upstream point in the Tongue River (Brandenberg Bridge), this results in an estimated average annual loss of 2,237 tons of suspended solids (Table 3-26). Combined with the suspended solid loss from the Tongue River Reservoir, the two dams reduce the total suspended solids load at Miles City by an estimated average of 50 percent (19,071 versus 38,927 tons per year).

As shown above, anthropogenic bank erosion and upland sources constitute a small portion of the total load at Miles City (together, an average of 2 percent of the total existing load). Even with these anthropogenic sources, the Tongue River at Miles City has estimated 48 percent less suspended solids load than would otherwise be present under natural conditions.

Table 3-25. Relationship between flow and SSC at four representative Tongue River stations.

Tongue River Location	Station Number	Period of Record	Number of SSC Samples	Regression Equation	R^2
State Line[a]	06306300 06305500	1971-2004	235	$SSC = 1.1681(Flow)^{0.6947}$	0.46
Below Tongue River Reservoir Dam	06307500	1975-2004	201	NA	NA
Brandenberg Bridge[b]	03307830	1974-2004	2,585	$SSC = 0.0733(Flow)^{1.1099}$	0.52
Miles City[b]	06308500	1974-2004	3,240	$SSC = 0.967(Flow)^{0.7996}$	0.30

[a]Due to lack of data at station 06306300, relationship was developed in combination with data from 06306300 and 06305500.
[b]Data obtained from grab samples and from USGS continuous sediment samplers.

Table 3-26. Estimated yearly suspended solids load in the Tongue River, Montana (tons/year).

Year	State Line	TRR Dam	Brandenberg Bridge[a]	Miles City	T&Y Ditch	Total Output[b]
2000	45,170	8,518	5,785	28,430	2,416	30,847
2001	6,768	1,445	3,627	7,275	976	8,251
2002	6,623	1,371	2,161	2,514	969	3,483
2003	43,522	8,355	36,785	53,335	5,349	58,684
2004	5,456	1,476	3,011	3,803	1,474	5,277
Average	21,508	4,233	10,274	19,071	2,237	21,308

[a]Incomplete data for 2000 and 2004.
[b]The total load that would be delivered to the Yellowstone River if not for the T&Y Diversion Dam.

3.5 Other Inorganics (Sulfates)

The agriculture, warm-water fishery and aquatic life beneficial uses of the Tongue River were listed as impaired by "other inorganics" on the Montana 1996 303(d) list; the other inorganics listing was in reference to sulfates. Sulfate was not identified as a cause of impairment for any uses on the 2006 303(d) lists.

Sulfate data for the Tongue River are summarized in Table 3-27 and Figure 3-21. The data do not indicate any areas of localized sulfate loading, and there are no indications of increasing sulfate concentrations.

Table 3-27. Summary of surface water sulfate data in the Tongue River (mg/L).

Tongue River Segment	Station ID	River Mile	Count	Average	Min	Max	Period of Record
T&Y Diversion Dam to the Mouth	06308500	2.5	463	226	38	730	1962-2006
Tongue River Reservoir Dam to the T&Y Diversion Dam	06307990	28.0	34	185	57	268	2004-2006
	06307830	88.1	162	194	49	430	1974-2006
	06307616	154.3	143	158	34	330	1979-2006
	06307610	164.9	64	193	47	420	1974-1979
	06307500	201.0	234	145	23	320	1975-2006
WY-MT border to the Tongue River Reservoir	06306300	215.4	133	116	16	302	1985-2006
Headwaters to the WY-MT Border	06299980	246.3	121	59	11	240	1974-2006
	06298000	271.3	220	5	0	19	1966-2002

Data collected by USGS. Stations with 20 or more total sample dates are shown.

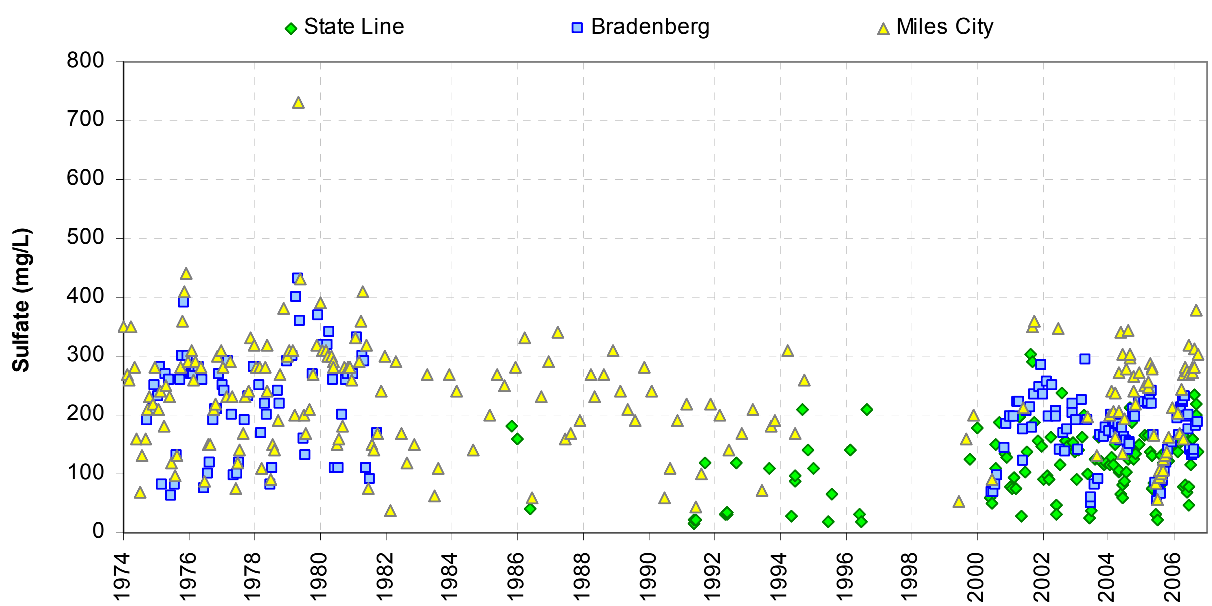


Figure 3-21. Sulfate data at three USGS stations in the Tongue River, Montana.

4.0 HANGING WOMAN CREEK

Hanging Woman Creek flows 62 miles from its origin in Sheridan County, Wyoming to the confluence with the Tongue River near Birney, Montana (Figure 4-1). The total watershed covers roughly 477 square miles. The agriculture, warm-water fishery and aquatic life beneficial uses were listed as impaired by flow alterations, salinity/TDS/chlorides, and metals on the Montana 1996 303(d) list (MDEQ, 1996). The basis for the 1996 listing is unknown. The 2006 303(d) list reported that aquatic life and fishery beneficial uses in Hanging Woman Creek were impaired because of siltation from Stroud Creek to the mouth (MDEQ, 2006). DEQ's Assessment Record Sheet provides the basis for the listing:

Hanging Woman Creek near the mouth
(Photo by Tetra Tech, Inc.)

"*A 1990 assessment conducted for DEQ revealed erosion problems due to grazing activity*," and, "*obvious signs of livestock watering, bank trampling, tracks on creek bottom; some grazing related cut and slough; bottom has not been scoured for at least 12 years; gravel is completely buried under silt and muck*," (MDEQ, 1999).

No segments of Hanging Woman Creek have appeared on the Wyoming 303(d) list.

This analysis specifically addresses the listed pollutants and impaired beneficial uses from the 1996 and 2006 303(d) lists (i.e., impairments to the agriculture, warm-water fishery, and aquatic life beneficial uses associated with salinity/TDS/chlorides, siltation, and metals). Sodium Adsorption Ratio (SAR) is also addressed given its potential importance related to future Coal Bed Methane development in the watershed. The purpose of this analysis was to determine if Montana's water quality standards are currently exceeded in Hanging Woman Creek and, if so, provide insight regarding the potential cause of the exceedance (i.e., natural versus anthropogenic).

Hanging Woman Creek near the confluence with Horse Creek
(Photo by Tetra Tech, Inc.)

The remainder of this section provides a summary and evaluation of the available data, and comparison to the applicable Montana water quality standards, one pollutant at a time. Biological data for Hanging Woman Creek are discussed in Appendix I, and Appendix H provides a general overview of the hydrologic characteristics of the Hanging Woman Creek watershed.

4.1 Salinity

Specific conductance (SC) data for Hanging Woman Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 20 stations in Hanging Woman Creek in Montana and Wyoming, dating from 1974 to 2006, and collected by multiple governmental agencies and private organizations (see Figure 4-1). USGS also collected continuous flow and salinity data at Hanging Woman Creek near the mouth (06307600) from November 1, 1980 to September 30, 1987, and from June 1, 2004 to the present. The available data from stations with at least five samples are listed in Table 4-1 and the sample site locations are shown in Figure 4-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only salinity grab samples are used so that the continuous data do not bias the results.[i]

Table 4-1. Specific conductance (SC) data for the main stem Hanging Woman Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06307540	**Hanging Woman Creek at State Line near Otter, MT**	**USGS**	**46.8**	**7**	**1980-1983**
2078HA01	Hanging Women Creek	MDEQ	24.5	23	1974-1979
6307570	**Hanging Woman Cr Below Horse Creek Near Birney MT**	**USGS**	**24.2**	**65**	**1977-1987; 2005**
6307600	**Hanging Woman Creek Near Birney, MT**	**USGS**	**4.0**	**2,160**	**1974-1995; 2004-2006**
2278HA01	Hanging Women Creek	MDEQ	3.3	32	1974-1979; 1990

[1]Stations with 5 or more samples are included in this table. Entire period of record is shown. Highlighted stations are used in the analyses presented in the following sections.

[i] Continuous salinity data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

Figure 4-1. Surface water quality monitoring stations on the main stem of Hanging Woman Creek.

4.1.1 Spatial Characterization

The USGS sample stations highlighted above in Table 4-1 have been used to provide a general spatial characterization of SC in the Hanging Woman Creek. As shown in Figure 4-2 and Table 4-2, specific conductance decreases in a downstream direction, from a mean of 7,096 µS/cm near the Montana-Wyoming Stateline to 2,412 µS/cm near the mouth. This may be due to localized saline seeps, high salinity soils, and geology in the upper Hanging Woman Creek watershed which are not present in the lower watershed (see Appendix G.1.1). However, the exact cause is unknown.

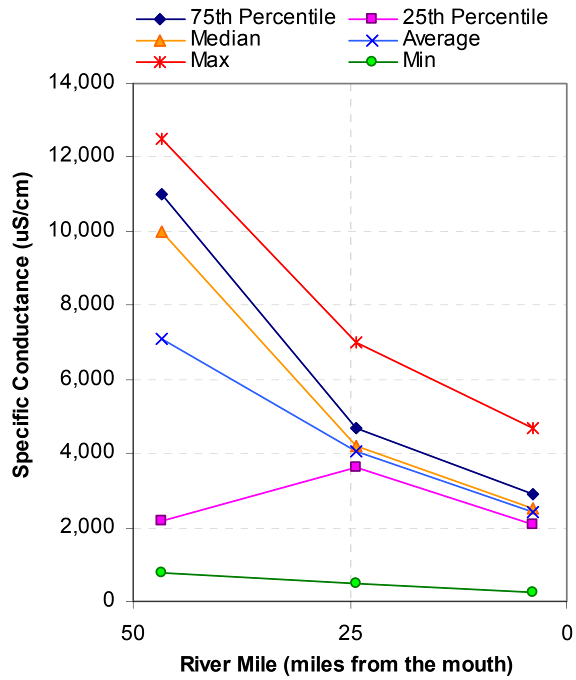


Figure 4-2. Statistics for USGS stations with 10 or more samples in the mainstem Hanging Woman Creek. The entire period of record is shown for each station.

Table 4-2. Specific conductance statistics for various time periods, flows, and stations on the mainstem Hanging Woman Creek, all available grab samples.[1]

Station	Stat	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Hanging Woman Creek at Stateline near Otter, Montana (USGS Gage 06307540)	n	7	NA	NA	NA	NA
	Min	785	NA	NA	NA	NA
	Max	12,500	NA	NA	NA	NA
	Mean	7,096	NA	NA	NA	NA
	Median	10,000	NA	NA	NA	NA
Hanging Woman Creek below Horse Creek near Birney, MT (USGS Gage 06307570)	n	65	7	17	16	32
	Min	473	2,784	1,730	473	2,510
	Max	7,010	5,000	5,000	7,010	5,800
	Mean	4,050	4,009	3,539	3,918	4,388
	Median	4,180	4,243	3,750	4,580	4,410
Hanging Woman Creek near Birney, Montana (USGS Gage 06307600)	n	225	33	56	56	113
	Min	226	1,650	1,400	226	990
	Max	4,220	3,410	3,410	4,220	3,590
	Mean	2,412	2,146	2,216	2,093	2,667
	Median	2,500	2,130	2,165	2,405	2,700

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SC data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

4.1.2 Relationship between Specific Conductance and Discharge

The relationship between discharge and SC was evaluated at two stations in Hanging Woman Creek – Hanging Woman Creek near the mouth (USGS Gage 06307600) and Hanging Woman Creek near the confluence with Horse Creek (USGS gage 06307570). The relationship between flow and SC varies depending on the magnitude of the flow. At less than 8 cubic feet per second, salinity increases with increasing flow. Above 8 cubic feet per second, salinity decreases with increasing flow.

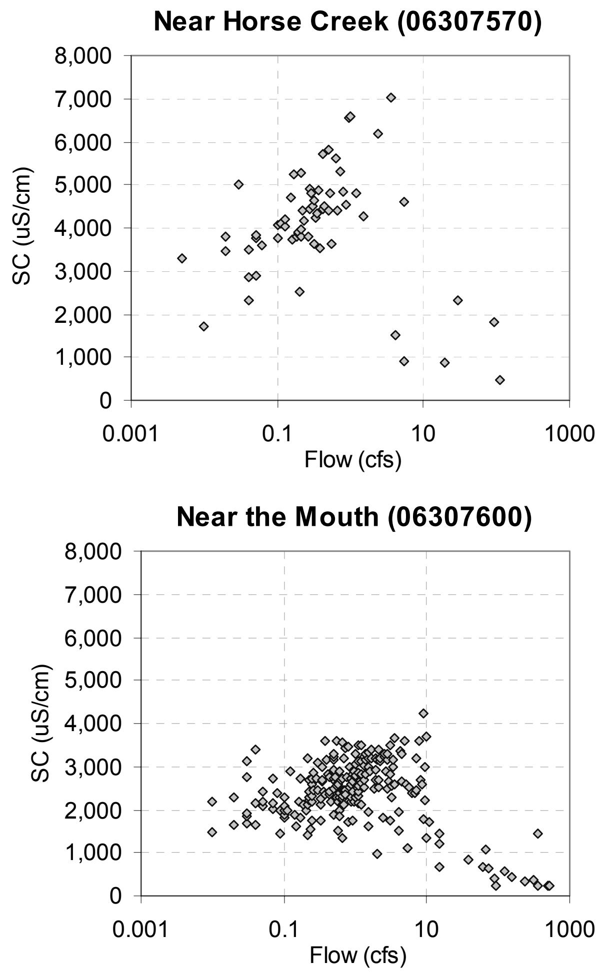


Figure 4-3. Relationship between flow and SC at selected USGS stations on the main stem of Hanging Woman Creek. Entire period of record is shown; grab samples only.

4.1.3 Comparison to Applicable Standards

Of the two jurisdictions in the Hanging Woman Creek watershed (Wyoming and Montana), only Montana has approved numeric water quality standards for salinity. Wyoming's salinity standards are narrative. As a result, this analysis focuses on Montana's salinity standards (described in Appendix B). In the absence of guidance in the Administrative Rules of Montana (ARM), it is assumed that the "electrical conductivity" standard can be applied to "specific conductance" (SC) data, which is simply electrical conductivity that has been corrected to a temperature of 25º Celsius. Both the instantaneous maximum and monthly average salinity standards for tributaries to the Tongue River (i.e., Hanging Woman Creek) are 500 µS/cm. The standards in Hanging Woman Creek do not vary by season.

4.1.3.1 Instantaneous Maximum Salinity Standard

The instantaneous maximum salinity criterion for Hanging Woman Creek is 500 µS/cm. Based on all of the available data, the instantaneous maximum salinity standard has been exceeded 99 percent of the time (2,318 out of 2,331 samples) (Table 4-3). As shown in Figure 4-4, the only time the standard was not exceeded was during the highest 5 percent of flows.

Table 4-3. SC data and exceedances of the instantaneous maximum water quality standards for Hanging Woman Creek; daily and grab samples.

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – October 2, 1974 to June 16, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	1623	1618	99.69%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	708	700	98.87%
"Past 5 Years" – October 1, 2001 to September 30, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	295	294	99.66%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	10	10	100%

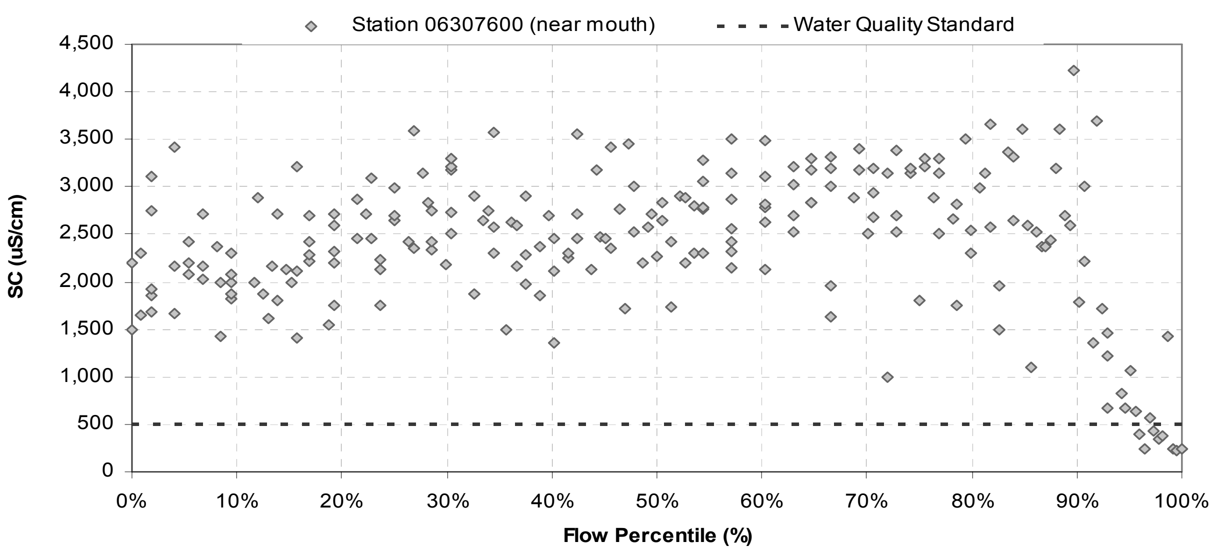


Figure 4-4. Specific conductance versus flow percentile for Hanging Woman Creek near the mouth (USGS Gage 06307600). Entire period of record is shown; grab samples only.

4.1.3.2 Monthly Average Salinity Standard

The monthly average salinity standard for Hanging Woman Creek is 500 µS/cm (the same as the instantaneous maximum standard). However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix E and shows that, in general:

- There are four or more samples per month at only one USGS station – Hanging Woman Creek near the mouth (06307600) and even here, daily data are limited to two time periods - between November 1980 and September 1987, and May 2004 to July 2006.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SC on a monthly basis (maximum measured change in one month of 2,708 µS/cm near the mouth, March 1986), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

Given the limited data, separate evaluations have been conducted: 1) using the full period of record and; 2) using only the data collected in the past five years. Only months with 4 or more samples were used in the analysis. The frequency of exceedance is shown in Table 4-4. The monthly average standard is always exceeded during both the growing season and nongrowing season (where data were available).

Table 4-4. Average monthly SC data and exceedances of the average monthly water quality standards for Hanging Woman Creek for the last five years assuming ≥ four daily and/or grab samples per month.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 2, 1974 to June 16, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	50	50	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	20	20	100%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	12	12	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	0	NA	NA

4.1.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[j]. This is illustrated for SC in Figure 3-7, Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SC at station 06307600 to the nondegradation threshold is presented in Figure 4-5. The nondegradation threshold (200 µS/cm) is exceeded all of the time. It is also exceeded 100 percent of the time at all other available Hanging Woman Creek monitoring stations.

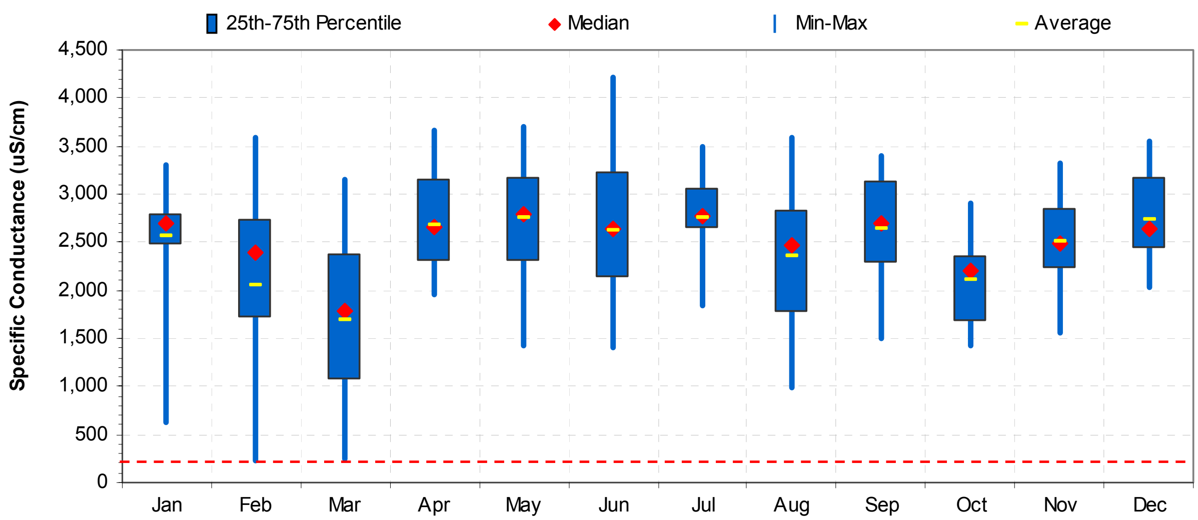


Figure 4-5. SC data and nondegradation thresholds for Hanging Woman Creek (near the mouth). Entire period of record is shown; grab samples only.

4.1.4 Sources of Salinity and Their Influence on Hanging Woman Creek

As described above, exceedances of Montana's salinity standards have been observed in Hanging Woman Creek. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both).

A modeling analysis similar to that which was described in Section 3.1.4 was conducted to estimate the salinity levels that may have occurred in the absence of human influence (see Appendix J).
Mean SC under the simulated natural condition is not significantly different (P=0.05) than the simulated existing condition. Therefore, based on model results, the observed exceedances of Montana's SC standards for Hanging Woman Creek are due to natural causes.

[j] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

4.2 SAR

Sodium adsorption ratio (SAR) data for Hanging Woman Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 24 stations in Hanging Woman Creek in Montana and Wyoming, dating from 1974 to 2006, and collected by multiple governmental agencies and private organizations. USGS also collected continuous flow and SAR data at Hanging Woman Creek near the mouth (06307600) from May 22, 2004 to June 16, 2006. The available data from stations with at least five samples are listed in Table 4-5 and the sample site locations are shown in Figure 4-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only SAR grab samples are used so that the continuous data do not bias the results.[k]

Table 4-5. SAR data for the mainstem Hanging Woman Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06307540	**Hanging Woman Creek at State Line near Otter, MT**	**USGS**	**46.8**	**7**	**1980-1983**
2078HA01	Hanging Women Creek	MDEQ	24.5	10	1974-1979
6307570	**Hanging Woman Cr Below Horse Creek Near Birney MT**	**USGS**	**24.2**	**65**	**1977-1987; 2003; 2005**
6307600	**Hanging Woman Creek Near Birney, MT**	**USGS**	**4.0**	**405**	**1974-1995; 2003-2006**
2278HA01	Hanging Women Creek	MDEQ	3.3	17	1974-1979; 1990

[1]Stations with 5 or more samples are included in this table. Highlighted stations are used in the analyses presented in the following sections.

4.2.1 Spatial Characterization

The USGS sample stations highlighted in Table 4-1 have been used to provide a general spatial characterization of SAR in Hanging Woman Creek. As shown in Figure 4-6 and Table 4-6, SAR decreases in a downstream direction, from a mean of 10.92 near the Montana-Wyoming Stateline to 4.94 near the mouth. This is potentially due to localized saline seeps, high SAR soils, and geology in the upper Hanging Woman Creek watershed which are not present in the lower watershed (see Appendix G.1.1).

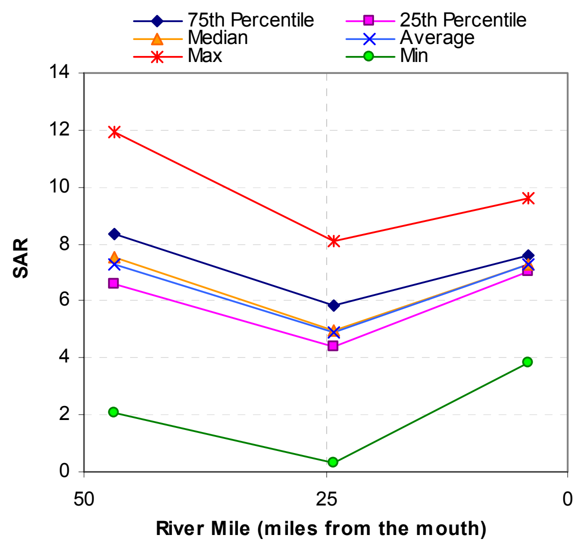


Figure 4-6. SAR Statistics for USGS stations with 5 or more samples in the mainstem Hanging Woman Creek. The entire period of record is shown for each station; grab samples only.

[k] Continuous SAR data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

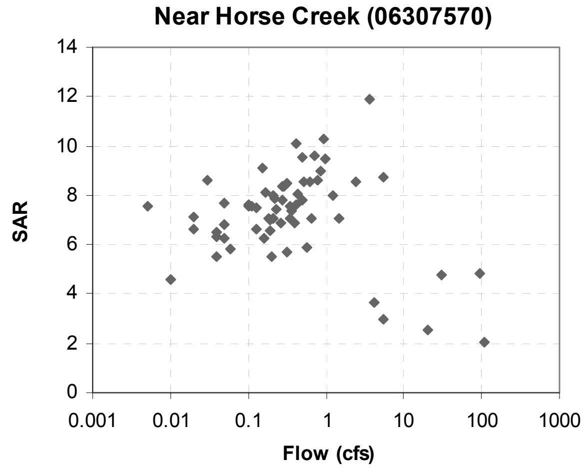
Table 4-6. SAR statistics for various time periods, flows, and stations on the mainstem Hanging Woman Creek, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Hanging Woman Creek at Stateline near Otter, Montana (USGS Gage 06307540)	n	7	0	2	2	3
	Min	3.19	NA	15.50	3.19	4.27
	Max	17.19	NA	17.19	5.79	15.81
	Mean	10.92	NA	16.34	4.49	11.58
	Median	14.65	NA	16.34	4.49	14.65
Hanging Woman Creek below Horse Creek near Birney, MT (USGS Gage 06307570)	n	65	1	17	16	32
	Min	2.07	8.59	4.56	2.07	5.50
	Max	11.91	8.59	8.59	11.91	10.08
	Mean	7.25	8.59	6.83	7.00	7.59
	Median	7.49	8.59	6.78	8.27	7.60
Hanging Woman Creek near Birney, Montana (USGS Gage 06307600)	n	177	32	46	44	87
	Min	0.33	0.33	0.33	0.70	0.36
	Max	8.08	6.00	8.08	8.08	7.17
	Mean	4.94	3.55	4.25	4.96	5.29
	Median	5.04	4.39	4.52	5.28	5.44

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SAR data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

4.2.2 Relationship between SAR and Discharge

The relationship between discharge and SAR was evaluated at two stations in Hanging Woman Creek – Hanging Woman Creek near the mouth (USGS Gage 06307600) and Hanging Woman Creek near the confluence with Horse Creek (USGS gage 06307570). Similar to salinity, the relationship between flow and SAR varies depending on the flow magnitude. At flows less than 8 cubic feet per second, SAR increases with increasing flow. After 8 cubic feet per second, SAR decreases with increasing flow.



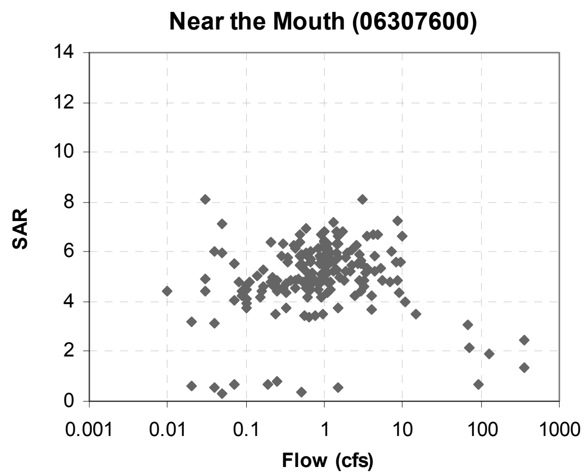


Figure 4-7. Relationship between flow and SAR at selected USGS stations on the main stem of Hanging Woman Creek. Entire period of record is shown; grab samples only.

4.2.3 Comparison to Applicable Standards

Of the two jurisdictions in the Hanging Woman Creek watershed (Wyoming and Montana), only Montana has approved numeric water quality standards for SAR. Wyoming's SAR standards are narrative. As a result, this analysis focuses on Montana's SAR standards (described in Appendix B). The standards are seasonal, with separate criteria for the growing season (March 2 – October 31) and non-growing season (November 1 – March 1) and include monthly average criteria as well as instantaneous maximum criteria.

4.2.3.1 Instantaneous Maximum SAR Standard

The instantaneous maximum SAR criteria for Hanging Woman Creek are 4.5 during the growing season and 7.5 during the nongrowing season. Based on all of the available data, the instantaneous maximum SAR standard has been exceeded 70 percent of the time during the growing season, and 6 percent of the time during the nongrowing season (Table 4-7). As shown in Figure 4-8, exceedances during the growing season have occurred during the full range of flows.

Table 4-7. SAR data and exceedances of the Instantaneous maximum water quality standards for Hanging Woman Creek; daily and grab samples.

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – October 2, 1974 to June 16, 2006	Growing Season (March 2 to October 31)	< 4.5	455	320	70.33%
	Nongrowing Season (November 1 to March 1)	< 7.5	84	5	5.95%
"Past 5 Years" – October 1, 2001 to September 30, 2006	Growing Season (March 2 to October 31)	< 4.5	274	170	62.04%
	Nongrowing Season (November 1 to March 1)	< 7.5	7	0	0%

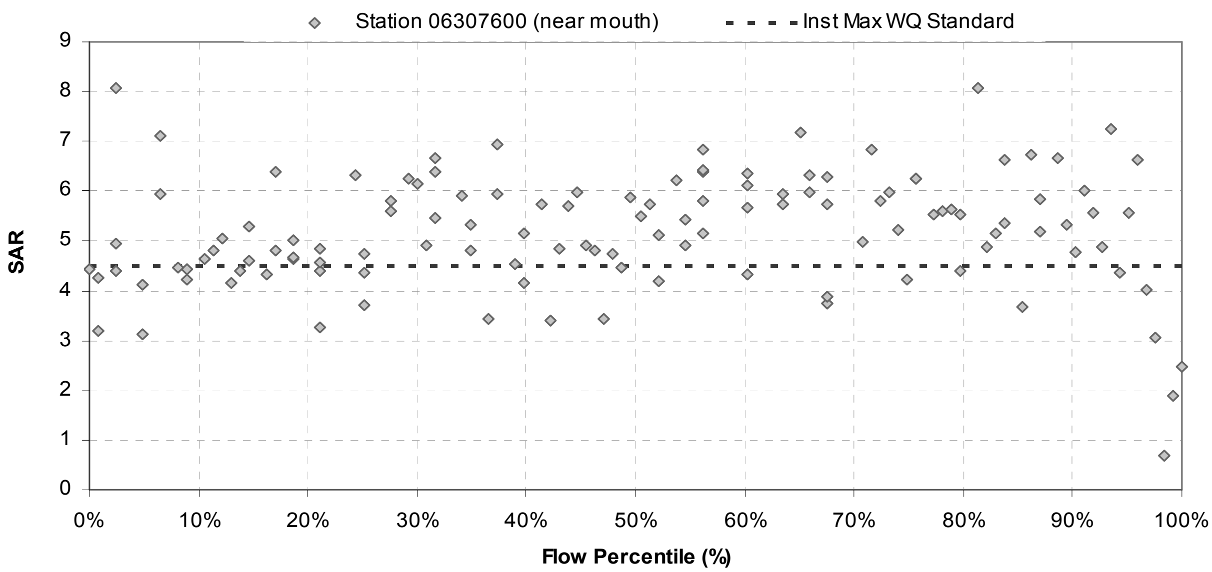


Figure 4-8. SAR versus flow percentile for Hanging Woman Creek near the mouth (USGS Gage 06307600). Growing season grab samples only.

4.2.3.2 Monthly Average SAR Standard

The monthly average SAR standards for Hanging Woman Creek are 3.0 for the growing season and 5.0 for the nongrowing season. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix F and shows that, in general:

- There are four or more samples per month at only one USGS station – Hanging Woman Creek near the mouth (06307600). Daily data were collected between May 2004 and June 2006.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SAR on a monthly basis (maximum measured change in one month of 4.5 in June 2006), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

There is limited data to evaluate the monthly average standard using months with 4 or more samples. The months with 4 or more samples only occurred between 2004 and 2006, which were relatively dry years. Therefore, for the purposes of providing a comparison of the available data to the monthly average SAR criteria, all of the available data were compared to the monthly average standard, as well as only data collected in the past five years. The frequency of exceedance is shown in Table 4-4.

Table 4-8. Average monthly SAR data and exceedances of the average monthly water quality standards for Hanging Woman Creek; daily and grab samples.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 2, 1974 to June 16, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	114	112	98.25%
		Nongrowing Season (November 1 to March 1)	< 5.0	52	49	94.23%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	11	11	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	18	17	94.44%
		Nongrowing Season (November 1 to March 1)	< 5.0	7	5	71.43%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	11	11	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

4.2.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[1]. This is illustrated for SC in Figure 3-7 and Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SAR at station 06307600 to the nondegradation threshold is presented in Figure 4-9. The nondegradation threshold (2.0 and 1.2) is exceeded most of the time during all months.

[1] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

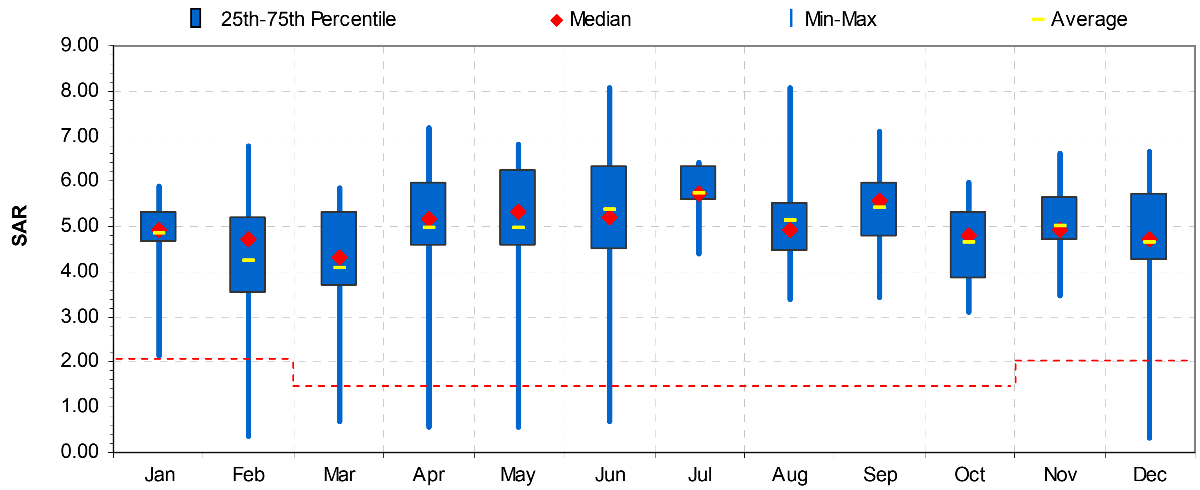


Figure 4-9. SAR data and nondegradation thresholds for Hanging Woman Creek (near the mouth). Entire period of record is shown; grab samples only.

4.2.4 Sources of SAR and Their Influence on Hanging Woman Creek

As described above, exceedances of Montana's SAR standards have been observed in Hanging Woman Creek. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both).

A modeling analysis similar to that which was described in Section 3.1.4 was conducted to estimate the SAR levels that may have occurred in the absence of human influence (see Appendix J). Mean SAR under the natural condition is not significantly different (P=0.05) than the existing condition. Therefore, based on model results, the observed exceedances of Montana's SAR standards for Hanging Woman Creek are due to natural causes.

4.3 Metals

Aquatic life and fishery beneficial uses in Hanging Woman Creek (MT-WY State Line to the mouth) were listed as impaired because of metals on the Montana 1996 303(d) list (Segment MT42B002-003) (MDEQ, 1996). No specific metals were listed as the cause of impairment, but the metals listing on the 1996 list applies to one or more of the following parameters – arsenic, cadmium, chromium, copper, iron, lead, nickel, selenium, silver, and zinc (Personal communications, Montana DEQ, 2002). Metals were not listed as a cause of impairment on the 2006 303(d) list.

As described in Section B.1.5 of Appendix B, metals data for the following analysis consist only of USGS, USEPA, and Montana DEQ data collected between January 1, 1997 and the present. Data were compared to the Montana total recoverable metals standards, but both "total" and "total recoverable" data were used in the assessment (see Appendix B, Section B.1.5). Where no hardness data were available, the average value for Hanging Woman Creek was used to calculate hardness dependant criteria.

Table 4-9 presents a summary of the available metals data obtained in Hanging Woman Creek. Samples were only available at three sites: two sites near the mouth (USGS Gage 06307600 and MTDEQ Gage Y15HNGWC01) and one site near the MT-WY State Line (Y15HGWC2-1) (see Figure 4-1). Most of the samples were obtained at USGS Gage 06307600. Between 7 and 24 samples were obtained for each parameter, and data were available between October 16, 2002 and May 16, 2006.

Table 4-9. Summary of metals data in Hanging Woman Creek near the mouth.

Parameter	Count	Average (µg/L)	Min (µg/L)	Max (µg/L)	Period of Record
Arsenic (Total) (µg/L as As)	24	1.47	0.76	4.00	10/16/02-5/16/06
Cadmium (Total) (µg/L as Cd)	23	0.04	0.02	0.20	4/26/03-5/16/06
Chromium (Total) (µg/L as Cr)	21	3.40	0.50	14.00	5/30/03-5/16/06
Copper (Total) (µg/L as Cu)	24	5.05	2.00	11.80	10/16/02-5/16/06
Iron, (Total), (µg/L as Fe)	24	474.00	202.00	1,410	10/16/02-5/16/06
Lead (Total) (µg/L as Pb)	23	0.49	0.07	1.50	4/26/03-5/16/06
Nickel (Total) (µg/L as Ni)	23	5.84	0.01	10.00	4/26/03-5/16/06
Selenium (Total) (µg/L as Se)	23	1.02	0.21	3.00	4/26/03-5/16/06
Silver (Total) (µg/L as Ag)	7	0.68	0.25	2.00	10/16/02-10/02/03
Zinc (Total) (µg/L as Zn)	24	11.46	0.01	120.00	10/16/02-5/16/06

One iron sample exceeded the chronic criterion of 1,000 µg/L. The date of the exceedance, the concentration, and the percent increase from the standard are presented in Table 4-10. At most, iron samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. No other metals samples exceeded the metals standards in Hanging Woman Creek.

Table 4-10. Summary of the iron exceedances in Hanging Woman Creek.

Station	Date of the Exceedance	Chronic Standard	Value	% Increase from the Standard
Y15HNGWC01	June 27, 2003	1,000 µg/L	1,410 µg/L	40.0%

4.4 Siltation/Suspended Solids

Hanging Woman Creek was not listed as impaired because of siltation on the 1996 303(d) list (MDEQ, 1996). The 2006 303(d) lists reported that aquatic life and fishery beneficial uses in Hanging Woman Creek from Stroud Creek to the mouth were impaired because of siltation (MDEQ, 2006a). Grazing and agriculture were cited as the source of the siltation impairment, based primarily on a 1990 field survey of riparian conditions in lower Hanging Woman Creek (MDEQ, 1990).

In the absence of formal numeric sediment criteria, the following presents an evaluation of a suite of indicators that have been selected to create a measurable point of reference for Montana's narrative sediment criteria. Details regarding each of the factors discussed below are provided in Appendix B.

It should be noted that application of Montana's narrative sediment standards to Hanging Woman Creek is complicated by the following factors:

- In their natural condition, prairie streams have more fine sediments than streams in the mountains or foothills regions in Montana (Bramblett et al., 2005; Zelt et al., 1999; USEPA, 2005). Human activities that increase fine sediment may simply mimic natural conditions; thus differentiating between natural and human caused in-stream sediment conditions is especially challenging in this region.

- The harsh environment in this region creates the possibility that natural factors will, on occasion, impact biota irrespective of human influence (Bramblett et al., 2004). Therefore, it is not always possible to determine the specific cause of impairment using biological data. This is true when trying to differentiate between human versus naturally caused biological impairments and also when trying to determine which pollutant or pollutants (e.g., sediment, metals, salinity, etc.) are causing the biological impairment.
- Having an understanding of the reference or natural condition is a prerequisite to the application of Montana's narrative water quality standards for sediment (ARM 17.30.602(19); ARM 17.30.629(2)[d]; ARM 17.30.629(2)[f]). Human influence, though often subtle, is pervasive in the eastern plains of Montana, and defining reference conditions is difficult. As a result, little reference data are currently available for defining the natural condition in prairie streams relative to sediment.

4.4.1 1990 Nonpoint Source Stream Reach Assessment and Physical Characterization

The Montana Water Quality Bureau conducted a survey of Hanging Woman Creek in October of 1990 using the standardized forms "Nonpoint Source Stream Reach Assessment" and "Physical Characterization/Water Quality Field Data Sheet", (MDEQ, 1990). This was a qualitative, visual field survey of Hanging Woman Creek from Stroud Creek to the mouth and represents an interpretation of conditions existing roughly 17 years ago. Therefore the results should be used with caution. A summary of the results from the Field Data Sheet (MDEQ, 1990) is provided below.

- Stream was intermittent for most of the reach, having seasonal flows during wet weather and spring runoff.
- Noted that grazing is affecting bank stability.
- There are a significant number of naturally exposed soils and knobs, possibly aggravated by livestock.
- Watershed is dominated by grazing and limited cultivation.
- High erosion/sediment loads are natural in the watershed, but the overall condition is aggravated by grazing.
- Noted moderate to substantial instability, frequent areas of bank erosion/failure (10-40 percent of the total stream length).
- Mixed streamside vegetation, ranging from "fair" to excellent depending on location.
- Beaver dams, small irrigation dams affecting flows.
- Noted that channel may be dry for periods of time and low enough to preclude/impact aquatic organisms.
- Grazing noted in 100 percent of the stream corridor.

Overall, there were impacts to Hanging Woman Creek that possibly affected sediment erosion and delivery. However, the stream is also naturally high in sediment due to naturally exposed soils and badland areas (NRCS, 2002). Also, it should be noted that only a small portion of the stream was evaluated and this survey was conducted 17 years ago.

4.4.2 Relative Bed Stability Index

The relative bed stability (RBS) metric is used to determine if a stream has excessive sediment (Kaufmann et al., 1999). Basically, the metric compares the measured median substrate size in the streambed to the maximum substrate size carried during bankfull events (see Appendix B). The RBS was calculated at one site in 2001 as part of the EMAP program (Station EMAPS05). Hanging Woman Creek scored -2.16, which indicates that substrate conditions were "good" with respect to expected substrate conditions. However, lack of data for other years or segments limit the use of this result.

4.4.3 HII

Bramblett et al. (2004) developed a human influence index (HII) to systematically compare human disturbance among multiple watersheds (see Appendix B). Measured HII scores ranged from 235 to 845, and scores greater than 615 were considered "good" (Tom Johnson, personal communications, January 31, 2005). In Hanging Woman Creek, the HII score was calculated at one site in 2001 as part of the EMAP program (Station EMAPS05). Hanging Woman Creek scored 701, which indicates that there were few anthropogenic stressors in Hanging Woman Creek as compared to other southeast Montana streams.

4.4.4 Riparian and Bank Condition

Bank stability and riparian vegetation assessments were combined to form a riparian and bank condition (RBC) index (see Appendix B) (USEPA, 2005). The RBC was calculated at one site in 2001 as part of the EMAP program (Station EMAPS05). Hanging Woman Creek scored 90, which indicates that bank stability and vegetation were good with respect to other Great Plains streams.

4.4.5 Rapid Habitat Assessment

As described in Appendix B, rapid habitat assessments are a methodology for quickly evaluating physical stream parameters. Confluence Consulting assessed stream channel and riparian condition in Hanging Woman Creek near the confluence with Corral Creek (Station BLMHWC10) (Confluence Consulting, 2003). The site was evaluated with the USEPA forms developed by Peck et. al (2003). Results from the survey were mixed – while there was little evidence of channel alteration or flow modifications, there was some evidence of grazing and sediment deposition (Table 4-11). The report stated that:

> *Livestock grazing was the primary influence on this reach. While banks were stable, streamside graminoids consisted of short stubble. Extensive stock trails traversed the area. Green ash and peachleaf willow (Salix amygdaloides) occurred as isolated, mature specimens. Relatively large pools and undercut banks provided fish habitat through most of the reach. Fine, organic muck dominated the streambed. The stream channel was relatively entrenched; however, it was not clear if this was due to land use or was natural (Confluence Consulting, 2003).*

The site scored a total of 73 percent on the rapid habitat assessment form, which is less than the 81 percent threshold for optimal conditions (see Appendix B).

Table 4-11. Results of the Rapid Habitat Assessment for site BLM-HWC10.

Parameter	Score (Out of 20 Possible Points)
Bank vegetative protection	15
Channel alteration	19
Channel flow status	19
Channel sinuosity	15
Condition of banks	15
Epifaunal substrate	15
Grazing or other disruptive pressure	8
Instream cover	12
Pool substrate characterization	12
Pool variability	16
Riparian vegetation zone width	19
Sediment deposition	11
Percent of possible score	**73%**

>81% indicates an optimal condition 75-56% indicates a sub-optimal condition
<49-29% indicates a marginal condition <23% indicates a poor condition

4.4.6 NRCS Riparian Assessment

NRCS inventoried point and linear features for Hanging Woman Creek in Big Horn County (see Appendix B). There were few identified features – floodplain dikes, channel plugs, and bridges/fords (Figure 4-10) (NRCS, 2001). Features in Rosebud County were not inventoried. Channelization was noted in several areas; however, NRCS could not determine if the channelization was natural or anthropogenic. Woody vegetation was absent from most of the upstream portions of Hanging Woman Creek (Figure 4-10, Reach 1). NRCS noted that the upstream reaches were also intermittent with groundwater-fed pools. Saline soils and seeps were common in the upstream reaches (evidenced by alkali deposits, pan spots, exposure of salt bearing shales, salt crusts, and greasewood), and likely limited riparian establishment as evidenced during the survey (NRCS, 2001). Near the mouth of Hanging Woman Creek, the gradient is low and flows are affected by backwater from the Tongue River. Increased sediment deposition was noted here (Reach 6) due to this phenomenon.

Only three floodplain dikes were noted as limiting floodplain access in Hanging Woman Creek. NRCS reported that, "numerous other such systems were noted, however, dike placement did not appear to have much potential to limit regular floodplain access, and so were not recorded," (NRCS, 2001). Dikes are more prevalent in the downstream reaches (Rosebud County), where flows are higher. However, information about these systems was not available at the time of this report.

Results of the riparian assessment showed that most Hanging Woman Creek segments were ranked as "sustainable," indicating good channel and riparian conditions (NRCS, 2002). The most upstream reach (Reach 1), however, was ranked as "Not Sustainable," (Table 4-12). This was mostly due to a high degree of incisement, lack of woody vegetation, and lack of deep binding root mass, which may or may not be related to recent human-caused sources. Overall, NRCS noted that, "sediment supply and deposition appeared to be in balance" throughout the watershed (NRCS, 2002).

Table 4-12. Results of the NRCS riparian assessment in Hanging Woman Creek.

Segment[a]	Incisement	Lateral Cutting	Sediment Balance	Soil	Binding Root Mass	Woody Establishment	% Utilization	Riparian/Wetland Characteristics	Floodplain	Irrigation Impacts	Land Use Activities	Subtotal	Potential Score	% of Potential	Sustainability Rating
HWC-1-1	2	4	6	3	0	NA	NA	0	0	NA	NA	15	41	37%	**Not Sustainable**
HWC-1-2	6	6	6	3	4	NA	NA	4	6	8	8	51	57	89%	Sustainable
HWC-1-3	6	6	6	3	4	NA	NA	4	6	NA	NA	35	41	85%	Sustainable
HWC-2-1	8	6	6	3	6	NA	NA	6	6	8	6	55	57	96%	Sustainable
HWC-3-1	6	6	6	3	6	NA	NA	6	6	8	6	53	57	93%	Sustainable
HWC-4-1	6	6	4	3	4	2	4	4	6	8	6	53	69	77%	Sustainable
HWC-5-1	6	6	4	3	4	4	4	6	6	8	6	57	69	83%	Sustainable
HWC-6-1	6	6	4	3	6	4	4	6	6	8	6	59	69	86%	Sustainable
HWC-6-2	6	6	4	3	6	6	3	6	6	8	8	62	69	90%	Sustainable

Sustainable: >75%; At Risk: 50-75%; Not Sustainable: <50%

Note: targets were adopted from the NRCS Report, "Tongue River Stream Corridor Assessment Montana Reaches – Phase II – Physical Habitat Assessment."

[a]See Figure 4-10 for segment locations.

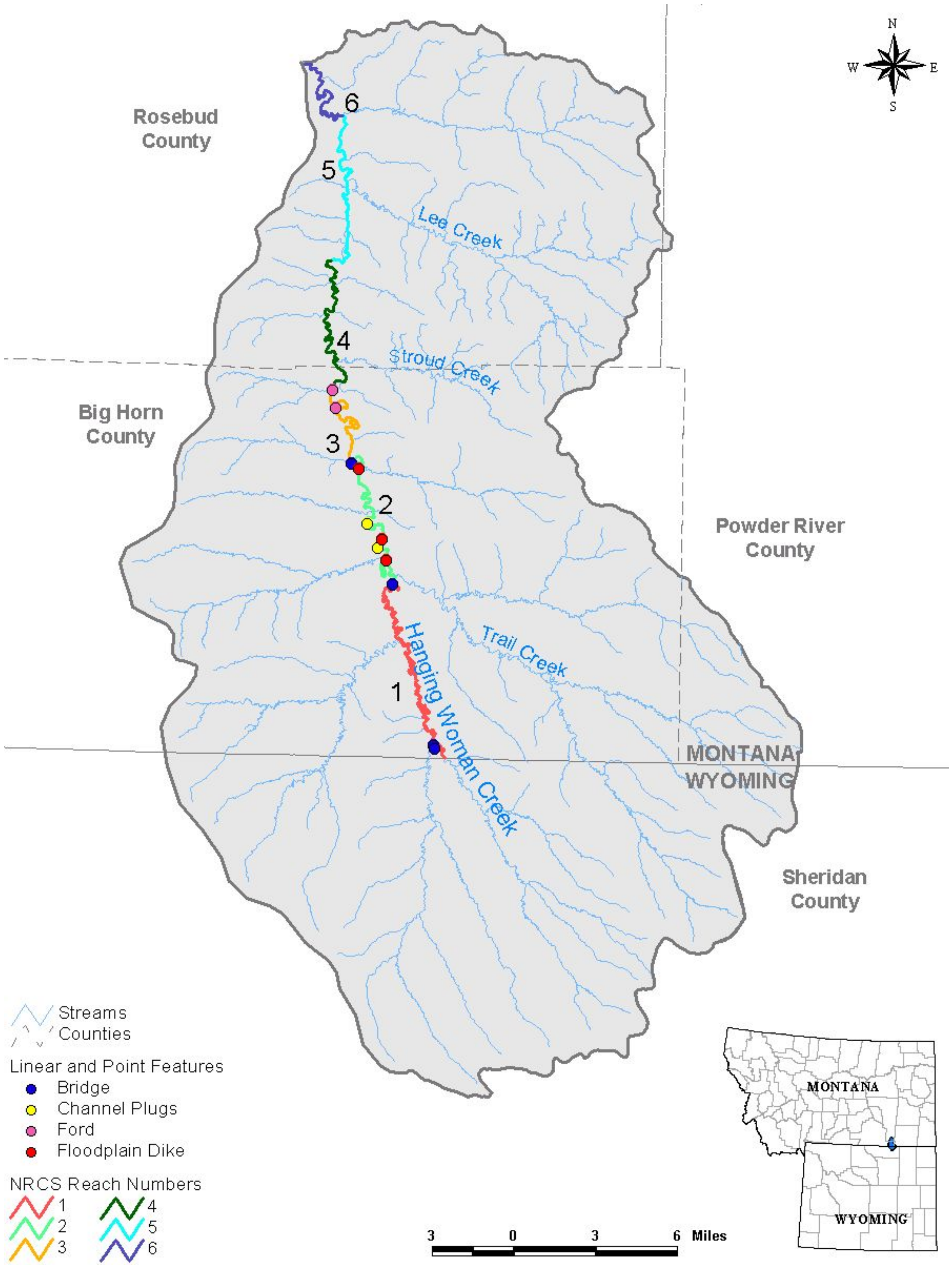


Figure 4-10. NRCS riparian assessment for Hanging Woman Creek.

4.4.7 In-Stream Sediment Concentrations

Total suspended solids (TSS) and suspended sediment concentrations (SSC) were collected at multiple sites and years in Hanging Woman Creek (Table 4-13). Between 1974 and 2006, there were 314 TSS or SSC samples collected in the stream. As described in Appendix B, TSS and SSC data are combined and used together in this analysis.

Without an appropriate reference stream, it is impossible to determine if the available TSS and SSC data are exceeding reference conditions. Overall, there were no discernable temporal trends in the data (Figure 4-11). Also, concentrations were relatively similar at all stations and did not indicate localized sediment loading (Figure 4-12).

Table 4-13. Summary of TSS and SSC data, Hanging Woman Creek.

Station	Count	Median	Average	Min	Max	Period of Record
2278HA01 (Downstream)	24	22	26	4	131	1975-1990
6307600	173	65	87	7	650	1974-2006
Y15HNGWC01	6	9	16	2	58	2003-2003
2278EA01	18	2	9	0.4	47	1978-1979
2178HA02	1	11	11	11	11	1979-1979
2178HA01	1	14	14	14	14	1979-1979
Y15HNGWC02	5	43	39	17	63	2003-2003
6307570	60	47	62	5	609	1977-1987
2078HA01	18	9	12	2	31	1978-1979
Y15HGWC2-1	1	14	14	14	14	2002-2002
6307540 (Upstream)	7	24	37	9	120	1980-1983
All Stations	314	14	30	0.4	650	1975-2006

Data collected by USGS, NRCS, and MDEQ. Station locations shown in Figure 4-1.

Suspended sediment data from Hanging Woman Creek were compared to other similar streams in the Great Plains ecoregion (see Appendix K). Data from 19 streams (21 sites) show that Hanging Woman Creek had relatively low TSS and SSC concentrations (fourth lowest median concentration), and similar variability to other streams in the ecoregion. There was no indication of elevated TSS or SSC concentrations when compared to other regional streams.

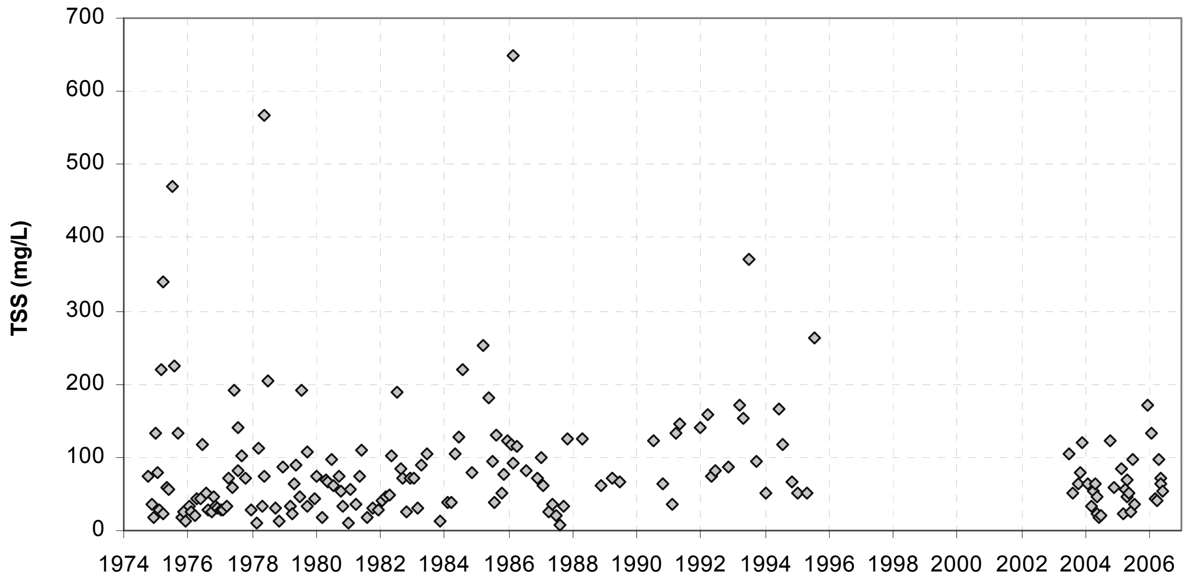


Figure 4-11. TSS and SSC data for Hanging Woman Creek near the mouth (USGS Gage 06307600).

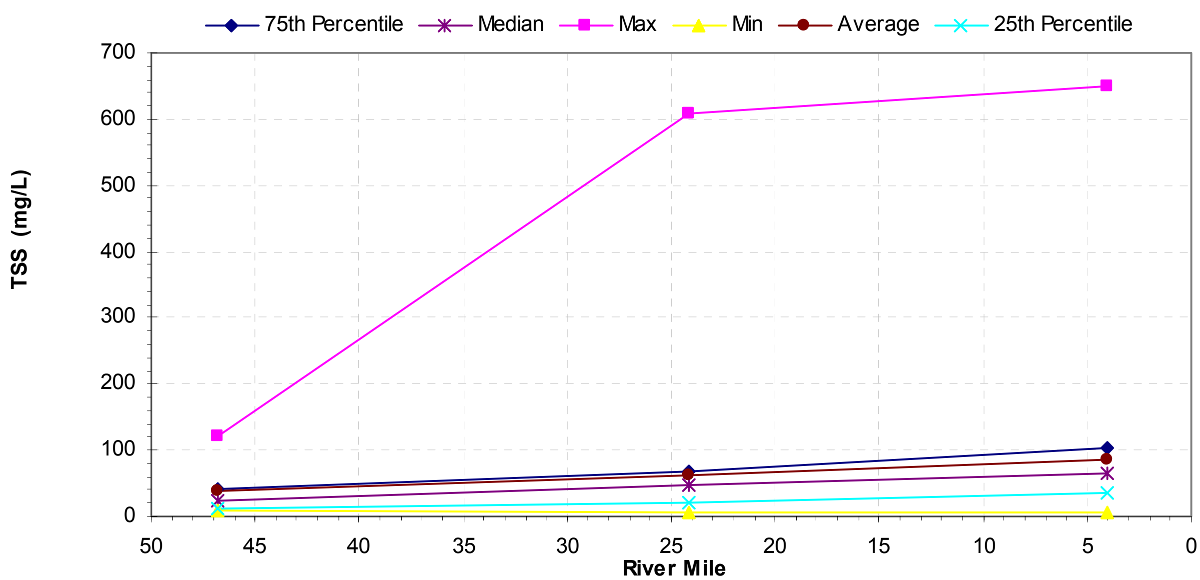


Figure 4-12. TSS and SSC data for Hanging Woman Creek stations 06307540, 06307570, and 06307600.

4.4.8 Sediment Source Identification and Load Quantification

As described in the March 2003 Phase I report (MDEQ, 2003), soils in the Hanging Woman Creek watershed are naturally highly erodible, with slow to very slow infiltration rates. These attributes, in combination with semiarid conditions, flashy rain events, and sparse ground cover, result in naturally high sediment erosion. Buttes and badlands occur throughout the landscape, and saline or sodic soils limit plant growth in several areas. NRCS (2002) reported that:

> *The majority of the Tongue River watershed is mapped as yielding 0.2 to 0.5 acre-feet/mile^2/year of sediment. Using an average bulk density of sixty-pounds/cubic foot, these volumes would be equivalent to 0.4 to 1.0 tons/acre/year. Juvan estimated percent contribution of erosion source was forty-percent gully and sixty percent sheet erosion within most of the Tongue River-Montana watershed (Juvan, undated).*

Bison were once native to this area and likely impacted streams and upland rangeland. Historic accounts (mid 1800s) indicated that there was widespread scarcity of grasses and water throughout the Tongue River watershed due to bison (NRCS, 2002). Cattle are currently the predominant agricultural resource in the watershed (NASS, 2002). It is well documented that cattle have the potential to impact the landscape, if not managed properly (Hoorman and McCutcheon, 2007; Haan et al., 2004). In the uplands, decreased ground cover, increased erosion, and the promotion of invasive species can occur from overgrazing. In the lowlands and stream valleys, cattle grazing can have direct impacts to the stream and riparian area (destabilized stream banks, lack of riparian cover, habitat degradation). However, the relative contribution of sediment to the stream is unknown.

Other potential sediment sources within the watershed may include unpaved roads, irrigated agriculture, various drainage features (stock ponds and irrigation dikes) that may alter both the flow and sediment dynamics in the system, and disturbed lands associated with the construction and operation of coal bed methane development. Irrigation can affect flows and sediment supply in the stream, resulting in a lack of flushing flows and sediment imbalances. The effect of irrigation on in-stream sediment and sediment supply is unknown and unquantifiable at the time of this report.

Upland sediment loads were estimated using soil survey data, GIS, and the Universal Soil Loss Equation (USLE). Details of the analysis for all watersheds are described in Appendix B. In the Hanging Woman Creek watershed, there was very little difference between the existing and “natural” upland sediment delivery. Natural conditions are defined as “no human alterations, resulting in no active agricultural land and increased total vegetative ground cover.” USLE calculations showed that there is only a 0.42 percent increase in sediment load over naturally occurring conditions (17,992 versus 18,069 tons of sediment per year). This suggests that human management has not had a major effect on upland sources in the Hanging Woman Creek watershed. It should be noted that this analysis does not take into account streambank erosion or riparian degradation.

As evidenced by NRCS (2002), cattle have impacted riparian areas and stream banks in several areas. The extent of this effect is unknown, although NRCS did not find any major areas of bank erosion in their 2001 survey (NRCS, 2002). The 1990 Montana Water Quality Bureau survey noted moderate to substantial instability with frequent areas of bank erosion/failure (10-40 percent of the total stream length).

To estimate bank erosion in Hanging Woman Creek, a simple analysis was performed using literature values and conservative assumptions. It was assumed that stream banks are eroding an average of 0.10 feet per year, and have a height of one foot (adapted from Rosgen, 1996). Although the 2001 NRCS riparian assessment found 43.0 of 47.8 assessed miles to be “sustainable”, it is conservatively assumed that bank erosion occurs along 40 percent (based on the worst-case estimate from the previously discussed 1990 survey) of the total stream bank length (126 miles), and all of that erosion is human-caused. Assuming an average bulk density of 60 pounds per cubic feet, this equates to an average sediment load of 786 tons of sediment per year from bank erosion. From this worst-case analysis, it is estimated that 18,000 tons of sediment per year are contributed to the stream from upland sources. Therefore, using conservative estimates, streambank erosion is less than five percent of the total sediment load delivered to the stream. This analysis shows that streambank erosion is relatively small compared to the total amount of sediment contributed from upland erosion.

5.0 OTTER CREEK

Otter Creek flows 103 miles from its origin in Powder River County, Montana to the confluence with the Tongue River near Ashland, Montana (Figure 5-1). The total watershed covers roughly 709 square miles. The agriculture, warm-water fishery, and aquatic life beneficial uses were listed as impaired by salinity/ TDS/chlorides, metals, suspended solids, and other habitat alterations on the Montana 1996 303(d) list (Segment MT42C002-020) (MDEQ, 1996). The basis for the 1996 listing is unknown. There were insufficient credible data to make an impairment determination for the 2006 303(d) list (MDEQ, 2006a).

Otter Creek near Ashland, Montana
(Photo by Tetra Tech, Inc.)

This analysis specifically addresses the listed pollutants and impaired beneficial uses from the 1996 303(d) list (i.e., impairments to the agriculture, warm-water fishery, and aquatic life beneficial uses associated with salinity/TDS/chlorides, suspended solids, and metals). Sodium Adsorption Ratio (SAR) is also addressed given its potential importance related to future Coal Bed Methane development in the watershed. The purpose of this analysis was to determine if Montana's water quality standards are currently exceeded in Otter Creek and, if so, provide insight regarding the potential cause (i.e., natural versus anthropogenic).

The remainder of this section provides a summary and evaluation of the available data, and comparison to the applicable Montana water quality standards, one pollutant at a time. Biological data for Otter Creek are discussed in Appendix I, and Appendix H provides a general overview of the hydrologic characteristics of the Otter Creek watershed.

5.1 Salinity

Specific conductance (SC) data for Otter Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 40 stations in the main stem of Otter Creek, collected by multiple governmental agencies and private organizations (see Figure 5-1). USGS collected continuous flow and salinity data at Otter Creek near the mouth (06307740) from November 1, 1980 to August 31, 1985, and from May 25, 2004 to the present. Continuous flow and salinity data were also obtained at Otter Creek below Fifteen Mile Creek (USGS Gage 06307717) from October 5, 1983 to September 30, 1985. The available data are listed in Table 5-1 and the sample site locations (i.e., those with 10 or more data points) are shown in Figure 5-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only salinity grab samples are used so that the continuous data do not bias the results.[m]

Table 5-1. Specific conductance (SC) data for the main stem Otter Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06307665	Otter Creek Near Otter, MT	USGS	90.06	56	1977-1984
06307717	Otter Cr Below Fifteenmile Creek Near Otter, MT	USGS	43.01	994	1982-1985
06307725	Otter Creek Above Tenmile Creek Near Ashland, MT	USGS	37.07	39	1977-1983
2579OT01	Otter Creek	MDEQ	4.40	29	1974-1983
06307740	Otter Creek at Ashland MT	USGS	3.27	2,339	1974-1995; 2004-2006

[1]Stations with 10 or more samples are included in this table.

[m] Continuous salinity data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

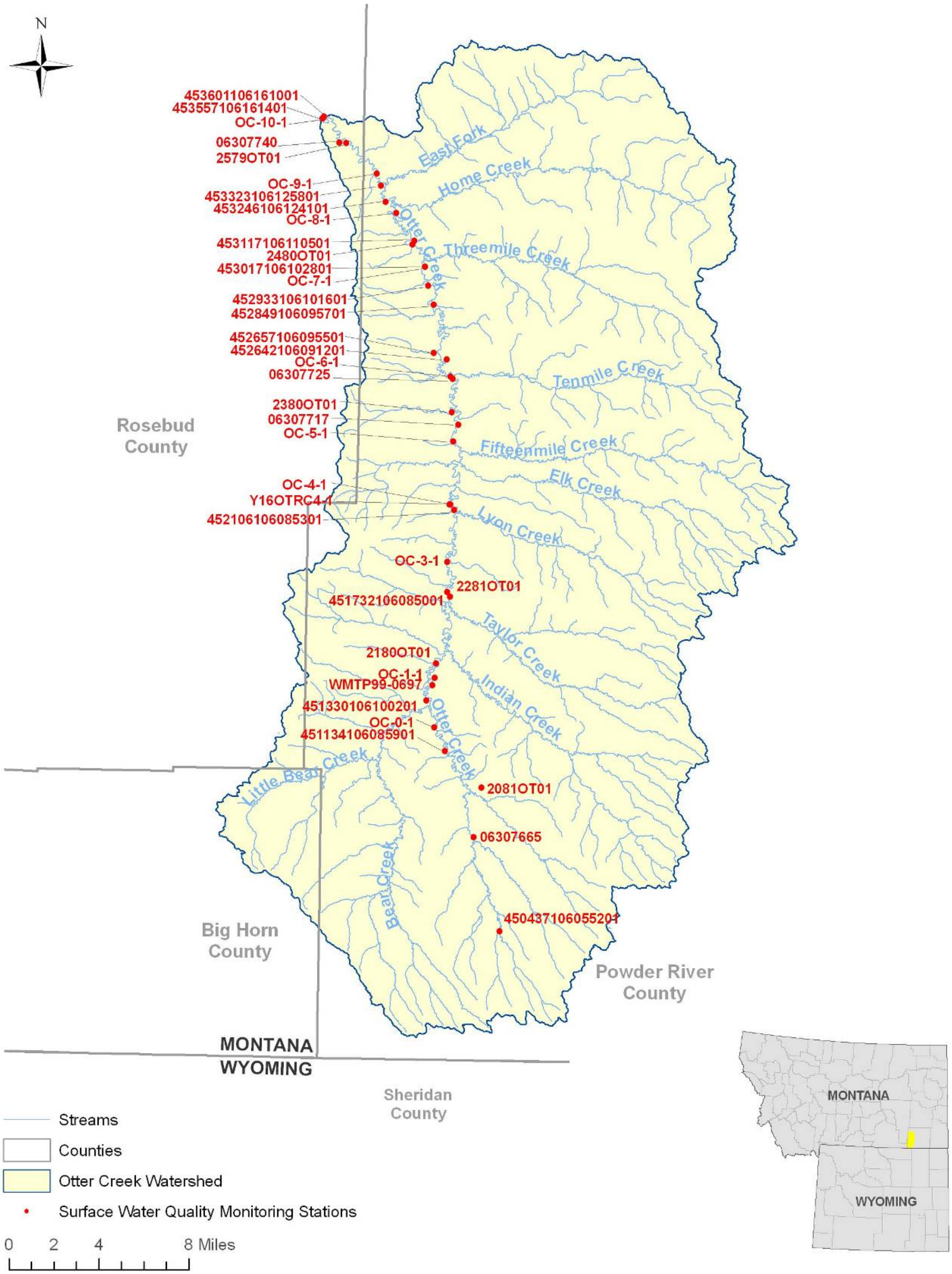


Figure 5-1. Surface water quality monitoring stations on the main stem of Otter Creek.

5.1.1 Spatial Characterization

The USGS sample stations in Table 5-1 have been used to provide a general spatial characterization of SC in Otter Creek. As shown in Figure 5-2 and Table 5-2, specific conductance decreases in a downstream direction, from a mean of 6,164 µS/cm near Otter, Montana to 2,728 µS/cm near the mouth at Ashland, Montana. This is potentially due to localized saline seeps, high salinity soils, and geology in the upper Otter Creek watershed which are not present in the lower watershed (see Appendix G.2.1).

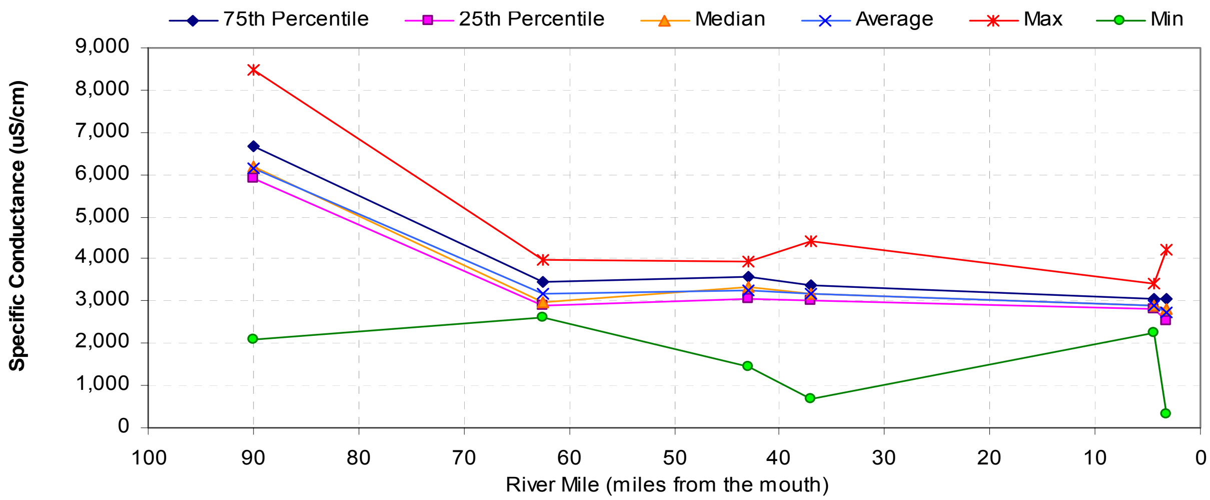


Figure 5-2. Statistics for stations with 10 or more samples in the mainstem Otter Creek. The entire period of record is shown for each station; grab samples only.

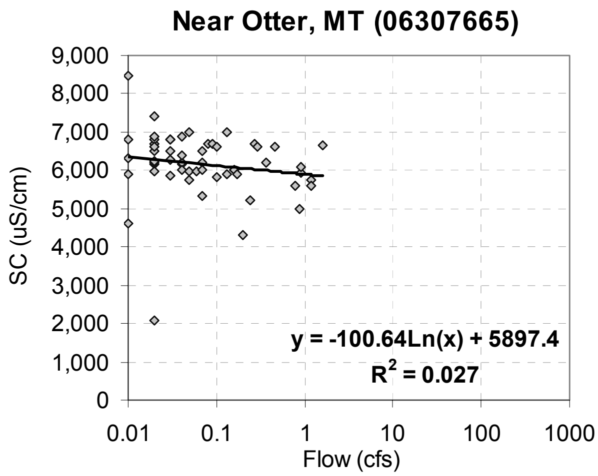
Table 5-2. Specific conductance statistics for various time periods, flows, and stations on the mainstem Otter Creek, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Otter Creek near Otter MT (USGS Gage 06307665)	n	56	0	16	14	26
	Min	2,070	NA	2,070	4,300	5,350
	Max	8,480	NA	8,480	6,700	7,000
	Mean	6,164	NA	6,228	5,869	6,283
	Median	6,200	NA	6,400	5,900	6,200
Otter Creek below Fifteenmile Creek near Otter, MT (USGS Gage 06307717)	n	32	0	8	6	18
	Min	1,440	NA	3,300	1,440	2,430
	Max	3,940	NA	3,940	3,650	3,580
	Mean	3,253	NA	3,681	2,808	3,211
	Median	3,325	NA	3,660	2,865	3,240
Otter Creek above Tenmile Creek near Ashland, MT (USGS Gage 06307725)	n	39	0	10	10	19
	Min	680	NA	2,830	680	2,520
	Max	4,400	NA	4,400	3,490	3,730
	Mean	3,159	NA	3,457	2,902	3,138
	Median	3,160	NA	3,340	3,175	3,110
Otter Creek near Ashland, MT (MDEQ Gage 2579OT01)	n	29	0	3	4	8
	Min	2,250	NA	2,670	3,000	2,359
	Max	3,399	NA	2,950	3,310	3,399
	Mean	2,912	NA	2,827	3,163	2,890
	Median	2,900	NA	2,860	3,050	2,900
Otter Creek at Ashland, MT (USGS Gage 06307740)	n	218	41	56	53	109
	Min	325	1,960	2,200	325	1,840
	Max	3,960	3,180	3,420	3,960	3,900
	Mean	2,728	2,688	2,786	2,479	2,819
	Median	2,800	2,760	2,795	2,700	2,820

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SC data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

5.1.2 Relationship between Specific Conductance and Discharge

The relationship between discharge and SC was evaluated at two stations in Otter Creek – Otter Creek near the mouth (USGS Gage 06307740) and Otter Creek near Otter, Montana (USGS gage 06307665). There is a weak inverse relationship between flow and SC at both stations.



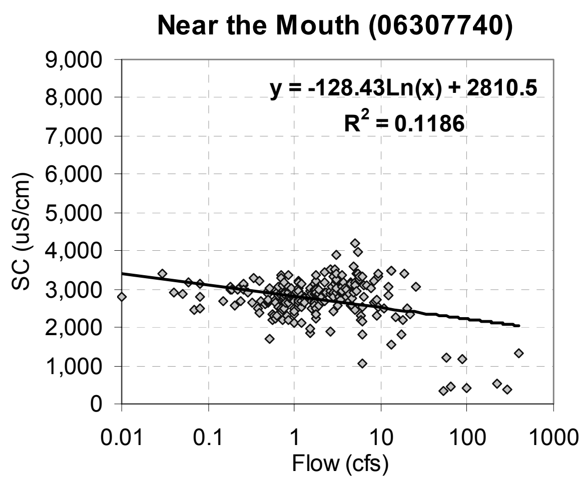


Figure 5-3. Relationship between flow and SC at selected USGS stations on the main stem of Otter Creek. Entire period of record is shown; grab samples only.

5.1.3 Comparison to Applicable Standards

The following sections compare the available observed salinity data in Otter Creek to Montana's numeric salinity standards. Since there is no guidance in the Administrative Rules of Montana (ARM), it is assumed that the "electrical conductivity" standard can be applied to "specific conductance" (SC) data, which is simply electrical conductivity that has been corrected to a temperature of 25º Celsius. Both the instantaneous maximum and monthly average salinity standards for tributaries to the Tongue River (i.e., Otter Creek) are 500 µS/cm. The standards do not vary per season.

5.1.3.1 Instantaneous Maximum Salinity Standard

The instantaneous maximum salinity criterion for Otter Creek is 500 µS/cm. Based on all of the available data in the main stem of Otter Creek, the instantaneous maximum salinity standard has been exceeded almost 100 percent of the time during both the growing and nongrowing seasons. As shown in Figure 5-4, the only time the standard was not exceeded was during the highest 5 percent of flows.

Table 5-3. SC data and exceedances of the instantaneous maximum water quality standard for Otter Creek; daily and grab samples.

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – January 17, 1974 to September 30, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	2,523	2,519	99.8%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	994	993	99.9%
"Past 5 Years" – October 1, 2001 to September 30, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	543	543	100%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	7	7	100%

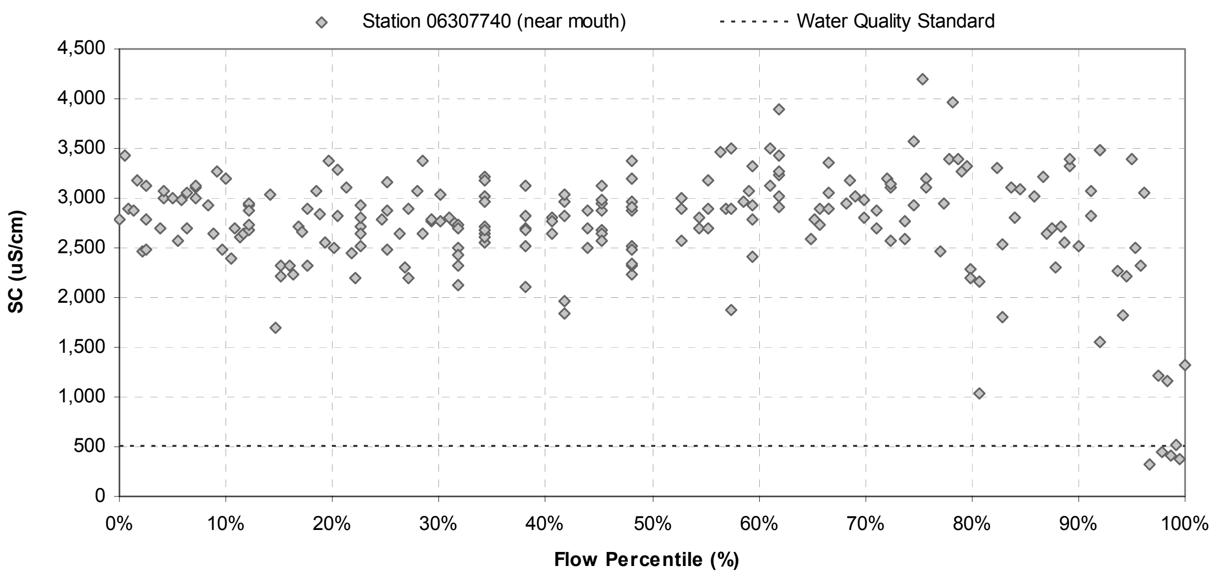


Figure 5-4. Specific conductance versus flow percentile for Otter Creek near the mouth (USGS Gage 06307740). Entire period of record is shown; grab samples only.

5.1.3.2 Monthly Average Salinity Standard

The monthly average salinity standard for Otter Creek is 500 µS/cm. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix E and shows that, in general:

- There are four or more samples per month at only one USGS station – Otter Creek near the mouth (06307740). Daily data were collected between November 1980 and August 1985, and May 2004 to September 2006.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SC on a monthly basis (maximum measured change in one month of 3,090 µS/cm near the mouth, January 1975), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

For the purposes of providing a comparison of the available data to the monthly average SC criteria, all of the available data were compared to the monthly average standard, as well as only data collected in the past five years. Only months with 4 or more samples were used in the analysis. The frequency of exceedances is shown in Table 5-4. The monthly average standard is always exceeded during both the growing season and nongrowing season (where data were available).

Table 5-4. Average monthly SC data and exceedances of the average monthly water quality standard for Otter Creek for the last five years assuming ≥ four daily and/or grab samples per month.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – January 17, 1974 to September 30, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	56	56	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	20	20	100%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	20	20	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	0	NA	NA

5.1.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[n]. This is illustrated for SC in Figure 3-7, Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SC at station 06307740 to the nondegradation threshold is presented in Figure 5-5. The nondegradation threshold (200 µS/cm) is exceeded all of the time.

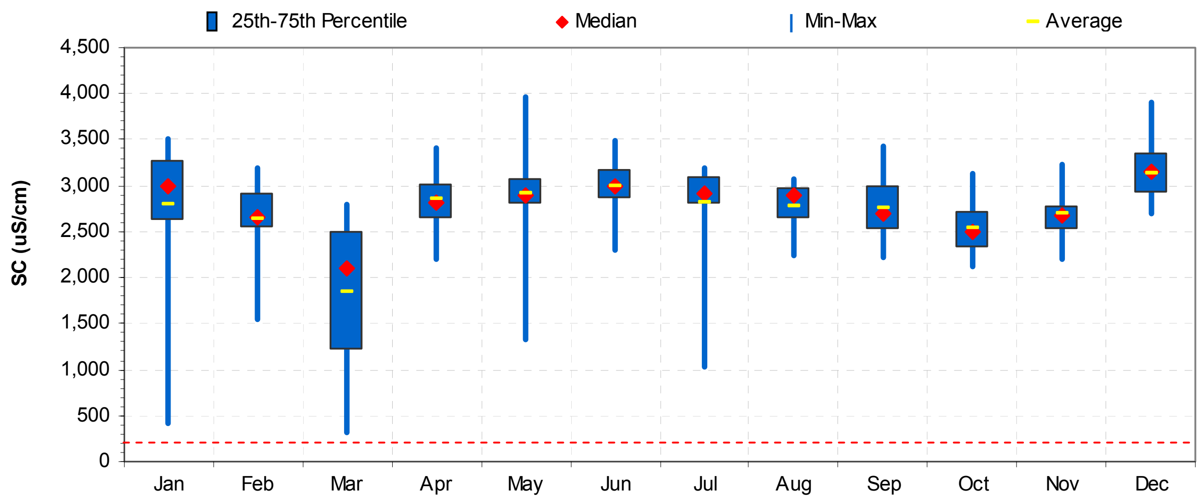


Figure 5-5. SC data and nondegradation thresholds for Otter Creek (near the mouth). Entire period of record is shown; grab samples only.

5.1.4 Sources of Salinity and Their Influence on Otter Creek

As described above, exceedances of Montana's salinity standards have been observed in Otter Creek. However, it is unclear if the observed exceedances were due to natural or anthropogenic sources (or a combination of both).

A modeling analysis similar to that which was described in Section 3.1.4 was conducted to estimate the salinity levels that may have occurred in the absence of human influence (see Appendix J).
Mean SC is slightly lower (at $P = 0.05$) under the simulated natural condition when compared to the simulated existing condition (i.e., a mean of 2,806 µS/cm versus a mean of 2,826 µS/cm). However, the simulated values are so close (i.e., < 1 percent difference) that the model results suggest the exceedances of the salinity standard in Otter Creek are due largely to natural causes. See the Modeling Report for details and a discussion of uncertainty.

[n] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

5.2 SAR

Sodium adsorption ratio (SAR) data for Otter Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 23 stations in the main stem of Otter Creek, and were collected by multiple governmental agencies and private organizations. USGS also collected continuous flow and SAR data at Otter Creek near the mouth (06307740) from May 25, 2004 to Present. The available data are listed in Table 5-5 and the sample site locations (i.e., those with 10 or more data points) are shown in Figure 5-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only SAR grab samples are used so that the continuous data do not bias the results.[o]

Table 5-5. SAR data for the main stem Otter Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06307665	Otter Creek Near Otter, MT	USGS	90.06	55	1977-1984
451732106085001[2]	Otter Creek Below Taylor Creek Near Otter, MT	USGS	62.55	12	1977-1983; 2003; 2005
06307717	Otter Cr Below Fifteenmile Creek Near Otter, MT	USGS	43.01	30	1982-1985
06307725	Otter Creek Above Tenmile Creek Near Ashland, MT	USGS	37.07	37	1977-1983
2579OT01	Otter Creek	MDEQ	4.40	13	1974-1983
06307740[3]	Otter Creek at Ashland MT	USGS	3.27	666	1974-1995; 2003-2006

[1]Stations with 10 or more grab samples are included in this table.
[2]Includes samples from station Y16OTTRC02, which was sampled at the same location as the USGS gage by USEPA in 2003.
[3]Includes samples from station Y16OTTRC01, which was sampled at the same location as the USGS gage by USEPA in 2003.

5.2.1 Spatial Characterization

The USGS sample stations in Table 5-5 have been used to provide a general spatial characterization of SAR the Otter Creek. As shown in Figure 5-6 and Table 5-6, SAR decreases in a downstream direction, from a mean of 7.53 near Otter, Montana to 5.41 near the mouth. This is potentially due to localized saline seeps, high SAR soils, and geology in the upper Otter Creek watershed (see Appendix G).

[o] Continuous SAR data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

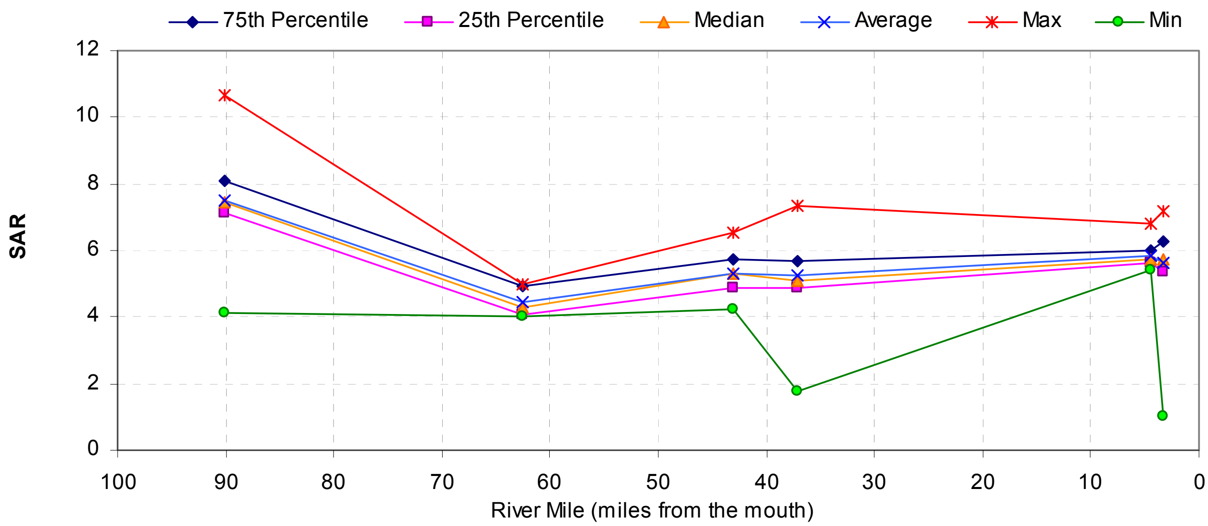


Figure 5-6. SAR statistics for USGS stations with 10 or more samples in the mainstem Otter Creek. The entire period of record is shown for each station; grab samples only.

Table 5-6. SAR statistics for various time periods, flows, and stations on the mainstem Otter Creek, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Otter Creek near Otter MT (USGS Gage 06307665)	n	55	0	15	14	26
	Min	4.14	NA	4.14	5.89	6.60
	Max	10.68	NA	10.15	8.91	10.68
	Mean	7.53	NA	7.71	7.25	7.57
	Median	7.46	NA	8.05	7.26	7.42
Otter Cr below Taylor Creek near Otter, MT (USGS Gage 451732106085001)	n	12	7	3	3	5
	Min	4.04	4.80	4.91	4.28	4.07
	Max	5.87	5.87	5.50	5.01	5.87
	Mean	5.00	5.37	5.30	4.74	5.15
	Median	4.97	5.49	5.49	4.93	5.15
Otter Creek below Fifteenmile Creek near Otter, MT (USGS Gage 06307717)	n	30	0	8	8	14
	Min	4.23	NA	5.30	4.27	4.23
	Max	6.52	NA	6.52	5.35	5.94
	Mean	5.32	NA	5.85	4.87	5.27
	Median	5.32	NA	5.70	4.82	5.40
Otter Creek above Tenmile Creek near Ashland, MT (USGS Gage 06307725)	n	37	0	9	9	19
	Min	1.78	NA	4.99	1.78	4.35
	Max	7.32	NA	7.32	5.68	6.70
	Mean	5.25	NA	6.00	4.70	5.16
	Median	5.09	NA	5.79	5.03	5.09
Otter Creek near Ashland, MT (MDEQ Gage 2579OT01)	n	13	0	NA	NA	NA
	Min	5.42	NA	NA	NA	NA
	Max	6.79	NA	NA	NA	NA
	Mean	5.84	NA	NA	NA	NA
	Median	5.75	NA	NA	NA	NA
Otter Creek at Ashland, MT (USGS Gage 06307740)	n	182	40	47	45	90
	Min	0.34	0.34	0.78	1.00	0.34
	Max	7.16	6.86	7.16	6.96	6.86
	Mean	5.36	4.41	5.88	4.96	5.30
	Median	5.74	5.63	6.16	5.36	5.69

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SAR data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

5.2.2 Relationship between SAR and Discharge

The relationship between discharge and SAR was evaluated at two stations in Otter Creek – Otter Creek near the mouth (USGS Gage 06307740) and Otter Creek near the Otter, Montana (USGS gage 06307665). There is a weak inverse relationship between flow and SAR at both stations.

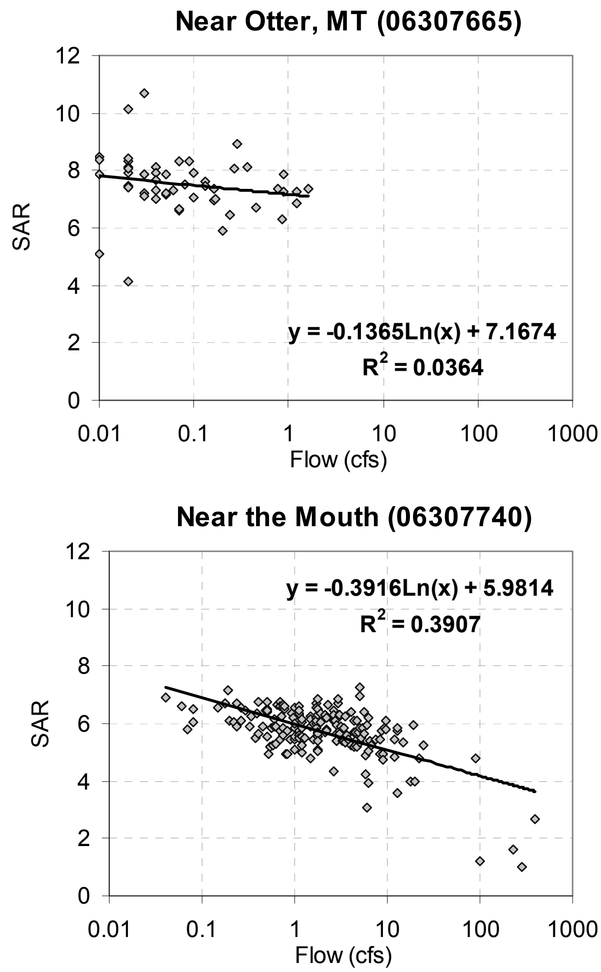


Figure 5-7. Relationship between flow and SAR at selected USGS stations on the mainstem of Otter Creek. Entire period of record is shown; grab samples only.

5.2.3 Comparison to Applicable Standards

The following sections compare the available observed SAR data in Otter Creek to Montana's numeric SAR standards. The standards are seasonal, with separate criteria for the growing season (March 2 – October 31) and non-growing season (November 1 – March 1) and include monthly average criteria as well as instantaneous maximum criteria.

5.2.3.1 Instantaneous Maximum SAR Standard

The instantaneous maximum SAR criteria for Otter Creek are 4.5 during the growing season and 7.5 during the nongrowing season. Based on all of the available data, the instantaneous maximum SAR standard has been exceeded 96.2 percent of the time during the growing season, and 4.8 percent of the time during the nongrowing season (Table 5-7). As shown in Figure 5-8, the exceedances during the growing season occur at the full range of flows except for the highest two percent.

Table 5-7. SAR data and exceedances of the Instantaneous maximum water quality standards for Otter Creek; daily and grab samples

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – October 2, 1974 to June 16, 2006	Growing Season (March 2 to October 31)	< 4.5	764	735	96.2%
	Nongrowing Season (November 1 to March 1)	< 7.5	84	4	4.8%
"Past 5 Years" – October 1, 2001 to September 30, 2006	Growing Season (March 2 to October 31)	< 4.5	532	522	98.1%
	Nongrowing Season (November 1 to March 1)	< 7.5	7	0	0%

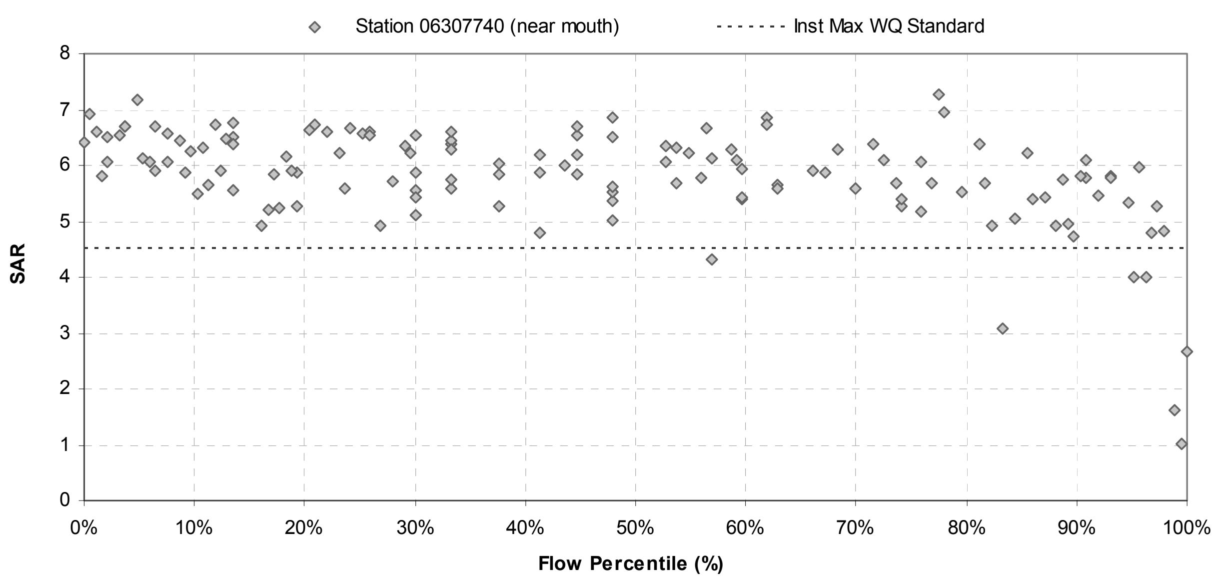


Figure 5-8. SAR versus flow percentile for Otter Creek near the mouth (USGS Gage 06307740). Growing season grab samples only.

5.2.3.2 Monthly Average SAR Standard

The monthly average SAR standards for Otter Creek are 3.0 for the growing season and 5.0 for the nongrowing season. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix F and shows that, in general:

- There are four or more samples per month at only one USGS station – Otter Creek near the mouth (06307740). Daily data were collected between May 2004 to September 2006.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SAR on a monthly basis (maximum measured change in one month of 6.4 in April 2006), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

There are limited data to evaluate the monthly average standard using months with 4 or more samples. The months with 4 or more samples only occurred between 2004 and 2006, which were relatively dry years. Therefore, for the purposes of providing a comparison of the available data to the monthly average SAR criteria, all of the available data were compared to the monthly average standard, as well as only data collected in the past five years. The frequency of exceedances is shown in Table 5-8. The monthly average standard was almost always exceeded during both the growing season and nongrowing season (where data were available).

Table 5-8. Average monthly SAR data and exceedances of the average monthly water quality standards for Otter Creek; daily and grab samples.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 2, 1974 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	125	123	98.40%
		Nongrowing Season (November 1 to March 1)	< 5.0	47	47	100%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	20	20	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	27	27	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	7	7	100%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	20	20	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

5.2.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[p]. This is illustrated for SC in Figure 3-7 and Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SAR at station 06307740 to the nondegradation threshold is presented in Figure 5-9. The nondegradation threshold (2.0 and 1.2) was exceeded most of the time during all months.

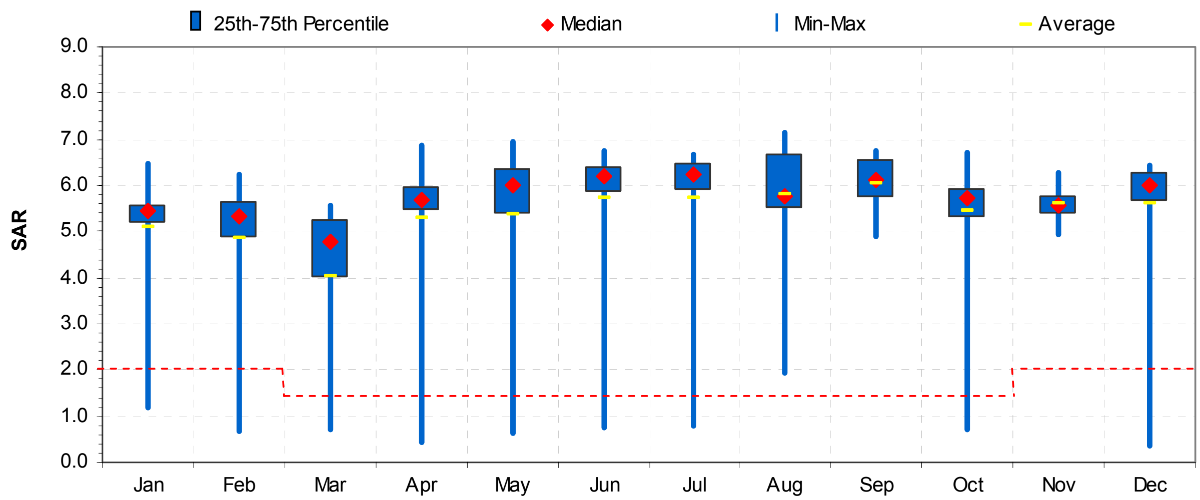


Figure 5-9. SAR data and nondegradation thresholds for Otter Creek (near the mouth). Entire period of record is shown; grab samples only.

5.2.4 Sources of SAR and Their Influence on Otter Creek

As described above, exceedances of Montana's SAR standards have been observed in Otter Creek. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both).

A modeling analysis similar to that which was described in Section 3.1.4 was conducted to estimate the salinity levels that may have occurred in the absence of human influence (see Appendix J). Mean SAR under the simulated natural condition is virtually the same as the simulated existing condition (i.e., a mean of 5.89 versus a mean of 5.86). The model results suggest that the exceedances of Montana's SAR standards are largely due to natural causes. See the Modeling Report for details and a discussion of uncertainty.

[p] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

5.3 Metals

Aquatic life and fishery beneficial uses in Otter Creek (headwaters to the mouth) were listed as impaired because of metals on the Montana 1996 303(d) list (Segment MT42C002-020) (MDEQ, 1996). No specific metals were listed as the cause of impairment, but the metals listing on the 1996 list applies to one or more of the following parameters – arsenic, cadmium, chromium, copper, iron, lead, nickel, selenium, silver, and zinc (Personal communications, Montana DEQ, 2002). Metals were not listed as a cause of impairment on the 2006 303(d) list.

As described in Appendix B, metals data for the following analysis consist only of USGS, USEPA, and Montana DEQ data collected between January 1, 1997 and the present. Data were compared to the Montana total recoverable metals standards, but both "total" and "total recoverable" data were used in the assessment (see Appendix B). Where no hardness data were available, the average value for Otter Creek was used to calculate hardness dependant criteria.

Table 5-9 presents a summary of the available metals data obtained in Otter Creek. Samples were available at two sites: Otter Creek near the mouth (USGS Gage 06307740 and MTDEQ Gage Y16OTTRC01) (see Figure 5-1). Most of the samples were obtained at USGS Gage 06307740. Between 7 and 28 samples were obtained for each parameter, and data were available between October 16, 2002 and May 16, 2006.

Table 5-9. Summary of metals data in Otter Creek.

Parameter	Count	Average (µg/L)	Min (µg/L)	Max (µg/L)	Period of Record
Arsenic (Total) (µg/L as As)	28	2.04	1.00	6.00	10/16/02-5/16/06
Cadmium (Total) (µg/L as Cd)	27	0.04	0.02	0.07	4/24/03-5/16/06
Chromium (Total) (µg/L as Cr)	25	4.34	0.50	14.00	5/30/03-5/16/06
Copper (Total) (µg/L as Cu)	27	6.81	0.50	20.10	4/24/03-5/16/06
Iron, (Total), (µg/L as Fe)	28	844.54	150.00	2,220	10/16/02-5/16/06
Lead (Total) (µg/L as Pb)	27	0.97	0.07	2.24	4/24/03-5/16/06
Nickel (Total) (µg/L as Ni)	27	6.20	0.01	10.00	4/24/03-5/16/06
Selenium (Total) (µg/L as Se)	27	1.61	0.82	3.00	4/24/03-5/16/06
Silver (Total) (µg/L as Ag)	7	0.54	0.25	1.50	10/16/02-10/02/03
Zinc (Total) (µg/L as Zn)	27	6.89	0.01	20.00	4/24/03-5/16/06

Nine iron samples (32 percent) exceeded the chronic criterion of 1,000 µg/L. The date of the exceedance, the concentration, and the percent increase from the standard are presented in Table 5-10. At most, iron samples were obtained once per month, and therefore the exceedances of the chronic criterion were based on single samples rather than an average of several values. No other metals samples exceeded the metals standards in Otter Creek.

Table 5-10. Summary of the iron exceedances in Otter Creek.

Station	Date of the Exceedance	Standard	Value	% Increase from the Standard
Y16OTTRC01	April 24, 2003	1,000 µg/L	2,220 µg/L	122%
Y16OTTRC01	May 30, 2003	1,000 µg/L	1,160 µg/L	16.00%
6307740	April 26, 2004	1,000 µg/L	1,360 µg/L	36.00%
6307740	May 24, 2004	1,000 µg/L	1,030 µg/L	3.00%
6307740	August 18, 2004	1,000 µg/L	1,600 µg/L	60.00%
6307740	April 5, 2005	1,000 µg/L	1,120 µg/L	12.00%
6307740	May 16, 2005	1,000 µg/L	2,030 µg/L	103%
6307740	August 2, 2005	1,000 µg/L	2,220 µg/L	122%
6307740	May 16, 2006	1,000 µg/L	1,080 µg/L	8.00%

5.4 Suspended Solids

Aquatic life and fishery beneficial uses in Otter Creek were listed as impaired because of suspended solids on the Montana 1996 303(d) list (Segment MT42C002-020) (MDEQ, 1996). Beneficial uses were not evaluated for the 2006 303(d) list. At the time of this report, there are no definitive measurable indicators available for direct application of Montana's narrative sediment standards to Otter Creek. In the absence of formal numeric sediment criteria, the following presents an evaluation of a suite of indicators that have been selected to create a measurable point of reference for Montana's narrative sediment criteria. Details regarding each of the factors discussed below are provided in Appendix B.

It should be noted that application of Montana's narrative sediment standards is complicated by the following factors:

- In their natural condition, prairie streams have more fine sediments than streams in the mountains or foothills regions in Montana (Bramblett et al., 2005; Zelt et al., 1999; USEPA, 2005). Human activities that increase fine sediment may simply mimic natural conditions; thus differentiating between natural and human caused in-stream sediment conditions is especially challenging in this region.
- The harsh environment in this region creates the possibility that natural factors will, on occasion, impact biota irrespective of human influence (Bramblett et al., 2004). Therefore, it is not always possible to determine the specific cause of impairment using biological data. This is true when trying to differentiate between human versus naturally caused biological impairments and also when trying to determine which pollutant or pollutants (e.g., sediment, metals, salinity, etc.) are causing the biological impairment.
- Having an understanding of the reference or natural condition is a prerequisite to the application of Montana's narrative water quality standards for sediment (ARM 17.30.602(19); ARM 17.30.629(2)[d]; ARM 17.30.629(2)[f]). Human influence, though often subtle, is pervasive in the eastern plains of Montana, and defining reference conditions is difficult. As a result, little reference data are currently available for defining the natural condition in prairie streams relative to sediment.

5.4.1 Relative Bed Stability Index

The relative bed stability (RBS) metric is used to determine if a stream has excessive sediment (Kaufmann et al., 1999). Basically, the metric compares the measured median substrate size in the streambed to the maximum substrate size carried during bankfull events (see Appendix B). The relative bed stability index (RBS) was calculated at one site in 2000 as part of the REMAP program (Station REMAP200). Otter Creek scored –3.55, which indicates that the channel substrates were "poor" with respect to expected conditions. However, lack of data for other years or segments limit the use of this information.

5.4.2 HII

Bramblett et al. (2004) developed a human influence index (HII) to systematically compare human disturbance among multiple watersheds (see Appendix B). Measured HII scores ranged from 235 to 845, and scores greater than 615 were considered "good" (Tom Johnson, personal communications, January 31, 2005). The HII was calculated at one site in 2000 as part of the REMAP program (Station REMAP200). Otter Creek scored 384, which indicates that Otter Creek had more human influence when compared to other REMAP streams.

5.4.3 Riparian and Bank Condition

Bank stability and riparian vegetation assessments were combined to form a riparian and bank condition (RBC) index (see Appendix B) (USEPA, 2005). The RBC was calculated at one site in 2001 as part of the REMAP program (Station REMAP200). Otter Creek scored 90, which indicates that bank stability and vegetation were good with respect to other Great Plains streams. However, lack of data for other years or segments limit the use of this information.

5.4.4 NRCS Assessment

NRCS inventoried point and linear features for Otter Creek in Powder River and Rosebud counties from the confluence with Bear Creek to the mouth (the majority of the main stem of Otter Creek). There were 64 identified point features in Otter Creek (Figure 5-10) (NRCS, 2001). Most of the point features were in-channel features: culverts, bridges, channel plugs, and waterspreading check structures related to the extensive irrigation along the stream corridor. Four linear features were also found with a total length of 1,700 feet. The largest linear feature was "channelized reach," accounting for about 64 percent of the linear features. Other linear features included car bodies, floodplain dikes, and riprap rocks. The presence of channelization, car bodies, and riprap rocks suggests that bank erosion and unstable channel conditions are present in some places. However, the total length of these features (1,700 feet) is less than one percent of the total surveyed reach.

Results of the riparian assessment showed that most Otter Creek sites were ranked as "sustainable," indicating good channel and riparian conditions. Two reaches were rated "At Risk," primarily due to a lack of deep, binding root mass and woody vegetation (NRCS, 2002) (Table 5-11). Extensive beaver activity and grazing in the lower reaches were the primary cause of the lack of woody vegetation. However, NRCS noted that, "banks were generally stable," and "woody species did not appear to be critical to the stability of Otter Creek," (NRCS, 2002). None of the reaches were rated as "Not Sustainable." While streambanks appear to be intact, NRCS noted that the riparian community is capable of supporting more woody vegetation, and improved grazing practices would help facilitate this community.

Table 5-11. Results of the NRCS riparian assessment in Otter Creek.

Segment	Incisement	Lateral Cutting	Sediment Balance	Soil	Binding Root Mass	Woody Establishment	% Utilization	Riparian/Wetland Characteristics	Floodplain	Irrigation Impacts	Land Use Activities	Subtotal	Potential Score	% of Potential	Sustainability Rating
OC-0-1	6	6	6	3	0	0	4	0	6	NA	NA	0	59	58	**At Risk**
OC-1-1	8	6	4	3	6	6	3	8	6	8	2	20	93	81	Sustainable
OC-3-1	8	6	6	3	6	4	4	8	6	8	8	34	93	98	Sustainable
OC-4-1	8	6	6	3	6	6	4	8	6	8	8	34	93	99	Sustainable
OC-5-1	8	4	4	3	4	4	4	6	6	8	6	30	93	83	Sustainable
OC-6-1	8	6	6	3	4	4	1	4	6	6	4	28	93	80	Sustainable
OC-7-1U	8	6	4	3	2	0	1	0	6	8	4	30	93	68	**At Risk**
OC-7-1D	8	6	4	3	4	0	1	8	6	6	4	30	93	81	Sustainable
OC-8-1	8	6	4	3	4	4	3	6	6	8	6	34	93	87	Sustainable
OC-9-1	8	4	4	3	4	4	1	4	6	8	4	32	93	78	Sustainable

Sustainable: >75%; At Risk: 50-75%; Not Sustainable: <50%

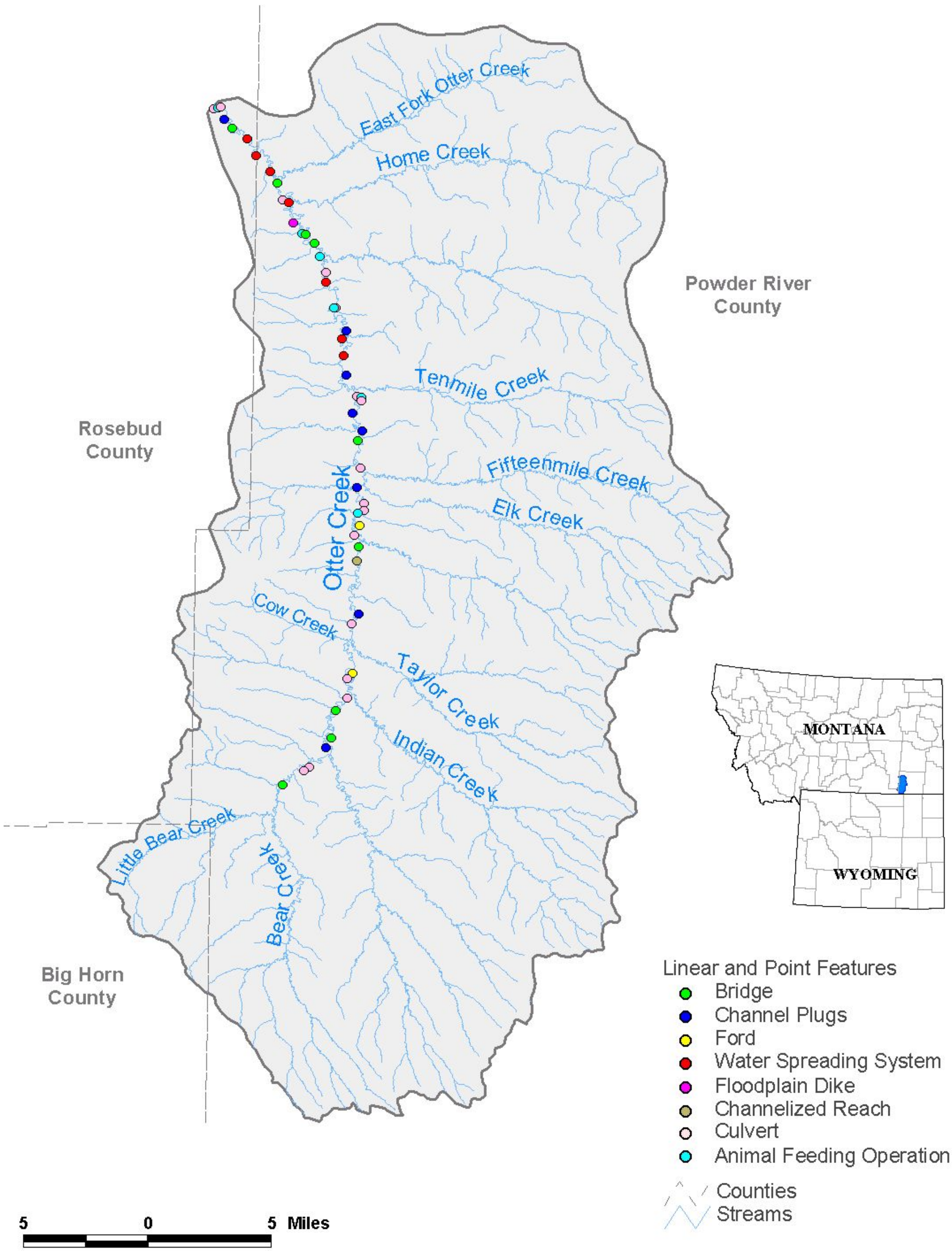


Figure 5-10. NRCS assessment for Otter Creek.

5.4.5 In-Stream Sediment Concentrations

Total suspended solids (TSS) and suspended sediment concentrations (SSC) were collected at multiple sites and years in Otter Creek (Table 5-12). Between 1974 and 2006, there were 340 TSS or SSC samples collected in the stream. As described in Appendix B, TSS and SSC data are combined and used together in this analysis.

Without an appropriate reference stream, it is impossible to determine if the available TSS and SSC data are exceeding reference conditions. However, there were no discernable temporal trends in the data (Figure 5-11). Also, concentrations were relatively similar at all stations and did not indicate localized sediment loading (Figure 5-12).

Table 5-12. Summary of TSS and SSC data, Otter Creek.

Station	Count	Median	Average	Min	Max	Period of Record
2584OT01 (Downstream)	1	24	24	24	24	1977-1977
Y16OTTRC01	6	33	44	8	100	2003-2003
6307740	179	78	95	2	536	1974-2006
2579OT01	20	23	26	7	68	1975-1983
2480OT01	1	48	48	48	48	1979-1979
6307725	35	24	38	4	132	1977-1981
2380OT01	1	6	6	6	6	1979-1979
6307717	30	51	57	1	178	1982-1985
2281OT01	2	11	11	10	12	1978-1978
Y16OTTRC02	5	3	3	1	9	2003-2003
2180OT01	5	12	23	1	61	1979-1979
WMTP99-0697	1	21	21	21	21	2002-2002
2081OT01	1	1	1	1	1	1979-1979
6307665 (Upstream)	53	47	79	5	490	1977-1984
All Stations	340	24	34	1	536	1974-2006

Data collected by USGS, NRCS, and MDEQ. Site locations are shown in Figure 5-1.

Figure 5-11. TSS and SSC data for Otter Creek near the mouth (USGS Gage 06307740).

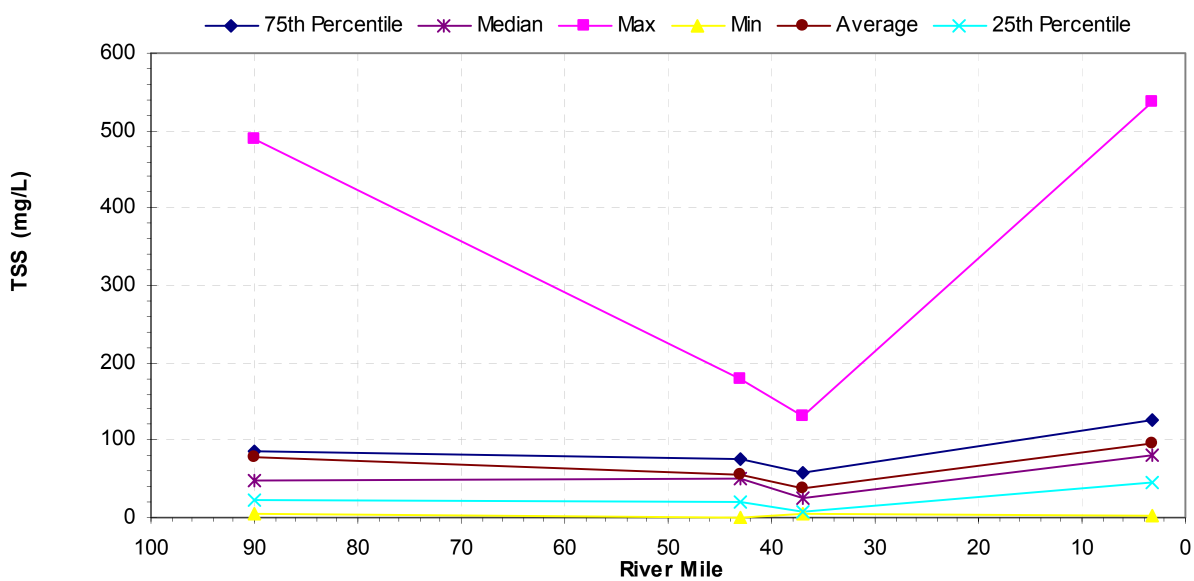


Figure 5-12. TSS and SSC data for Otter Creek stations with 10 or more samples per site (sites 06307740, 06307725, 06307717, and 06307665).

5.4.6 Sediment Source Identification and Load Quantification

As described in the March 2003 Phase I report (MDEQ, 2003), soils in the Otter Creek watershed are naturally highly erodible, with slow to very slow infiltration rates. These attributes, in combination with semiarid conditions, flashy rain events, and sparse ground cover, result in naturally high sediment erosion. Buttes and badlands occur throughout the landscape, and saline or sodic soils limit plant growth in several areas. NRCS (2002) reported that

> *The majority of the Tongue River watershed is mapped as yielding 0.2 to 0.5 acre-feet/mile^2/year of sediment. Using an average bulk density of sixty-pounds/cubic foot, these volumes would be equivalent to 0.4 to 1.0 tons/acre/year. Juvan estimated percent contribution of erosion source was forty-percent gully and sixty percent sheet erosion within most of the Tongue River-Montana watershed (Juvan, undated).*

Cattle are currently the predominant agricultural resource in the watershed, having 1.37 cattle per 100 acres of land in Powder River County, Montana (USDA, 2002). It is well documented that cattle have the potential to impact the landscape, if not managed properly (Meehan, 1991). In the uplands, decreased ground cover, increased erosion, and the promotion of invasive species can occur from overgrazing. In the lowlands and stream valleys, cattle grazing can have direct impacts to the stream and riparian area (destabilized stream banks, lack of riparian cover, habitat degradation) (Meehan, 1991). Cattle are grazed in the lowlands in Otter Creek from December to March, and usually moved to upland areas when the ground thaws in the spring (R. Iron, personal communications, February 25, 2005).

Irrigated agriculture is another potential source of sediment. Irrigated fields in Otter Creek generally consist of hay and alfalfa, and are plowed and reseeded every 5 to 10 years (or as necessary due to disease or crop failure) (R. Iron and C. Hillard, personal communications, February 25, 2005). When plowing does occur, it occurs in the spring, and fields are generally reseeded immediately. Overall, there is a small window of time every 5 to 10 years when the ground is in a bare, disturbed state, leaving little opportunity for excessive erosion from fields. Furthermore, irrigated fields have denser groundcover than what would otherwise be present, and act as a sediment buffer to the stream. As evidenced by the NRCS survey (NRCS, 2002), most sediment contributions from agriculture are caused by small, localized disturbances, such as headcuts and cattle trampling.

Although fires are considered a natural phenomenon, they can result in soil erosion, soil nutrient loss, stream channel effects, and water yield effects (Emmerich and Cox, 1994; Marcos et al., 2000; Belillas and Roda, 1993). A wildfire has the potential to affect the characteristics of soils by reducing the soil aggregate stability, reducing permeability, increasing runoff and erosion, and reducing organic matter/nutrient status (USGS, 2003). These combined effects can cause the runoff following a storm event to increase significantly, increasing the overland flow available to initiate soil erosion, as either sheet or rill erosion. The potential for erosion increases with slope and burn severity. In 2000, 10 percent of the Otter Creek watershed burned, mostly in upland areas of the Custer National Forest. The fires have likely increased sediment delivery to streams over the past six years, especially during intense summer storms (USGS, 2003).

Upland sediment loads were estimated using soil survey data, GIS, and the Universal Soil Loss Equation (USLE). Details of the analysis for all watersheds are described in Appendix B. In the Otter Creek watershed, there was very little difference between the existing and "natural" upland sediment delivery. Natural conditions are defined as "no human alterations, resulting in no active agricultural land and increased total vegetative ground cover." USLE calculations showed that there is only a 0.31 percent increase in sediment load over naturally occurring conditions (19,496 versus 19,558 tons of sediment per year). This suggests that human management has not had a major effect on upland sources in the Otter Creek watershed. It should be noted that this analysis does not take into account streambank erosion or riparian degradation.

As evidenced by the NRCS riparian assessment, cattle have impacted riparian areas and stream banks in several areas (NRCS, 2002). The extent of this effect is unknown, although NRCS attributed lack of deep binding root mass and woody vegetation at two segments to grazing impacts (NRCS, 2002).

To estimate bank erosion in Otter Creek, a simple analysis was performed using literature values and conservative assumptions. It was assumed that stream banks are eroding an average of 0.10 feet per year, and have a height of one foot (adapted from Rosgen, 1996). The 2001 NRCS riparian assessment found 59.9 of 76.6 assessed miles to be "sustainable." It is conservatively assumed that bank erosion occurs along the entire length of both banks of the total length rated "at risk" (33.4 miles), and that all of that erosion is human caused (note: this assumption is a gross over estimate presented as a "worst case" analysis). Assuming an average bulk density of 60 pounds per cubic feet, this equates to an average sediment load of 529 tons of sediment per year from bank erosion. From the USLE analysis, it is estimated that 19,500 tons of sediment per year are contributed to the stream from upland sources. Therefore, under this worst-case scenario, streambank erosion is less than three percent of the total sediment load delivered to the stream. This analysis shows that streambank erosion is relatively small compared to the total amount of sediment contributed from upland erosion.

6.0 PUMPKIN CREEK

Pumpkin Creek near the mouth
(Photo by Tetra Tech, Inc.)

Pumpkin Creek flows 171 miles from its origin in Powder River County, Montana to the confluence with the Tongue River near the T&Y irrigation dam (Figure 6-1). The total watershed covers roughly 707 square miles. The agriculture, warm-water fishery and aquatic life beneficial uses were listed as impaired by flow alterations, salinity/TDS/chlorides, and thermal modifications on the Montana 1996 303(d) list (Segment MT42C002-060) (MDEQ, 1996). The basis for the 1996 listings is unknown. Beneficial uses were not evaluated for the 2006 list because of insufficient credible data.

This analysis specifically addresses the listed pollutants and impaired beneficial uses from the 1996 303(d) list (i.e., impairments to the agriculture, warm-water fishery, and aquatic life beneficial uses associated with salinity/TDS/chlorides and thermal modifications). Sodium adsorption ratio (SAR) is also addressed given its potential importance related to future Coal Bed Methane development in the watershed. The purpose of this analysis was to determine if Montana's water quality standards are currently exceeded in Pumpkin Creek and, if so, provide insight into the potential cause (i.e., natural versus anthropogenic).

The remainder of this section provides a summary and evaluation of the available data, and comparison to the applicable Montana water quality standards one pollutant at a time. Biological data for Pumpkin Creek are discussed in Appendix I, and Appendix H provides a general overview of the hydrologic characteristics of the Pumpkin Creek watershed.

6.1 Salinity

Specific conductance (SC) data for Pumpkin Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 14 stations in Pumpkin Creek, dating from 1974 to 2006, and collected by multiple governmental agencies and private organizations (see Figure 6-1). USGS also collected continuous flow and salinity data at Pumpkin Creek near the mouth (06308400) from May 25, 2004 to the present. The available stations with more than 10 grab samples are summarized in Table 6-1 and the sample site locations are shown in Figure 6-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only salinity grab samples are used so that the continuous data do not bias the results.[q]

Table 6-1. Specific conductance (SC) data for the mainstem Pumpkin Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06308160	Pumpkin Creek near Loesch, MT	USGS	103.91	28	1975-1979
06308400	Pumpkin Creek near Miles City, MT	USGS	7.67	380	1975-1985; 2003-2006
3483PU01	Pumpkin Creek near the mouth	MDEQ	6.36	24	1974-1979

[1]Stations with 10 or more samples are included in this table.

[q] Continuous salinity data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

Figure 6-1. Surface water quality monitoring stations on the main stem of Pumpkin Creek.

6.1.1 Spatial Characterization

The USGS sample stations listed in Table 6-1 have been used to provide a general spatial characterization of SC in the Pumpkin Creek. As shown in Figure 6-2 and Table 6-2, specific conductance decreases in a downstream direction, from a mean of 5,146 µS/cm near Loesch, Montana to 2,600 µS/cm near the mouth.

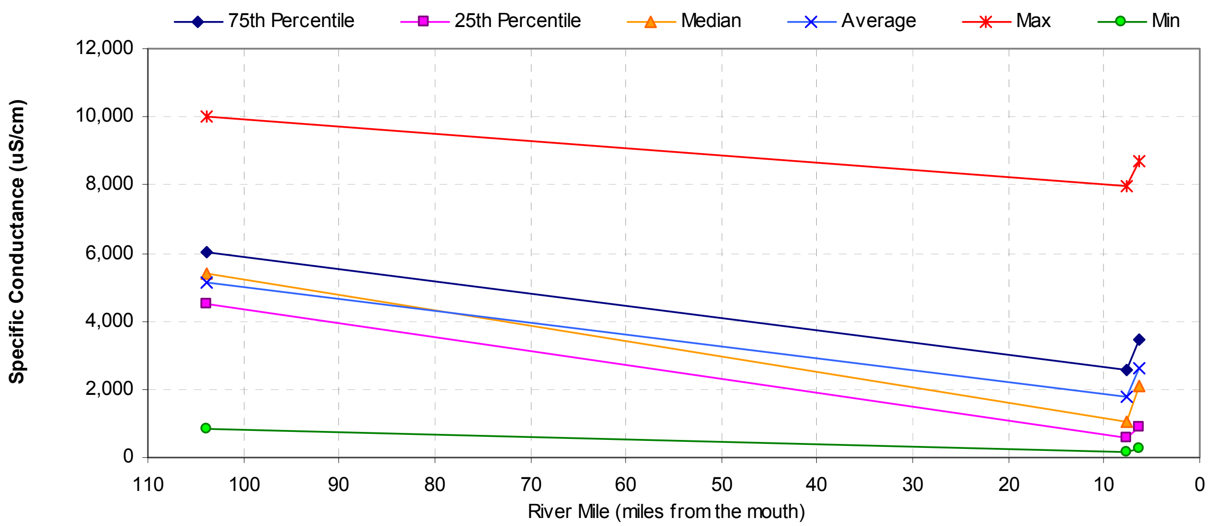


Figure 6-2. Statistics for stations with 10 or more samples in the mainstem Pumpkin Creek. The entire period of record is shown for each station; grab samples only.

Table 6-2. Specific conductance statistics for various time periods, flows, and stations on the mainstem Pumpkin Creek, all available grab samples.[1]

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Pumpkin Creek near Loesch, MT (USGS Gage 06308160)	n	28	0	7	7	14
	Min	819	NA	5,900	819	4,100
	Max	10,000	NA	10,000	4,700	6,450
	Mean	5,146	NA	6,786	3,167	5,315
	Median	5,405	NA	6200	3180	5405
Pumpkin Creek near Miles City, MT (USGS Gage 06308400)	n	88	28	22	21	45
	Min	168	311	345	168	240
	Max	7,990	2,530	7,990	3,680	5,100
	Mean	1,638	977	2,361	667	1,738
	Median	951	743	1,480	552	1,240
Pumpkin Creek near the Mouth (MDEQ Gage 3483PU01)	n	24	0	3	3	7
	Min	247	NA	1,205	247	369
	Max	8,700	NA	5,998	920	4,650
	Mean	2,600	NA	3,101	588	2,146
	Median	2,100	NA	2100	598	1880

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SC data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

6.1.2 Relationship between Specific Conductance and Discharge

The relationship between discharge and SC was evaluated at two stations in Pumpkin Creek – Pumpkin Creek near the mouth (USGS Gage 06308400) and Pumpkin Creek near Loesch, Montana (USGS gage 06308160). There is a weak inverse relationship between flow and SC at both stations.

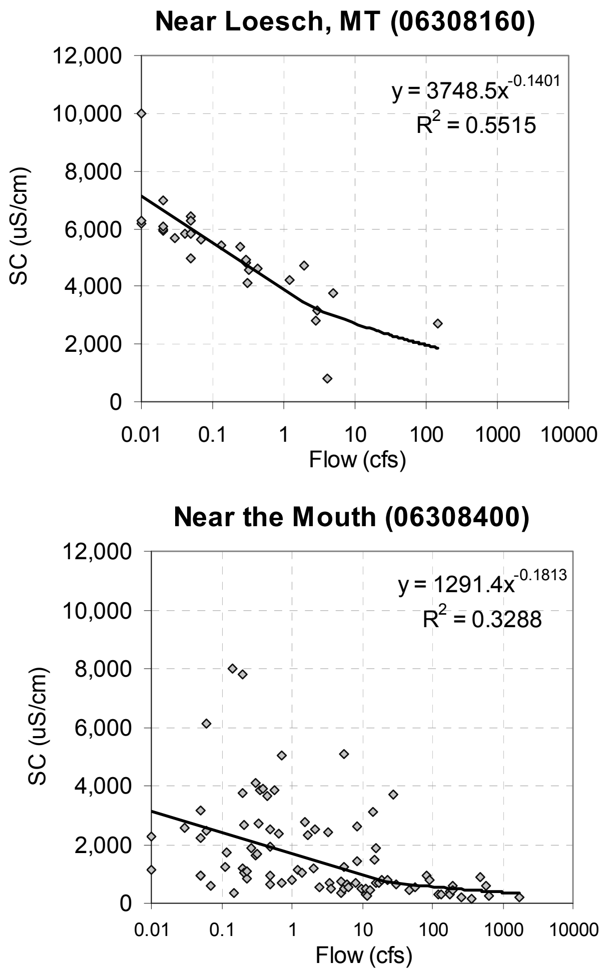


Figure 6-3. Relationship between flow and SC at selected USGS stations on the mainstem of Pumpkin Creek. Entire period of record is shown; grab samples only.

6.1.3 Comparison to Applicable Standards

The following sections compare the available observed salinity data in Pumpkin Creek to Montana's numeric salinity standards. Since there is no guidance in the Administrative Rules of Montana (ARM), it is assumed that the "electrical conductivity" standard can be applied to "specific conductance" (SC) data, which is simply electrical conductivity that has been corrected to a temperature of 25º Celsius. Both the instantaneous maximum and monthly average salinity standards for tributaries to the Tongue River (i.e., Pumpkin Creek) are 500 µS/cm. The standards do not vary per season.

6.1.3.1 Instantaneous Maximum Salinity Standard

The instantaneous maximum salinity criterion for Pumpkin Creek is 500 µS/cm. Based on all of the available data in the main stem of Pumpkin Creek, the instantaneous maximum salinity standard has been exceeded more than 88 percent of the time. As shown in Figure 6-4, exceedances have occurred under all flow conditions.

Table 6-3. SC data and exceedances of the instantaneous maximum water quality standards for Pumpkin Creek; daily and grab samples.

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – January 1, 1974 to September 30, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	431	384	89.1%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	35	30	85.7%
"Past 5 Years" – October 1, 2001 to September 30, 2006	Growing Season (March 2 to October 31)	< 500 µS/cm	332	295	88.9%
	Nongrowing Season (November 1 to March 1)	< 500 µS/cm	5	5	100%

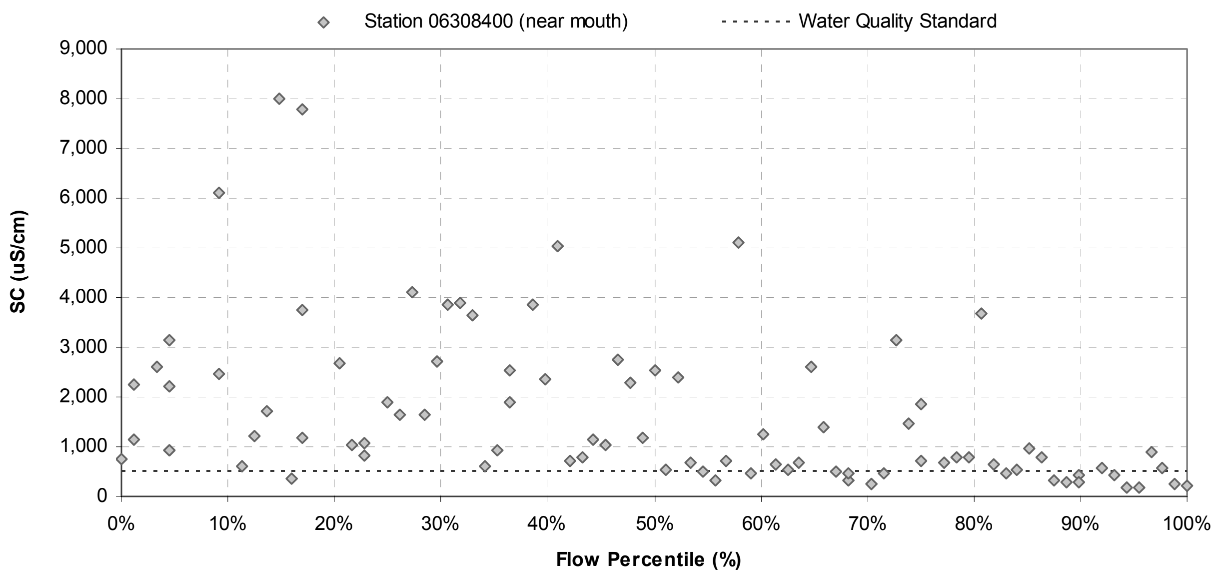


Figure 6-4. Specific conductance versus flow percentile for Pumpkin Creek near the mouth (USGS Gage 06308400). Entire period of record is shown; grab samples only.

6.1.3.2 Monthly Average Salinity Standard

The monthly average salinity standard for Pumpkin Creek is 500 µS/cm. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix E and shows that, in general:

- There are four or more samples per month at only one USGS station – Pumpkin Creek near the mouth (06308400). Daily data were collected between May 2004 and September 2006.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SC on a monthly basis (maximum measured change in one month of 2,688 µS/cm near the mouth, May 2006), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

For the purposes of providing a comparison of the available data to the monthly average SC criteria, all of the available data were compared to the monthly average standard, as well as only data collected in the past five years. Only months with 4 or more samples were used in the analysis. The frequency of exceedances is shown in Table 6-4. The monthly average standard was always exceeded during the growing season. No data were available for the nongrowing season.

Table 6-4. Average monthly SC data and exceedances of the average monthly water quality standards for Pumpkin Creek assuming ≥ four daily and/or grab samples per month.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – January 1, 1974 to September 30, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	15	15	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	0	NA	NA
"Past 5 Years" – October 1, 2001 to September 30, 2006	**4 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	15	15	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	0	NA	NA

6.1.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[r]. This is illustrated for SC in Figure 3-7, Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SC at station 06308400 to the nondegradation threshold is presented in Figure 6-5. The nondegradation threshold (200 µS/cm) was exceeded most of the time for most months, with the exception of February and March where the threshold was exceeded approximately 25 to 40 percent of the time.

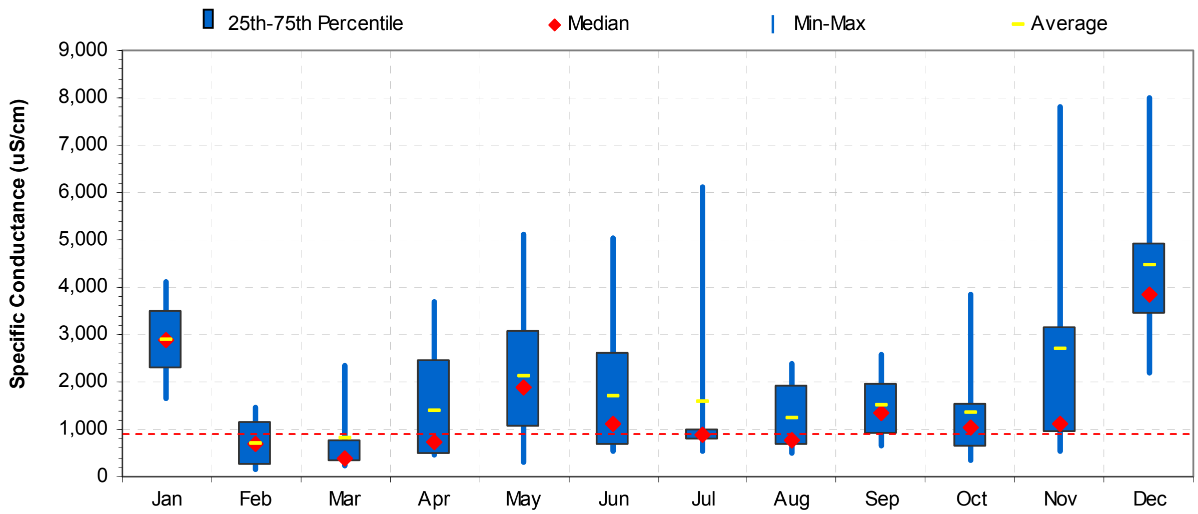


Figure 6-5. SC data and nondegradation thresholds for Pumpkin Creek (USGS Gage 06308400). Entire period of record is shown; grab samples only.

[r] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

6.1.4 Sources of Salinity and Their Influence on Pumpkin Creek

As described above, exceedances of Montana's salinity standards have been observed in Pumpkin Creek. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both).

A modeling analysis similar to that which was described in Section 3.1.4 was conducted to estimate the salinity levels that may have occurred in the absence of human influence (see Appendix J). Mean SC is slightly higher under the simulated natural condition when compared to the simulated existing condition (i.e., a mean of 1,200 µS/cm versus a mean of 1,103 µS/cm). This is thought to be a result of the way in which the model simulates impervious surfaces under the existing condition (i.e., there are areas of impervious surfaces associated with roadways that contribute lower SC water) and suggests that the observed exceedances are largely due to natural causes. See the Modeling Report for details and a discussion of uncertainty.

6.2 SAR

Sodium adsorption ratio (SAR) data for Pumpkin Creek are available from 1974 to the present, and include both grab and continuous samples. Grab samples are available from 8 stations in the main stem of Pumpkin Creek, and were collected by multiple governmental agencies and private organizations. No continuous SAR data have been collected in Pumpkin Creek. Stations with 10 or more SAR grab samples are summarized in Table 6-5, and the sample sites are shown in Figure 6-1. Where summary statistics are provided in the following sections (i.e., mean, median, maximum, minimum), only SAR grab samples are used so that the continuous data do not skew the results.[s]

Table 6-5. SAR data for the mainstem Pumpkin Creek.[1]

Station ID	Station Name	Agency	River Mile	n	Period of Record
06308160	Pumpkin Creek near Loesch MT	USGS	103.91	28	1975-1979
06308400	Pumpkin Creek near Miles City MT	USGS	7.67	82	1975-1985; 2003-2006
3483PU01	Pumpkin Creek	MDEQ	6.36	20	1974-1979

[1]Stations with 10 or more samples are included in this table.

6.2.1 Spatial Characterization

The USGS sample stations in Table 6-5 have been used to provide a general spatial characterization of SAR the Pumpkin Creek. As shown in Figure 6-6 and Table 6-6, SAR is relatively similar between the upstream and downstream sites, although maximum values are higher at the downstream stations.

[s] Continuous SAR data have been collected for specific discrete periods of time, whereas the grab samples are spread out over multiple years of record. Including the numerous continuous data points in the summary statistics would bias the results to those periods in which continuous monitoring was conducted.

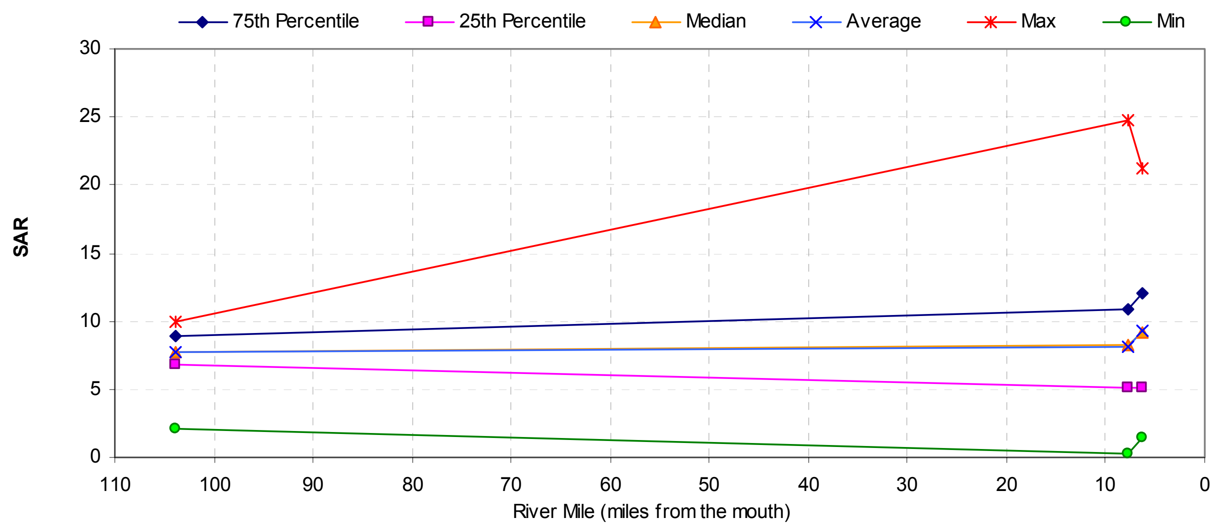


Figure 6-6. **SAR statistics for stations with 10 or more samples in the mainstem Pumpkin Creek. The entire period of record is shown for each station; grab samples only.**

Table 6-6. **SAR statistics for various time periods, flows, and stations on the mainstem Pumpkin Creek, all available grab samples.[1]**

Station	Statistic	Full Period of Record	Last Five Years[2]	Low Flow[3]	High Flow[3]	Average Flow[3]
Pumpkin Creek near Loesch, MT (USGS Gage 06308160)	n	28	0	7	7	14
	Min	2	NA	8.37	2.14	6.54
	Max	10	NA	10.01	7.35	9.09
	Mean	8	NA	9.52	5.64	7.81
	Median	8	NA	9.69	5.81	7.74
Pumpkin Creek near Miles City, MT (USGS Gage 06308400)	n	82	27	21	21	40
	Min	0.25	0.25	0.25	0.63	0.34
	Max	24.75	15.00	24.75	12.58	15.30
	Mean	7.87	6.01	10.44	5.63	7.70
	Median	7.45	6.66	10.16	5.40	8.56
Pumpkin Creek near the Mouth (MDEQ Gage 3483PU01)	n	20	0	NA	NA	NA
	Min	1	NA	NA	NA	NA
	Max	21	NA	NA	NA	NA
	Mean	9	NA	NA	NA	NA
	Median	9	NA	NA	NA	NA

[1] Grab samples only. Daily (i.e., continuous) data are not included in this analysis.
[2] "Last 5 Years" is defined as data collected between October 1, 2001 and September 30, 2006.
[3] Low flow, average flow, and high flow were determined from paired flow and SAR data at the representative station. Low flow is defined as the lowest 25 percent of flows (0-25th percentile); average flow as the middle 50 percent of flows (25th-75th percentile); high flow as the highest 25 percent of flows (75th-100th percentile).

6.2.2 Relationship between SAR and Discharge

The relationship between discharge and SAR was evaluated at two stations in Pumpkin Creek – Pumpkin Creek near the mouth (USGS Gage 06308400) and Pumpkin Creek near Loesch, Montana (USGS gage 06308160). There was no apparent relationship near Loesch, Montana, while there is a weak inverse relationship between discharge and SAR near the mouth.

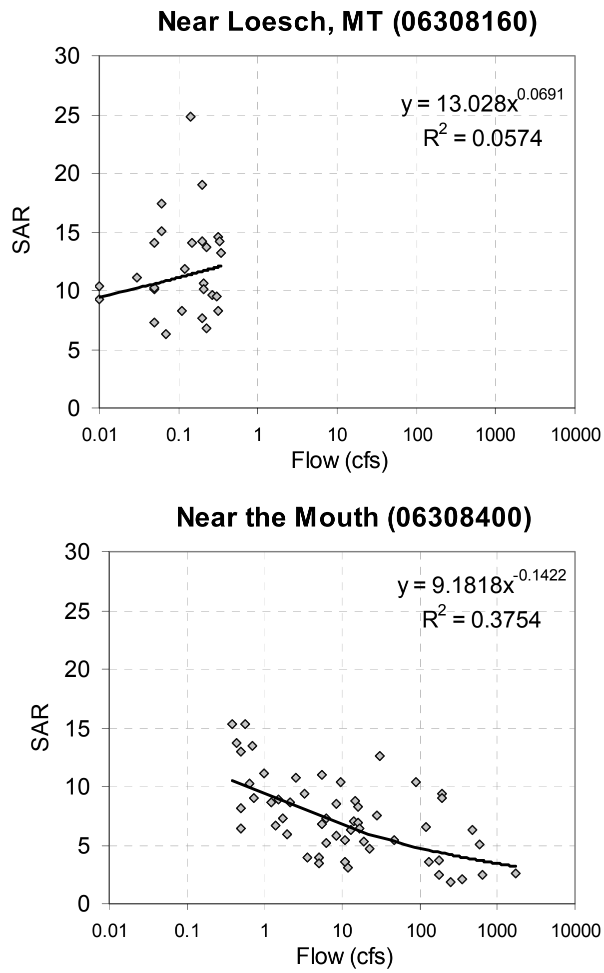


Figure 6-7. Relationship between flow and SAR at selected USGS stations on the mainstem of Pumpkin Creek. Entire period of record is shown; grab samples only.

6.2.3 Comparison to Applicable Standards

The following sections compare the available observed SAR data in Pumpkin Creek to Montana's numeric SAR standards. The standards are seasonal, with separate criteria for the growing season (March 2 – October 31) and non-growing season (November 1 – March 1) and include monthly average criteria as well as instantaneous maximum criteria.

6.2.3.1 Instantaneous Maximum SAR Standard

The instantaneous maximum SAR criteria for Pumpkin Creek are 4.5 during the growing season and 7.5 during the nongrowing season. Based on all of the available data, the instantaneous maximum SAR standard was exceeded 81.7 percent of the time during the growing season, and 54.9 percent of the time during the nongrowing season (Table 6-7). The frequency of exceedance is less for the last five years. The reason for the difference is unknown, but may be due to limited data from the recent time period. As shown in Figure 6-8, the exceedances during the growing season occur at the full range of flows except for the highest two percent.

Table 6-7. SAR data and exceedances of the Instantaneous maximum water quality standards for Pumpkin Creek; daily and grab samples.

Time Period	Season	Numeric Standard	# Samples	# Exceeding	% Exceeding
"All Data" – October 2, 1974 to June 16, 2006	Growing Season (March 2 to October 31)	< 4.5	120	98	81.7%
	Nongrowing Season (November 1 to March 1)	< 7.5	31	17	54.9%
"Past 5 Years" – October 1, 2001 to June 21, 2006	Growing Season (March 2 to October 31)	< 4.5	33	22	66.7%
	Nongrowing Season (November 1 to March 1)	< 7.5	3	1	33.3%

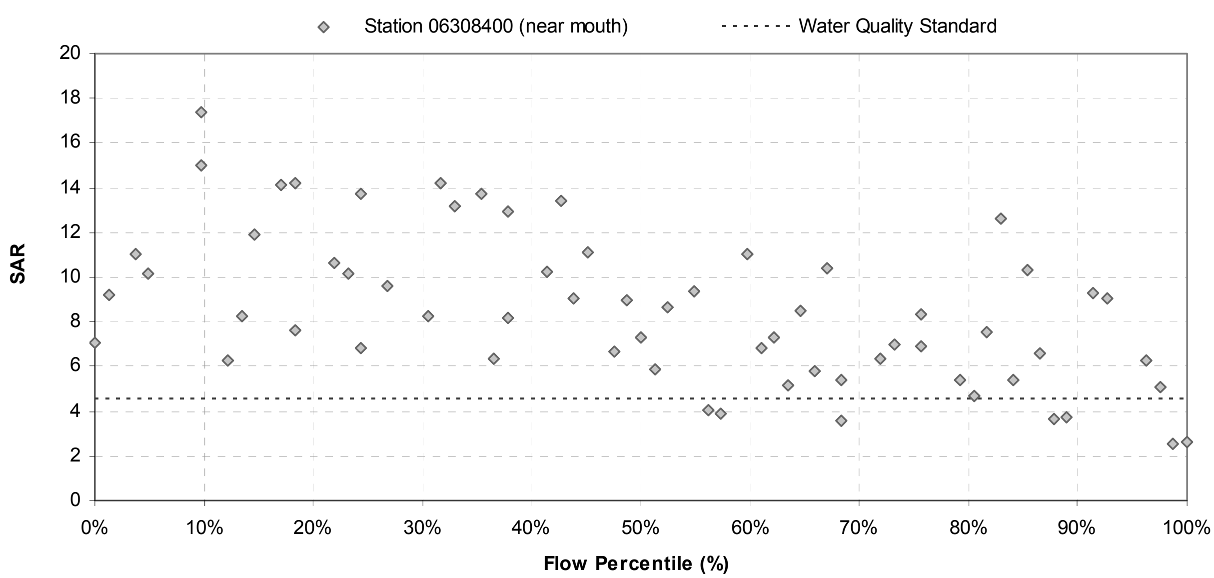


Figure 6-8. SAR versus flow percentile for Pumpkin Creek near the mouth (USGS Gage 06308400). Growing season grab samples only, entire period of record.

6.2.3.2 Monthly Average SAR Standard

The monthly average SAR standards for Pumpkin Creek are 3.0 for the growing season and 5.0 for the nongrowing season. However, the Administrative Rules of Montana (ARM 17.30.670) do not provide guidance regarding the minimum number of samples needed to calculate "monthly average" values. In the absence of such guidance, the available data were screened to determine the quantity of available data on a monthly basis and whether or not the available data represent the full range of flow conditions and the current time period. This analysis is presented in Appendix F and shows that, in general:

- There are few data at this gage. Only four months had four or more SAR samples.
- There is considerably less data during the non-growing season when compared to the growing season.
- Given the variability in SAR on a monthly basis (maximum measured change in one month of 6.4 in April 2006), it is logical to conclude that more samples per month would better represent the "monthly average" than fewer samples per month.

There are limited data to evaluate the monthly average standard using months with 4 or more samples. Therefore, for the purposes of providing a comparison of the available data to the monthly average SAR criteria, all of the available data were compared to the monthly average standard, as well as only data collected in the past five years. The frequency of exceedances is shown in Table 6-8. The monthly average standard has been exceeded greater than 83 percent of the time during both the growing season and nongrowing season (where data were available).

Table 6-8. Average monthly SAR data and exceedances of the average monthly water quality standards for Pumpkin Creek near the mouth – USGS Gage 06308400; daily and grab samples.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 15, 1975 to June 21, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	50	49	98.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	18	15	83.33%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	4	4	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA
"Past 5 Years" – October 1, 2001 to June 21, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	14	13	92.86%
		Nongrowing Season (November 1 to March 1)	< 5.0	3	3	100%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	4	4	100%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

6.2.3.3 Nondegradation

Montana's State nondegradation policy requires that when ambient water quality is below 40 percent of the standard (anti-degradation trigger), up to a 10 percent change in a harmful parameter (such as SC and SAR) can be allowed without being considered significant (ARM 17.30.715)[t]. This is illustrated for SC in Figure 3-7 and Section 3.1.3.3. If deemed significant, an authorization to degrade would be required from the Montana Department of Environmental Quality.

A monthly comparison of SAR at station 06307600 to the nondegradation threshold is presented in Figure 6-9. The nondegradation threshold (2.0 and 1.2) has been exceeded most of the time during all months.

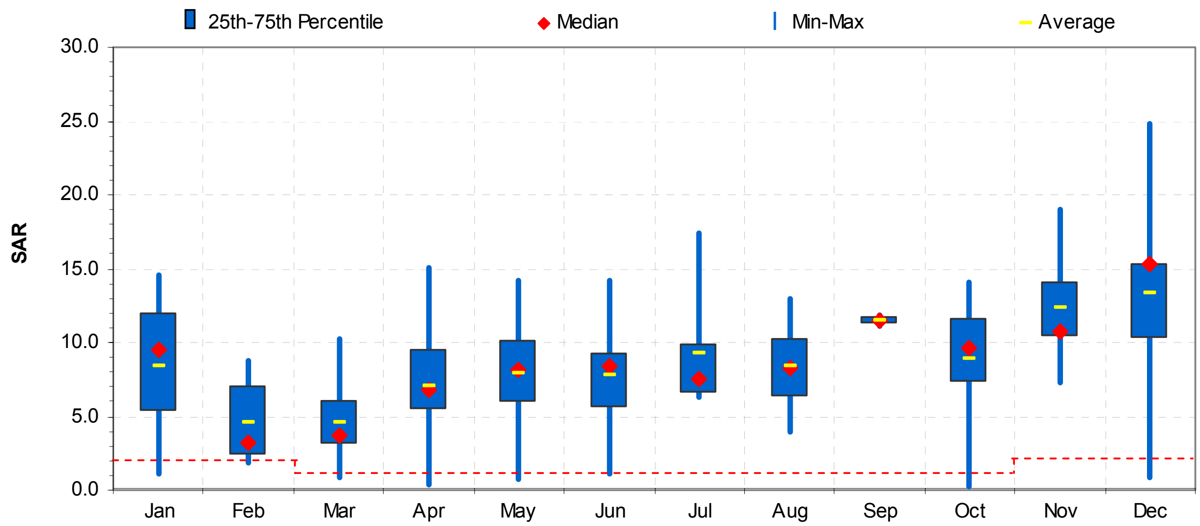


Figure 6-9. SAR data and nondegradation thresholds for Pumpkin Creek (near the mouth). Entire period of record is shown; grab samples only.

[t] Montana adopted its State nondegradation policy for the parameters of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) in March 2006. In June 2006, Montana submitted this change in its regulations to EPA for approval for federal Clean Water Act purposes. EPA has not yet acted on Montana's submission.

6.2.4 Sources of SAR and Their Influence on Pumpkin Creek

As described above, exceedances of Montana's salinity standards have been observed in Pumpkin Creek. However, it is unclear if the observed exceedances are due to natural or anthropogenic sources (or a combination of both).

As a result of insufficient data, it was not possible to quantitatively calibrate and or evaluate model performance for SAR in Pumpkin Creek. Therefore, no modeling analysis has been conducted (see the Modeling Report).

6.3 Thermal Modifications

Pumpkin Creek (Class C-3) was listed as impaired for thermal modifications on the 1996 303(d) list (Segment MT42C002-060) (MDEQ, 1996). Beneficial uses for Pumpkin Creek were not evaluated for the 2006 list. This section presents an updated evaluation of Pumpkin Creek relative to thermal modifications. Montana Class C-3 water quality standards state that, for waters classified as B-3 and C-3, the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 77º Fahrenheit) is 3° (F) and the rate of change cannot exceed 2°F per hour. If the natural occurring temperature is greater than 79.5º F, the maximum allowable increase is 0.5º F," (ARM 17.30.625(e), ARM 17.30.629(e)). Narrative standards also apply to thermal modifications (ARM 17.30.637).

The temperature analysis is divided into two sections: (1) analysis of measured data to provide an understanding of in-stream water temperatures, and; (2) comparison of Pumpkin Creek temperatures to similar Great Plains streams.

6.3.1 Measured Stream Temperature

Data were compiled from various sources to characterize water temperatures in Pumpkin Creek. Grab samples (collected at one day and time) are available at various sites from 1974 to 2006, and data are summarized in Table 6-9 and Figure 6-10. The data indicate that stream temperatures are dynamic throughout the stream, ranging from 32 °F to 85.1 degrees °F. There was no indication of temporal or spatial trends in the data.

Table 6-9. Summary of surface water temperature data (grab samples) in Pumpkin Creek (°F).

Station ID	Count	Average	Min	Max	Period of Record
Y16PUMPC10 (Downstream)	2	67.2	59.2	75.2	2001-2001
PC-8-1	1	61.3	61.3	61.3	2002-2002
3483PU01	26	59.0	32.0	83.8	1974-1979
06308400	87	51.8	32.0	85.1	1975-2006
REMAP_165_1	3	60.3	53.2	69.6	1999-2000
Y16PMPKC03	3	62.6	38.7	75.2	2005-2005
PC-7-1	1	62.8	62.8	62.8	2002-2002
PC-6-1	1	64.9	64.9	64.9	2002-2002
06308190	9	49.3	32.0	80.6	1975-1977
2983PU01	2	54.5	53.6	55.4	1974-1975
PC-1-2	1	54.0	54.0	54.0	2002-2002
06308160	28	51.7	32.0	78.8	1975-1979
452423105503001 (Upstream)	2	51.8	41.0	62.6	1978-1978
All Sites	166	58.8	32.0	85.1	1974-2005

Data collected by USGS, NRCS, and MDEQ. Site locations are shown in Figure 6-1.

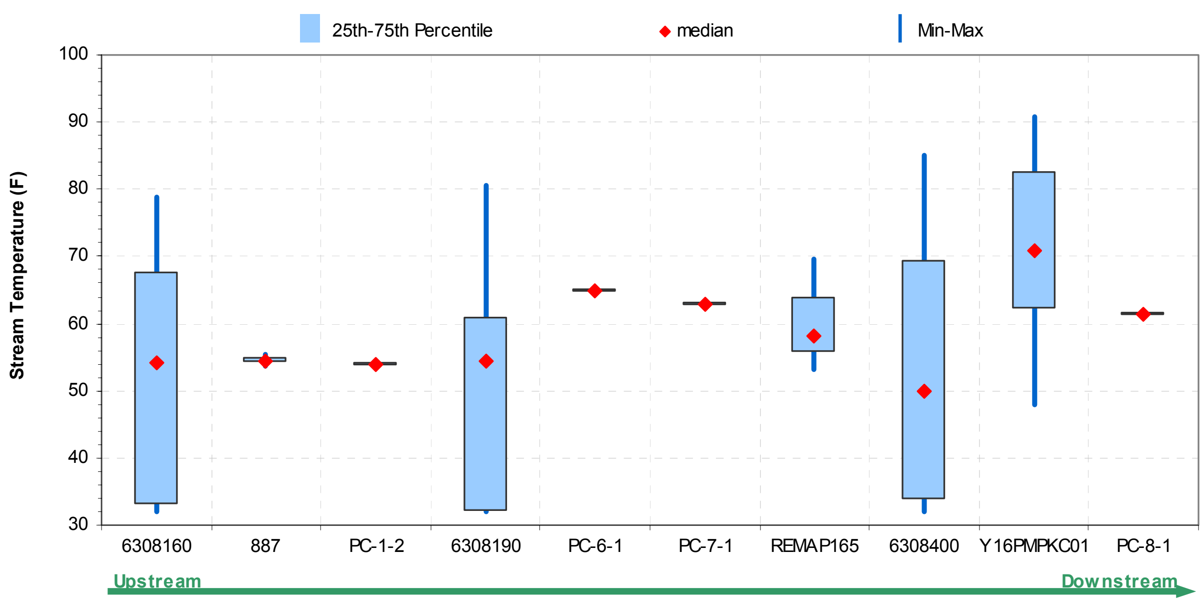


Figure 6-10. Stream temperatures in Pumpkin Creek (all stations, grab samples).

In 2003, temperature data loggers were deployed at two sites in Pumpkin Creek. The data loggers recorded hourly stream temperatures between April 24, 2003 and October 1, 2003.

- Site Y16PMKC02 – Pumpkin Creek approximately 5 miles upstream of the mouth in a deep pool (in an area with cottonwood trees and other large woody vegetation). The data logger at this site was activated on April 24, 2003 and removed on September 30, 2003.
- Site Y16PMKC01 – Pumpkin Creek approximately 0.5 river miles upstream from the mouth in a deep pool near the Tongue River Road Bridge (near an area with poor riparian cover, lack of shade). The data logger at this site was activated on April 24, 2003 and removed on October 1, 2003.

Pumpkin Creek monitoring site Y16PMKC02
(Photo by Tetra Tech, Inc.)

Pumpkin Creek monitoring site Y16PMKC01
(Photo by Tetra Tech, Inc.)

Data from the upstream data logger (Y16PMKC02) show that water temperatures between April 24 and August 10 ranged from 46 to 75 degrees F, with an average temperature of 66 degrees F (Figure 6-11). Pumpkin Creek dried up at this site on August 10, and did not have water for the remainder of the season.

Temperatures at the downstream site showed more variation, and suggest a pattern of daily warming and cooling closely matching air temperatures. This data probe was also placed in a deep pool; however, the pool did not dry up during the 2003 season. Monthly site visits found that after April, there was no flow at this site, and by August, the pool was almost dry.

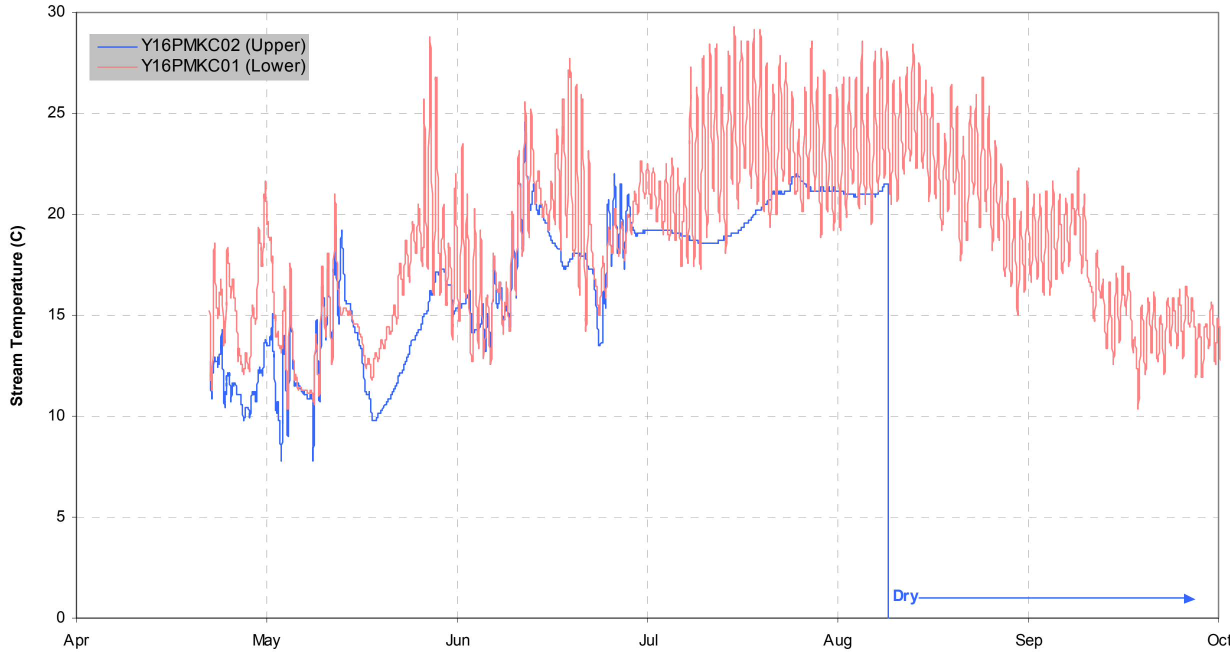


Figure 6-11. Hourly stream temperatures in Pumpkin Creek at two stations, 2003.

6.3.2 Comparison to Other Streams

Temperature standards for Montana are both numeric and narrative, and generally suggest that stream temperatures should strive towards a reference condition. However, there is little information about natural, or minimally impacted, stream temperatures in prairie streams. Because of this, stream temperatures in Pumpkin Creek were compared to other prairie streams in southeast Montana and northeast Wyoming to better understand regional patterns and trends.

In 2003, six temperature data loggers were deployed in tributaries to the Tongue River watershed.

- Pumpkin Creek near the Tongue River Road Bridge (Y16PMKC01).
- Pumpkin Creek five miles upstream from the mouth (Y16PMKC02).
- Hanging Woman Creek near the mouth (06307600)
- Hanging Woman Creek near Horse Creek (06307570)
- Otter Creek near the mouth (06307740)
- Otter Creek near Taylor Creek (451732106085001)

Two of the data loggers – Hanging Woman Creek near Horse Creek and Otter Creek near the mouth – were lost due to flood events or theft. Data from the four remaining temperature loggers are shown in Figure 6-12. The data suggest that temperatures near the mouth of Pumpkin Creek are similar to stream temperatures in Hanging Woman Creek near the mouth. On average, Pumpkin Creek near the mouth had the highest stream temperatures of the four data loggers, having one-degree higher temperatures than Hanging Woman Creek. However, this is somewhat expected, as flows and elevations are higher in Hanging Woman Creek, resulting in naturally lower stream temperatures.

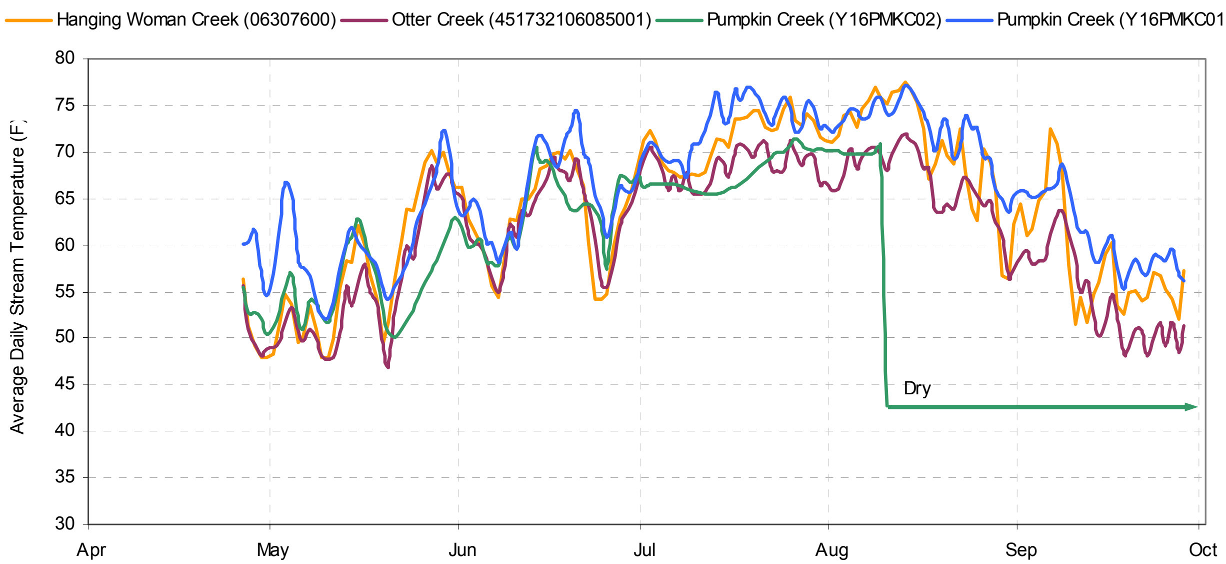


Figure 6-12. Average daily temperature at four sites in the Tongue River watershed, April-October, 2003.

Grab sample water temperatures in Pumpkin Creek at station 06308400 were compared to other Great Plains streams to obtain an understanding of regional stream temperatures. Data for station 06308400 were not available from 1986 to 2004 so the comparison covered the period from 1974 to 1985. Data from Appendix K shows that Pumpkin Creek generally has similar temperatures to other Great Plains streams, and had the fourth lowest median stream temperature (46 degrees F) (Figure 6-13).

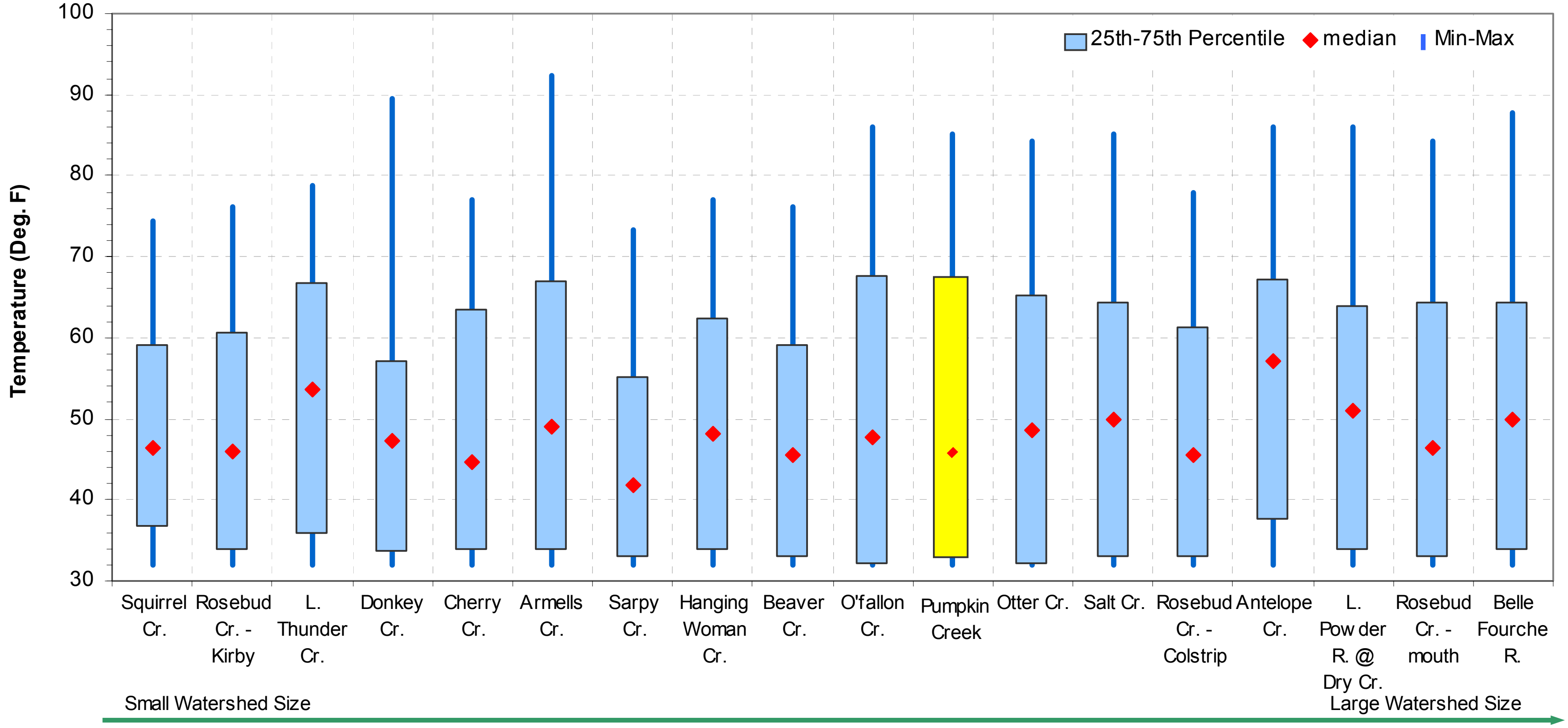


Figure 6-13. Comparison of water temperature data for 16 Great Plains streams in southeast Montana and northeast Wyoming, 1974-1985.

6.3.3 Temperature Sources

The following sections document potential indirect human impacts to stream temperature in Pumpkin Creek.

6.3.3.1 Flow

USGS maintained a continuous flow gage between 1972 and 1985 on Pumpkin Creek near the mouth (USGS gage 06308400). The gage was then reinstated in 2004. Flows in the creek are very low, with a median daily flow of 0.04 cubic feet per second and a mean annual discharge of 10,324 acre-feet per year. The stream is dynamic in that flows rapidly increase and decrease in response to storm events and snowmelt, resulting in steep "spikes" in the hydrograph (see Appendix H). Low flows occur in the summer, where flows are generally less than one cubic feet per second. In a shallow, low velocity, low volume, highly sinuous prairie stream like Pumpkin Creek, water temperatures are expected to be variable, with high water temperatures in the summer months. Stream temperatures are also expected to have large daily fluctuations that correspond to diurnal air temperatures fluctuations.

However, irrigation is prevalent throughout Pumpkin Creek, and may result in less water volume and longer travel times (see Section 3.5.2 of the modeling report). Flow alterations may, therefore, indirectly increase stream temperatures by reducing the amount of water in the stream, and also cause more variability in stream temperature (higher maximum and lower minimum temperatures). Due to a poor fit between predicted and observed discharge in Pumpkin Creek with the Tongue River LSPC model, no analysis of the magnitude of human-caused flow alteration has been conducted (see Modeling Report).

6.3.3.2 Habitat Alterations

Habitat alterations are another indirect source that can increase stream temperature. Riparian vegetation, and particularly large woody vegetation, provides shade to a stream, and if removed, can result in increased stream temperatures (Beschta, 1997; Poole and Berman, 2001; Li et al., 1994). Riparian vegetation along Pumpkin Creek was evaluated by NRCS in 2001 and 2002 from the confluence with Little Pumpkin Creek to the mouth (NRCS, 2001; NRCS, 2002). Scores for each of the eight segments are shown in Table 6-10, and stream segments are shown in Figure 6-14. NRCS found that (NRCS, 2002):

> *The banks along the entire creek were stable and well vegetated with prairie cordgrass, and several species of sedges, rushes and bulrushes. Emergent vegetation was prevalent within the channel bottom. It was not until the lower reaches, six to eight, that Kentucky bluegrass became a dominant component in the riparian vegetation. Even then, the banks appeared stable. Boxelder was evident on all of the upper reaches, but dropped out of the plant community in the lower reaches, as did all of the other woody species. In the upper five reaches, boxelder maple, currant, wild rose and western snowberry were common. Chokecherry was found scattered throughout the upper drainage. In the lower three reaches, the woody component dropped out completely.*
>
> *The potential for a boxelder maple and/or green ash canopy on Pumpkin Creek exists throughout nearly the entire stream but may be limited in the lower reaches due to higher salinity levels associated with the Lake Glendive sediments. The potential for an understory of shrubs including snowberry, wild rose and chokecherry existed as well. Past and present grazing practices have probably limited the extent and diversity of these species in most of the reaches. The amount of Kentucky bluegrass in the lower reaches is*

Lack of large woody vegetation and shade at Pumpkin Creek segment 6. (Photo by NRCS).

a cause for concern for the long-term stability of the banks since it has a shallow, relatively weak root system that offers little protection during high flow events.

Five of the eight reaches assessed on Pumpkin Creek were rated in the 'Sustainable' category. The lower three reaches, occurring on the lacustrine or glacial lake deposits, were found to be in the 'At Risk' category mainly due to the lack of deep-rooted species in the riparian zone. These are the reaches that more frequently have flowing water.

Overall, the evidence suggests that the lower three reaches of Pumpkin Creek (Reaches 6, 7, and 8 in Figure 6-14) have degraded riparian habitat, "*mainly due to the lack of deep-rooted species* [i.e., non-native Kentucky bluegrass as opposed to native herbaceous species] *in the riparian zone".* The potential for shade in the lower reaches of Pumpkin Creek from a shrub or tree canopy, however, "*may be limited"* due to natural soil conditions. This evidence suggests that the lower reaches of Pumpkin Creek may be meeting their potential from a shade perspective. Therefore, human-caused habitat alterations may not be contributing to a potential temperature problem.

Table 6-10. Results of the NRCS riparian assessment in Pumpkin Creek.

Segment	Incisement	Lateral Cutting	Sediment Balance	Soil	Binding Root Mass	Woody Establishment	% Utilization	Riparian/Wetland Characteristics	Floodplain	Irrigation Impacts	Land Use Activities	Subtotal	Potential Score	% of Potential	Sustainability Rating
PC-1-2	8	6	6	3	6	4	4	8	6	4	4	59	69	86%	Sustainable
PC-2-1	8	6	6	3	4	4	4	6	6	NA	NA	47	53	89%	Sustainable
PC-3-1	8	6	6	3	6	4	4	8	6	NA	NA	51	53	96%	Sustainable
PC-4-1	8	6	6	3	6	4	4	8	6	NA	NA	51	53	96%	Sustainable
PC-5-1	6	4	6	3	6	2	4	8	6	NA	NA	45	53	85%	Sustainable
PC-6-1	8	4	6	3	4	0	0	2	6	6	4	43	69	62%	**At Risk**
PC-7-1	8	4	6	3	4	0	0	2	6	8	4	45	69	65%	**At Risk**
PC-8-1	8	4	6	3	4	0	0	4	4	8	4	45	69	65%	**At Risk**

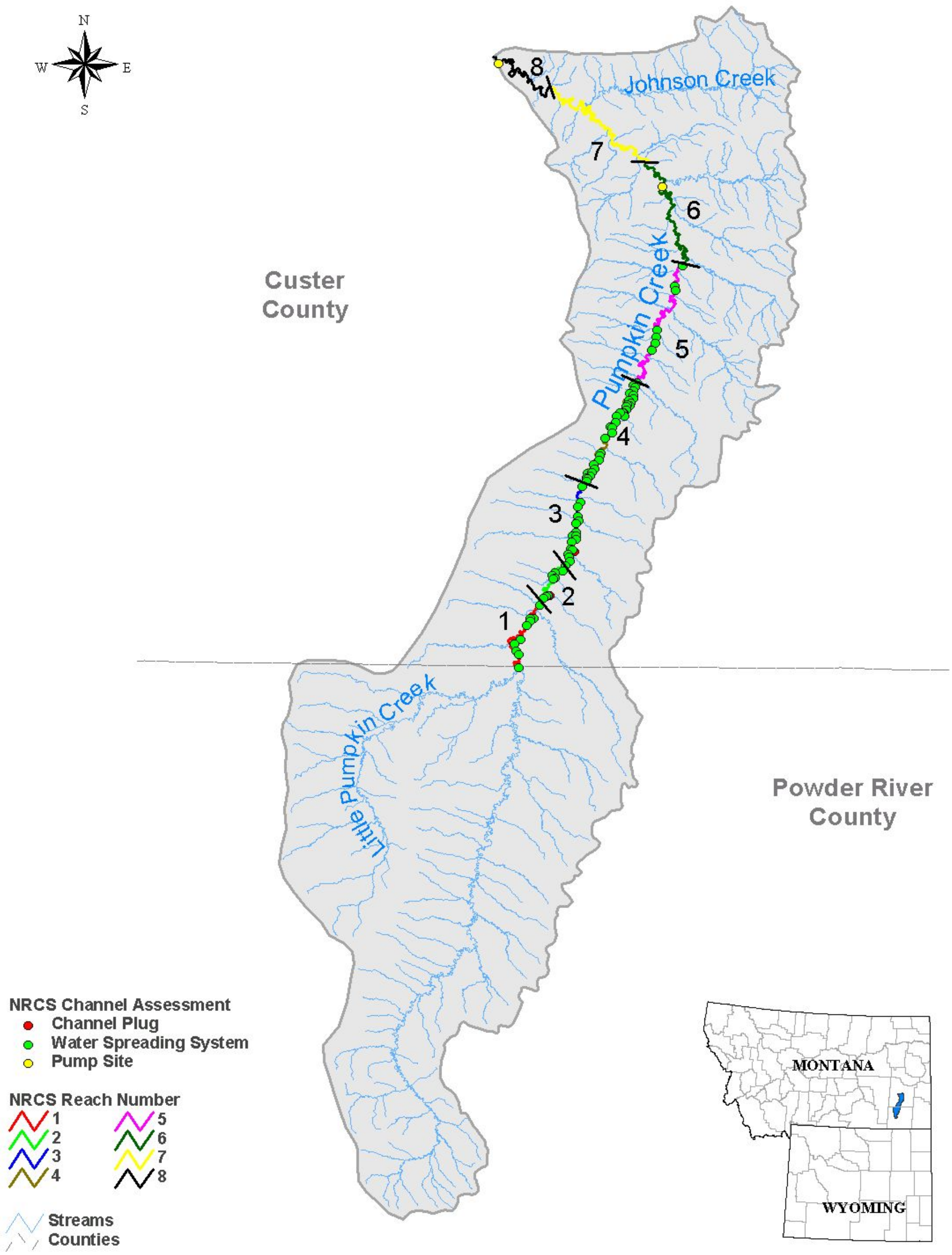


Figure 6-14. NRCS in-channel assessment for Pumpkin Creek (Little Pumpkin Creek to the mouth)

7.0 TONGUE RIVER RESERVOIR

The Montana 1996 303(d) list reported that the Tongue River Reservoir (Segment ID MT42B003-010) was impaired because of nutrients, organic enrichment/dissolved oxygen, and suspended solids (MDEQ, 1996). Aquatic life, fishery, and recreation/swimmable beneficial uses were impaired by these causes in 1996. The basis for the 1996 listing is unknown.

In 2006, MDEQ identified the Tongue River Reservoir as impaired due only to algal growth/chlorophyll-*a* (MDEQ, 2006a). Aquatic life and recreational uses were determined to be partially impaired because of algal growth/chlorophyll-*a*. DEQ's Assessment Record Sheet states that, *"the TRR is eutrophic due to eutrophication caused by phosphorus loads from agriculture and the Sheridan Wastewater Treatment Plant."* (MDEQ, 2006a). Agricultural and industrial uses were found to be fully supporting in the 2006 303(d) report and drinking water and fishery uses were not assessed.

Tongue River Reservoir and Dam.
Photo by Montana DNRC

This analysis specifically addresses the listed pollutants and impaired beneficial uses from the 1996 and 2006 303(d) lists. Salinity and sodium adsorption ratio (SAR) are also addressed given their potential importance related to existing and future coal bed methane development in the watershed. The purpose of this analysis is to determine if Montana's water quality standards are currently exceeded in the Tongue River Reservoir and, if so, provide insight regarding the cause (i.e., natural versus anthropogenic).

The remainder of this section provides a summary and evaluation of the available data, and comparison to the applicable Montana water quality standards one pollutant at a time. The methods by which Montana's water quality standards have been applied are presented in Appendix B. Information about the operation of the Tongue River Reservoir is presented in Appendix H, and sampling locations and reservoir bathometry are presented in Figure 7-1. Biological data for the Tongue River Reservoir are discussed in Appendix I.

7.1 Salinity

Limited amounts of SC data are available for the Tongue River Reservoir. MDEQ collected 40 samples during the period 1974 to 1976 and then no data were collected until MDEQ performed additional sampling during the summer and fall of 2001. USEPA collected additional data in the summer and fall of 2003. No additional reservoir salinity data have been collected since 2003.

All of the available data are summarized in Table 7-1 and station locations are shown in Figure 7-1. Most SC values range between 200 µS/cm and 800 µS/cm with the 2001 samples typically higher than the 1974 to 1976 and 2003 data. The 2001 samples were collected from July to October when the reservoir volume was relatively low (approximately 20,000 acre feet compared to 65,000 acre feet in 2003) and this might have contributed to the higher values. Of the 237 salinity samples analyzed in the Tongue River Reservoir, none has ever exceeded the 1,000 µS/cm monthly average standard or the 1,500 µS/cm maximum standard.

Table 7-1. Summary of all available surface water SC data, Tongue River Reservoir (µS/cm).

Station ID	Count	Average	Min	Max	Period of Record
1975TO04	6	298	201	457	1976
1975TO05	3	272	254	284	1975
2075TO01	14	538	213	879	1975
2075TO02	1	775	775	775	1974
2075TO03	16	440	237	830	1975
TRR-1-1	1	430	430	430	2002
Y15TNGRR01	29	353	168	470	2003
Y15TNGRR02	46	375	173	733	2003
Y15TNGRR03	54	483	327	967	2003
Y15TRR10	49	695	6.3	782	2001
Y15TRR20	30	701	595	833	2001
Y15TRR31	6	693	655	767	2001
Y15TRR32	7	795	768	865	2001

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Statistics are for all dates and sample depths.

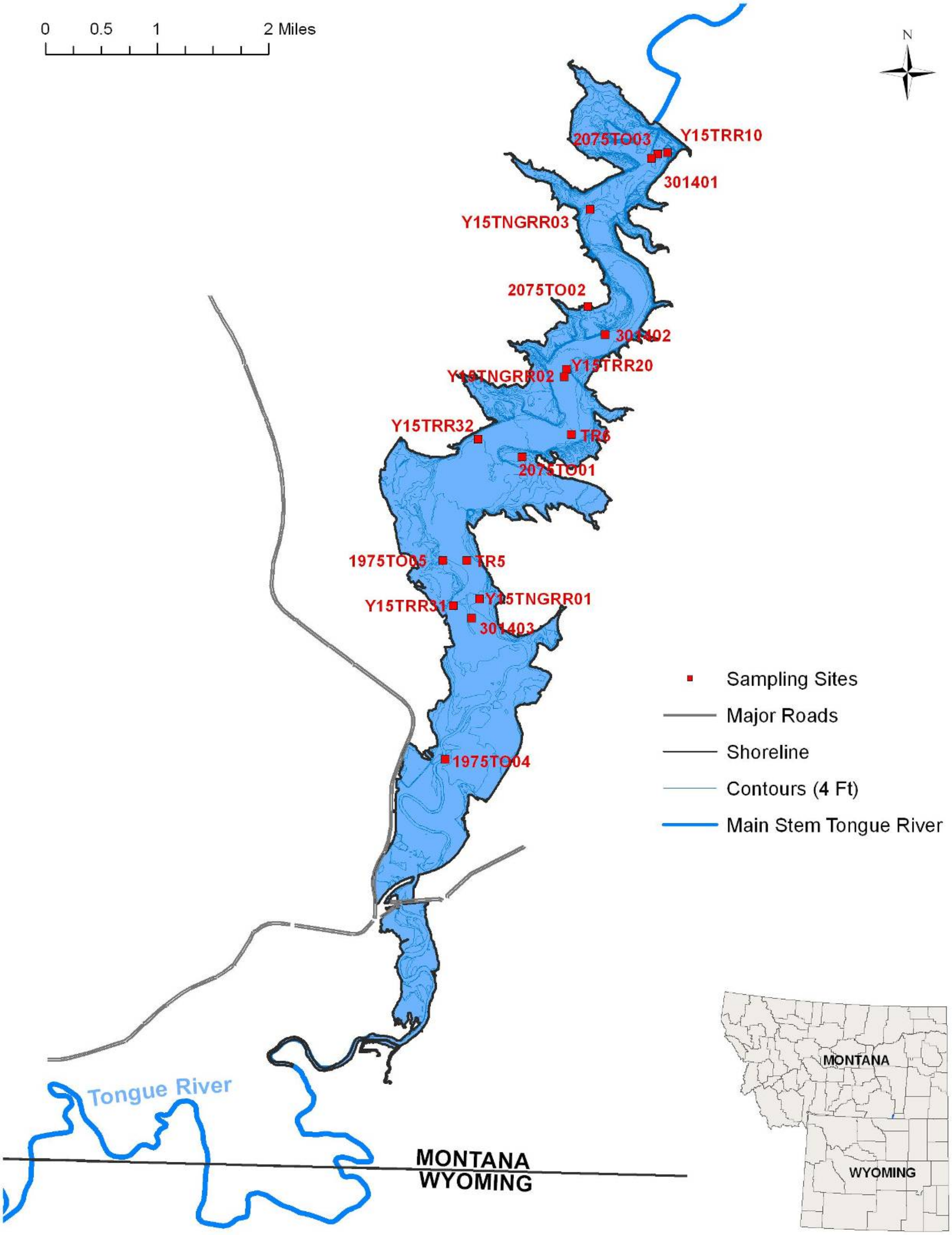


Figure 7-1. Tongue River Reservoir bathymetry and location of the water quality monitoring stations.

The variability of salinity by depth in the reservoir is presented graphically in Figure 7-2, which summarizes SC observations at the station near the dam (Y15TNGRR03) for the 2003 sampling events. The data indicate that SC typically increases with depth, with values near the bottom of the reservoir occasionally being greater than values at the surface.

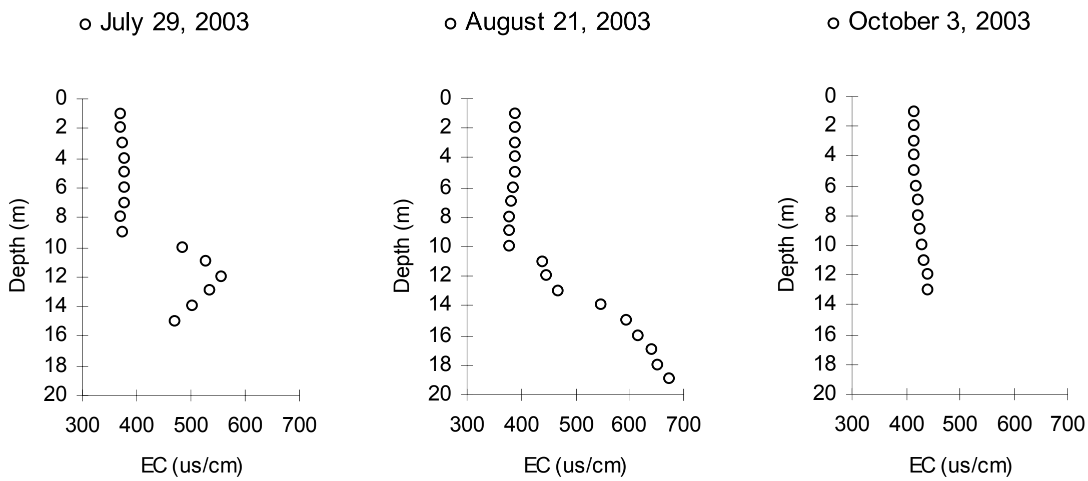


Figure 7-2. SC sampling by depth for 2003 Tongue River Reservoir sampling at station near dam (Y15TNGRR03).

7.2 Sodium Adsorption Ratio

Limited amounts of SAR data are available for the Tongue River Reservoir. MDEQ collected data in the summer of 2001 and USEPA collected additional data in the summer and fall of 2003. All of the available data are summarized in Table 7-2. No data have been collected in November, December, January, or February. Most SAR observations range between 0.3 and 1.5 with the 2001 samples typically higher than the 2003 samples. Of the 59 SAR samples analyzed in the Tongue River Reservoir, none has ever exceeded the 3.0 monthly average or the 4.5 maximum standards.

Table 7-2. Summary of SAR data, Tongue River Reservoir (March 2–October 31).

Station ID	Count	Average	Min	Max	Period of Record
Y15TRR01	8	1.15	0.91	1.45	2001
Y15TRR02	6	1.28	1.17	1.38	2001
Y15TRR03	4	1.41	1.2	1.58	2001
Y15TNGRR01	13	0.55	0.38	0.78	2003
Y15TNGRR02	13	0.52	0.37	0.88	2003
Y15TNGRR03	15	0.56	0.3	0.96	2003

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Statistics are for all dates and sample depths.

7.3 Nutrients

As described in Section 7.0, the Tongue River Reservoir was listed as impaired for nutrients and organic enrichment/dissolved oxygen on the 1996 303(d) list. In the 2006 303(d) list, nutrients were not identified as a cause of impairment for the reservoir. However, aquatic life and fishery uses in 2006 were listed as impaired because of chlorophyll-*a* (MDEQ, 2006a). Because of the interrelated nature of nutrients, organic enrichment/low dissolved oxygen, and algal growth/chlorophyll-*a* impairments, they are discussed together in this section under the general heading of nutrients.

As described in Appendix B, Montana's nutrient standards are narrative. In the absence of formal numeric nutrient criteria, a suite of measurable indicators are presented below to provide insight into current nutrient conditions in the Tongue River Reservoir relative to Montana's narrative nutrient standards.

7.3.1 Total Phosphorus and Total Nitrogen

Total phosphorus (TP) and total nitrogen (TN) data for the Tongue River Reservoir are summarized in Table 7-3 and Table 7-4. Median TP concentrations at the 13 stations range from 0.023 to 0.235 mg/L, and median TN concentrations range from 0.23 to 1.33 mg/L. Concentrations of both nutrients are somewhat higher during the 2001 and 2003 sampling compared to the 1975 sampling. As shown in Figure 7-3, phosphorus resuspension and release from bottom sediments appears to be present at times, causing significantly higher concentrations at depth.

Table 7-3. Summary of all available total phosphorus data, Tongue River Reservoir (mg/L).

Station ID	Count	Median	Min	Max	Period of Record
1975TO05	3	0.030	0.020	0.040	1975
2075TO01	4	0.023	0.020	0.050	1975
2075TO03	3	0.030	0.020	0.040	1975
301401	8	0.040	0.022	0.141	1975
301402	10	0.052	0.043	0.148	1975
301403	5	0.060	0.045	0.112	1975
Y15TNGRR01	15	0.040	0.020	0.300	2003
Y15TNGRR02	13	0.032	0.020	0.057	2003
Y15TNGRR03	12	0.030	0.020	0.210	2003
Y15TRR10	4	0.035	0.014	0.048	2001
Y15TRR20	3	0.069	0.040	0.093	2001
Y15TRR31	1	0.235	0.235	0.235	2001
Y15TRR32	3	0.078	0.075	0.106	2001

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Statistics are for all dates and sample depths. Detection limited data were used as ½ the detection limit value.

Table 7-4. Summary of all available total nitrogen data, Tongue River Reservoir (mg/L).

Station	Count	Median	Min	Max	Period of Record
1975TO05	3	0.32	0.31	0.41	1975
2075TO01	3	0.36	0.34	0.68	1975
2075TO03	3	0.23	0.17	0.29	1975
301401	8	0.51	0.41	1.21	1975
301402	10	0.62	0.41	1.01	1975
301403	5	0.61	0.42	0.75	1975
Y15TNGRR01	15	0.71	0.52	0.93	2003
Y15TNGRR02	17	0.61	0.50	1.73	2003
Y15TNGRR03	15	0.62	0.12	2.21	2003
Y15TRR10	1	1.07	1.07	1.07	2001
Y15TRR20	1	1.02	1.02	1.02	2001
Y15TRR32	2	1.33	1.12	1.54	2001

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Statistics are for all dates and sample depths. Detection limited data were used as ½ the detection limit value.

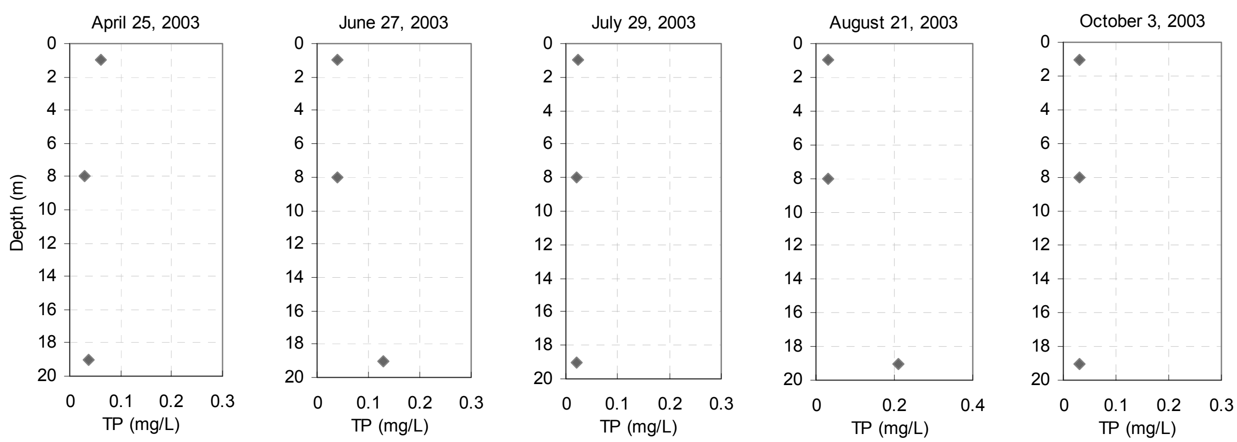


Figure 7-3. Total phosphorus concentrations at depth in the Tongue River Reservoir near the Dam (Station Y15TNGRR03).

A rough rule of thumb for assessing which nutrient limits plant growth relates to the nitrogen-to-phosphorus ratio. Since the ratio of nitrogen to phosphorus in algal biomass (Redfield ratio) is approximately 7.2, an N:P ratio in the water that is greater than 7.2:1 suggests that phosphorus is limiting (Chapra, 1997). As displayed in Figure 7-4, N:P ratios in the Tongue River Reservoir average approximately 18:1, suggesting that phosphorus is typically the limiting nutrient. Figure 7-5 also suggests that there is a moderate positive relationship between paired TP and chlorophyll *a* data in the reservoir.

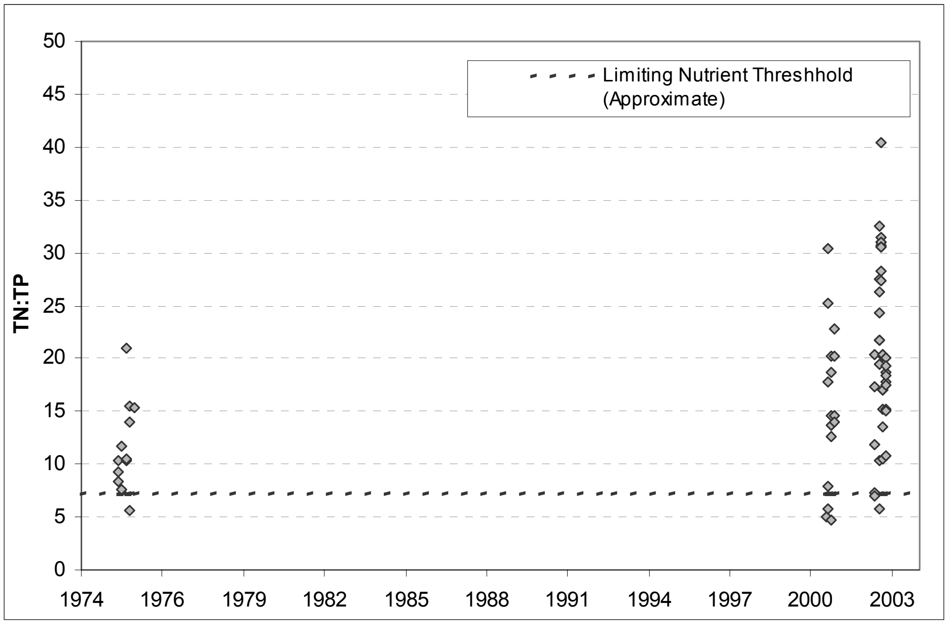


Figure 7-4. TN:TP ratio for the Tongue River Reservoir.

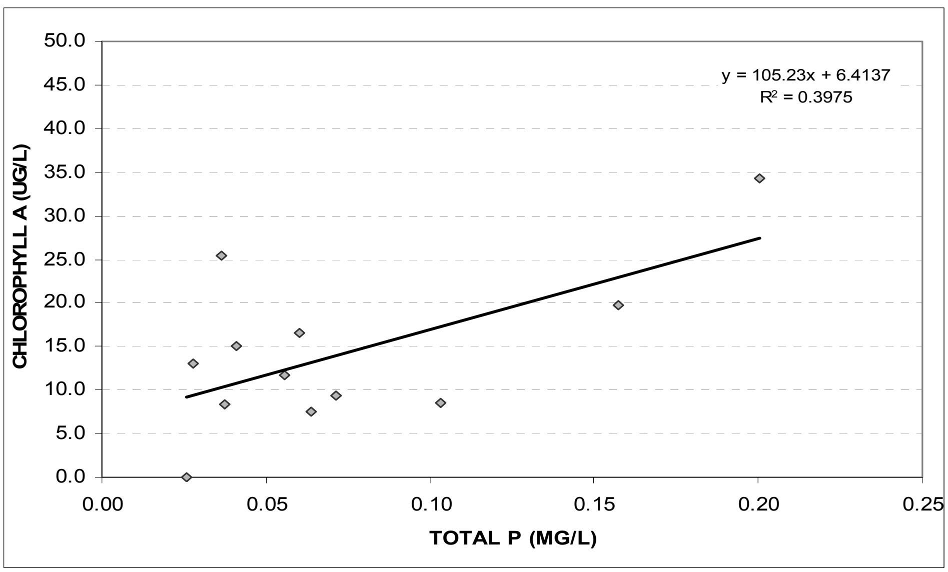


Figure 7-5. Relationship between total phosphorus and chlorophyll a for all paired samples in the Tongue River Reservoir.

7.3.2 Chlorophyll-*a*

Chlorophyll *a* data for the Tongue River Reservoir are summarized in Table 7-5. Median chlorophyll *a* concentrations range from 6.2 to 45.0 µg/L. Concentrations are similar over the entire period of record. No information is available on the algal taxa present in the reservoir (i.e., the extent to which the biomass is dominated by blue-green or other types of algae). As described in Appendix I, anecdotal evidence suggests that nuisance algal blooms are not uncommon in the reservoir.

Table 7-5. Summary of all available chlorophyll *a* data in the Tongue River Reservoir (µg/L).

Station ID	Count	Median	Min	Max	Period of Record
301401	3	16.9	7.3	20.5	1975
301402	3	20.5	11.2	24.5	1975
301403	3	7.3	4.9	38.8	1975
2075TO01	1	20.0	20.0	20.0	1993
Y15TNGRR01	6	14.0	6.0	20.0	2003
Y15TNGRR02	5	9.0	8.0	13.0	2003
Y15TNGRR03	6	10.5	7.0	12.0	2003
Y15TRR10	3	6.2	5.6	14.0	2001
Y15TRR20	3	12.0	8.6	35.0	2001
Y15TRR31	3	45.0	4.5	54.0	2001

Composite samples from the euphotic zone. Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Detection limited data were used as ½ the detection limit value.

7.3.3 Comparison to Other Reservoirs and Literature Values

The purpose of this section is to compare total phosphorus, total nitrogen, and chlorophyll-*a* data from the Tongue River Reservoir to other reservoirs that are located near, or in a similar ecoregional setting to the Tongue River watershed. The spatial extent of the analysis was determined by a number of factors including climate, elevation, ecoregion, stream type, contributing drainage area, and data availability. The goal was to select lakes and reservoirs that had characteristics similar to the Tongue River Reservoir watershed. Based on this, four reservoirs were selected from Montana, Wyoming, and North Dakota – Big Horn Reservoir (also referred to as Yellowtail Reservoir on the Big Horn River), Keyhole Reservoir (Belle Fourche River), Lake DeSmet (Piney Creek and Shell Creek), and Boysen Reservoir (Wind River). Data from these reservoirs were plotted with the data collected in the Tongue River Reservoir to provide a preliminary comparison. It should be noted that the number of samples and period of record varied for each reservoir, and recent data were limited in all of the reservoirs (Table 7-6). Because of the limited data, all available data (regardless of location within the reservoir, depth, or time period) are presented.

Table 7-6. Number of nutrient samples per reservoir and associated period of record.

Reservoir	# TP Samples	# TN Samples	# Chlorophyll-*a* Samples	Period of Record[1]
Tongue River Reservoir	88	83	27	1975; 1993; 2001; 2003
Big Horn Reservoir	35	60	65	1975; 1980; 1984-1985
Boysen Reservoir	67	67	25	1975; 1981
Keyhole Reservoir	53	53	21	1975;1981
Lake Desmet	27	64	6	1975

[1]Period of Record for all three parameters combined.

It should also be noted that the reservoirs selected for this analysis are not meant to represent "reference conditions" for the Tongue River Reservoir. It is beyond the scope of this analysis to conduct a detailed assessment for each of the four reservoirs. Rather, the purpose of this analysis is to put nutrient data in the Tongue River Reservoir into context with similar neighboring reservoirs to better understand existing conditions.

Nutrient data were also compared to nutrient targets obtained from a literature review. South Dakota developed ecoregional Carlson's Trophic State Index (Carlson, 1977) (TSI) targets for lakes and reservoirs. For reservoirs classified as "warm water permanent fisheries", South Dakota considers a TSI value greater than 58.5 as "impaired", and a score lower than 58.5 as "not impaired," (SDDNR, 2005). Using the formulas below, a Carlson's TSI score of 58.5 translates into a total phosphorus target of 0.043 mg/L, and a chlorophyll-*a* target of 17 µg/L.

$$TSI(TP) = 10 \times (6 - \frac{Ln(48/TP)}{Ln2})$$, where TP is in µg/L (Carlson, 1977)

$$TSI(Chl) = 10 \times \left(6 - \frac{2.04 - 0.68(Ln(Chl)}{Ln2}\right)$$, where chlorophyll-*a* is in µg/L (Carlson, 1977)

USEPA developed nutrient guidance for lakes and reservoirs using the 25th percentile of a large set of data obtained throughout a defined nutrient ecoregion. The 25th percentile approach assumes that 25 percent of the sampled lakes and reservoirs (e.g., the "best" 25 percent) are surrogates for reference conditions (USEPA, 2001). The Tongue River is located in nutrient Ecoregion 4 (Great Plains Grass and Shrublands), where the recommended nutrient targets are as follows: 0.020 mg/L TP, 0.44 mg/L TN, and 2.0 µg/L chlorophyll-*a* (USEPA, 2001).

The Tongue River watershed LSPC and CE-QUAL-W2 models were used to examine what conditions would be like in the Tongue River Reservoir in the absence of human actions (i.e., the "natural" condition). All human influences were removed from the two models (e.g., diversions, irrigation, developed land, point sources, etc.) and model output was examined. The average annual median concentrations for TP, TN, and chlorophyll-*a* under the natural condition were 0.010 mg/L, 0.028 mg/L, and 1.5 µg/L, respectively. The Modeling Report has additional details about model setup, use, and uncertainty, while the natural scenario is further defined in Appendix J.

The various reservoir data, literature values, and model results are presented graphically in Figure 7-6 and Figure 7-7. The following sections discuss total phosphorus, total nitrogen, and chlorophyll-*a* individually.

Total Phosphorus

The median TP value for the Tongue River Reservoir (0.040 mg/L) was similar to other median values found in reservoirs throughout the region (medians ranging from 0.029 to 0.061 mg/L), and it was less than the South Dakota recommended target of 0.043 mg/L. The maximum TP value (0.300 mg/L) was significantly less than those found in Big Horn and Keyhole Reservoirs (0.950 and 1.000 mg/L, respectively). However, the median value for the Tongue River Reservoir exceeded the modeled "natural" and USEPA targets.

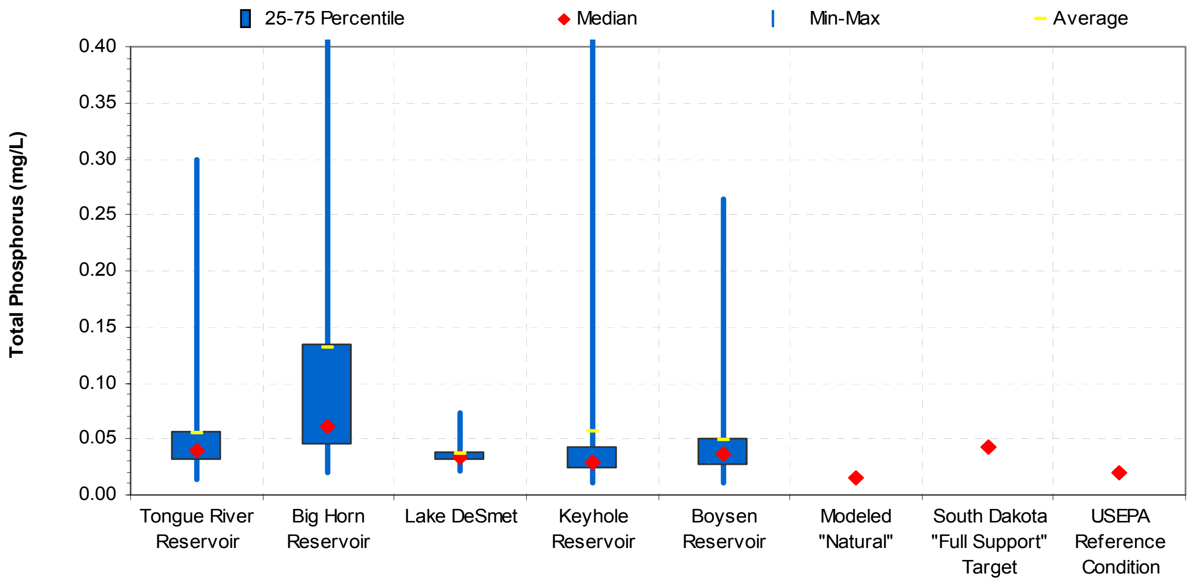


Figure 7-6. Comparison of total phosphorus data from the Tongue River Reservoir to other reservoirs and literature values.

Total Nitrogen

The median TN value for the Tongue River Reservoir (0.63 mg/L) was higher than all of the other median values for reservoirs throughout the region (medians ranging from 0.42 to 0.62 mg/L), and it was higher than the USEPA recommended target of 0.44 mg/L. The maximum TN value (2.21 mg/L) was more than those found in the Big Horn, Keyhole, and Lake DeSmet Reservoirs (1.23, 1.41, and 1.53 mg/L, respectively). Boysen Reservoir was the only reservoir with a higher maximum TN value (2.80 mg/L). All of the reservoirs exceeded the annual median modeling target of 0.027 for "natural" conditions.

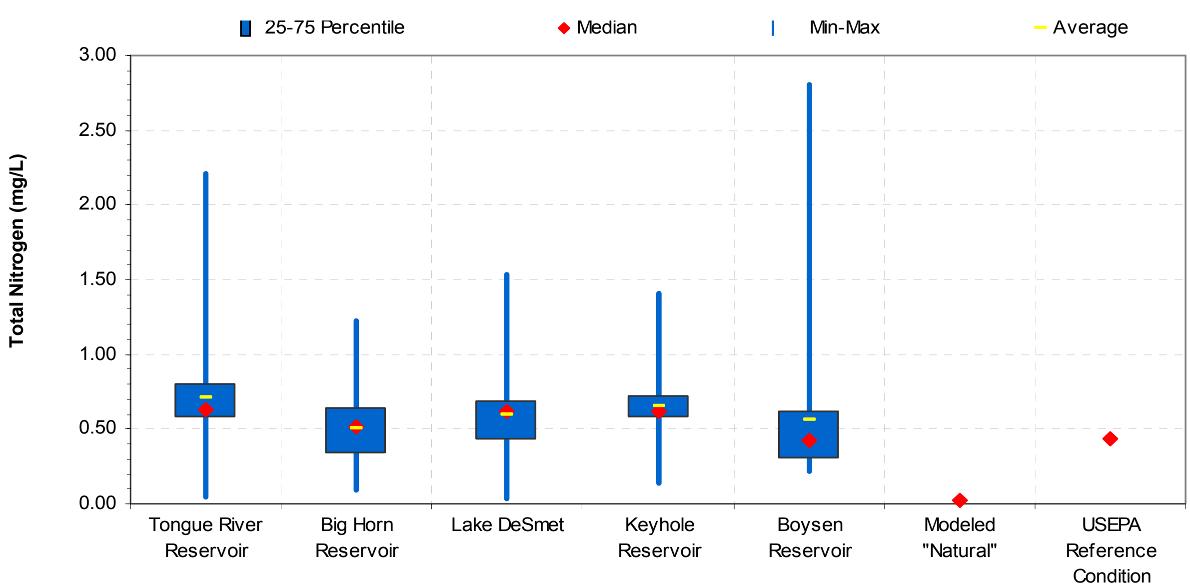


Figure 7-7. Comparison of total nitrogen data from the Tongue River Reservoir to other reservoirs and literature values.

Chlorophyll-a

The median chlorophyll-*a* value for the Tongue River Reservoir (11 µg/L) was higher than all of the other median values for reservoirs throughout the region (medians ranging from 2 to 10 µg/L). The maximum chlorophyll-*a* value (54 µg/L) was higher than those found in the Boysen, Keyhole, and Lake DeSmet Reservoirs (14, 14, and 21 µg/L, respectively). Big Horn Reservoir was the only reservoir with a higher maximum chlorophyll-*a* value (69 µg/L). All of the reservoirs exceeded the annual median modeling target of 1.4 µg/L for "natural" conditions, and all of the median values except for Boysen Reservoir exceeded the USEPA target of 2.0 µg/L. The South Dakota target of 17 µg/L was not exceeded.

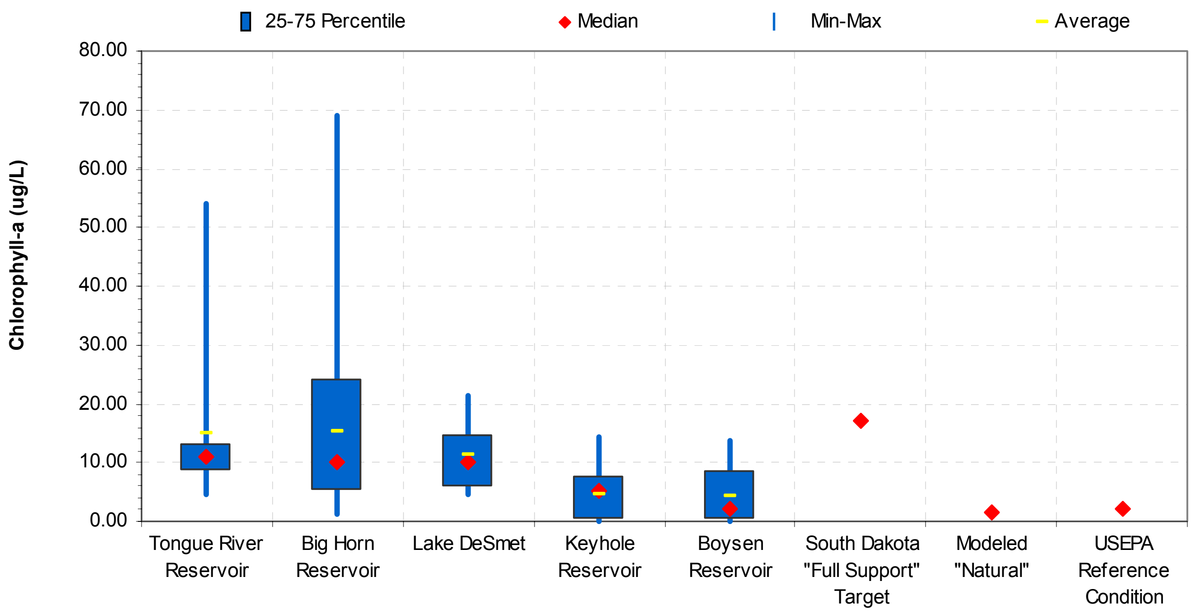


Figure 7-8. Comparison of chlorophyll-*a* data from the Tongue River Reservoir to other reservoirs and literature values.

7.3.4 Carlson's TSI

Secchi disk transparency, chlorophyll *a*, and total phosphorus are often used to define the degree of eutrophication or trophic status of a lake. The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) usually cause changes in algal biomass (measured by chlorophyll *a*) which in turn causes changes in lake clarity (measured by Secchi disk transparency).

A trophic state index is a convenient way to quantify this relationship. One popular index was developed by Carlson (1977). His index uses a log transformation of Secchi disk values as a measure of algal biomass on a scale from 0 to 110. Each increase of ten units on the scale represents a doubling of algal biomass. Companion measures are based on TP and chlorophyll-*a* concentrations.

The Carlson trophic state index is useful for comparing lakes within a region and for assessing changes in trophic status over time. However, the index was developed for use with lakes that have few rooted aquatic plants and little non-algal turbidity. Because non-algal turbidity can be significant in the Tongue River Reservoir, the index is used to provide primarily a qualitative perspective on the condition of the reservoir. The formulas for calculating Carlson's TSI are shown below.

$$TSI(TP) = 10 \times (6 - \frac{Ln(48/TP)}{Ln2})$$, where TP is in µg/L (Carlson, 1977)

$$TSI(Chl) = 10 \times \left(6 - \frac{2.04 - 0.68(Ln(Chl)}{Ln2} \right)$$, where chlorophyll-*a* is in µg/L (Carlson, 1977)

Chlorophyll-*a* and total phosphorus samples were obtained in the Tongue River Reservoir in 2001 and 2003 at three locations – north end, middle, and south end. TSI values were calculated for samples obtained in the surface layer between May 15 and September 15 of each year. A summary of the values is shown in Table 7-7. Values ranged from 42 to 83, indicating a range of conditions from mesotrophic (i.e., water moderately clear; increasing probability of hypolimnetic anoxia during summer) to hypereutrophic (i.e., light limited productivity with algal scum and few macrophytes) (Carlson and Simpson, 1996).

Table 7-7. Carlson's TSI values for the Tongue River Reservoir

Year	Parameter	Min	Max	Average
2001	Chlorophyll-*a*	48	68	56
	Total Phosphorus	42	83	61
2003	Chlorophyll-*a*	50	59	54
	Total Phosphorus	49	71	55

7.3.5 Dissolved Oxygen

The available dissolved oxygen data for the reservoir are summarized in Table 7-8. The average dissolved oxygen concentration from the 2001 and 2003 surveys is approximately 6 mg/L. However, 29 percent of all dissolved oxygen samples were below the 5.0 mg/L minimum water quality standard (74 out of 255 samples). Most samples below 5.0 mg/L occur at lower depths (Figure 7-9). These areas of low oxygen limit the extent of suitable habitat for various sensitive aquatic life species, but are not thought to be a major concern to the fishery (Brad Schmitz, Montana Fish, Wildlife and Parks, personal communication June 24, 2005).

Table 7-8. Summary of dissolved oxygen data, Tongue River Reservoir (mg/L).

Station	Count	Average	Min	Max	Period of Record
2075TO01	3	10.8	10.1	11.7	1976
301401	8	9.0	4.2	13.2	1975
301402	10	9.4	4.2	14.8	1975
301403	5	10.1	9.6	11.4	1975
TR5	1	8.5	8.5	8.5	1976
TR6	4	10.6	6.5	14.5	1975
TR7	3	7.6	3.1	10.9	1975
Y15TNGRR01	29	7.4	2.6	11.1	2003
Y15TNGRR02	46	6.5	0.1	12.0	2003
Y15TNGRR03	54	3.9	0.1	9.5	2003
Y15TRR10	49	4.8	0.1	9.2	2001
Y15TRR20	30	7.2	0.2	11.0	2001
Y15TRR31	6	9.6	8.5	11.0	2001
Y15TRR32	7	9.8	6.9	12.0	2001

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1. Statistics are for all dates and sample depths.

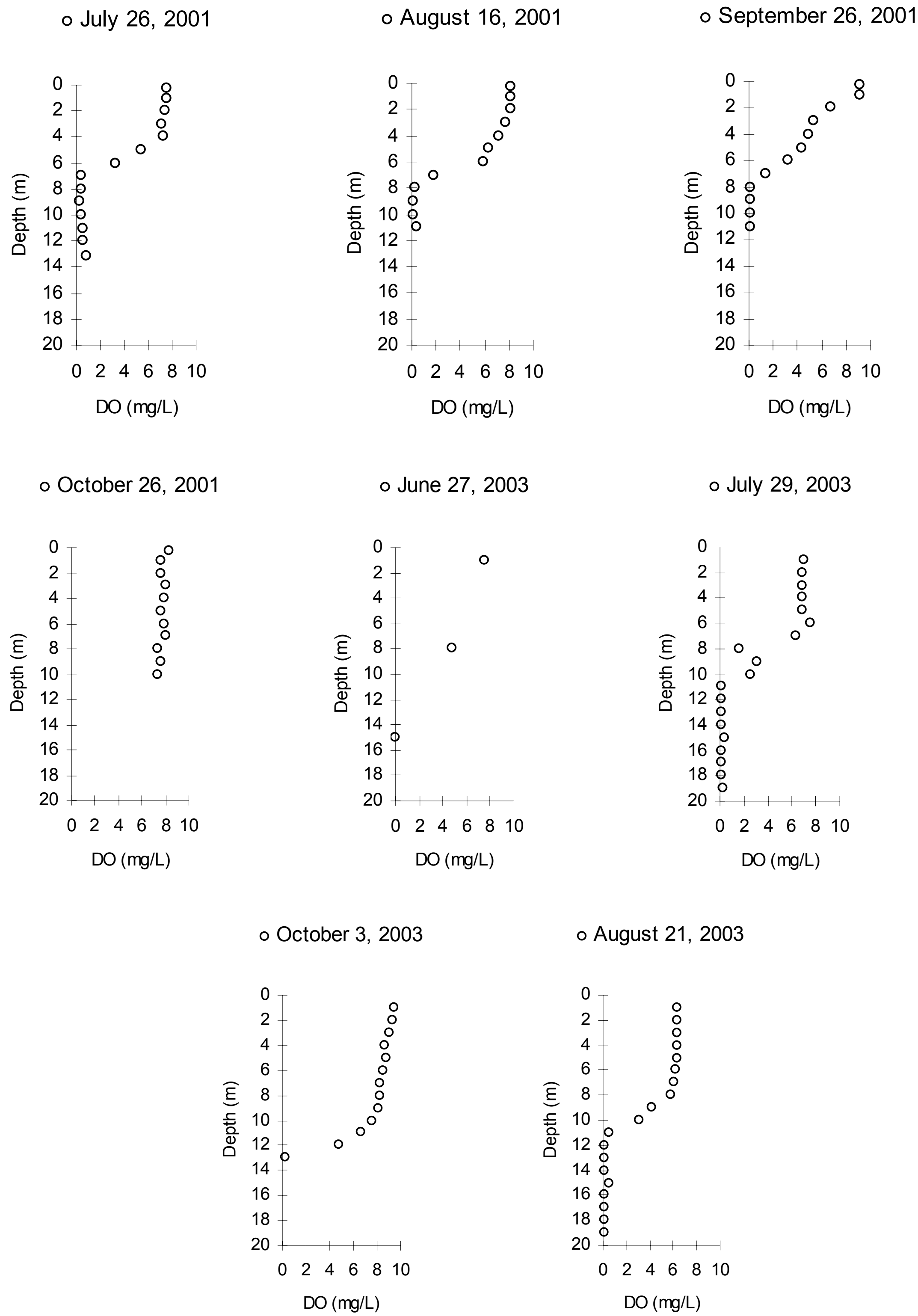


Figure 7-9. Dissolved oxygen data for Tongue River Reservoir by depth (2001 and 2003 sampling near TRR Dam).

The occurrence of stratification in a reservoir is a function of morphometry, weather, and release patterns (Krenkel and Novotny, 1980; Wetzel, 2001). Most deep reservoirs in temperate zones will stratify, and oxygen depletion in the hypolimnion will occur if stratification lasts long enough. Few data are available to determine the typical length of stratification in the Tongue River Reservoir but it was stratified for at least two months in 2001 and three months in 2003 (see Figure 7-9).

Oxygen depletion in the hypolimnion occurs as a result of both internal production of carbon and external loading of carbon (Wetzel, 2001). Phosphorus loading is an indicator of internal production, and is also typically correlated to landscape carbon loading. As a guide, Welch and Perkins (1979) estimated the hypolimnetic oxygen depletion rate as a function of external phosphorus load and residence time:

$$\log ODR = 1.51 + 0.39 \log (L/p)$$

where ODR is the hypolimnetic oxygen depletion rate ($mg/m^2/d$), L is the external phosphorus loading rate ($mg/m^2/T$), and p is the overlow rate (1/T). Given the oxygen depletion rate and the volume of the hypolimnion, the time required to reach hypoxia can be estimated. Using this equation and data from the LSPC and W2 models, the number of days in the Tongue River Reservoir with anoxic conditions could be estimated. Under the existing condition scenario, the estimated number of days with anoxic conditions was 1,011 out of 2,159 (47 percent). Under the natural scenario, the estimated number of days with anoxic conditions was 865 out of 2,159 (40 percent). Appendix J provides further details regarding the simulation of the existing and natural conditions.

7.3.6 Nutrient Sources

The potential sources of nutrients to the Tongue River Reservoir include:

- Upstream "natural" loads associated with groundwater and upland and streambank erosion
- Upstream applications of fertilizers to crops and residential lawns
- Upstream wastewater treatment effluent flows
- Other upstream point sources (i.e., CBM, coal mines)
- Upstream cattle grazing impacts
- In-reservoir cycling of phosphorus from the bottom sediments of the reservoir
- In-reservoir shoreline erosion

Summary information on the point sources is presented in Appendix A of the Modeling Report. Failing septic systems are assumed to be a minor source of total nutrient loadings due to the large size and sparsely populated nature of the watershed.

The LSPC model was used to estimate nutrient loads from upstream sources to the Tongue River Reservoir. Existing and natural condition scenarios were run, as well as scenarios to evaluate the impacts of irrigation, CBM, and wastewater treatment plants. Model output was evaluated at subbasin 3001, which is the last modeling subbasin before the Tongue River Reservoir. The total simulated TN and TP loads for various scenarios are shown in Table 7-9. In the absence of anthropogenic sources (i.e., the natural scenario), TN and TP loads would be 22 and 24 percent lower than the existing condition scenario. CBM had the largest impact on total nitrogen loads in the Tongue River (8 percent lower than existing conditions without CBM), followed by wastewater treatment and then irrigation.

By far, based on model results, the wastewater treatment plants appear to have the largest impact on total phosphorus (29 percent difference), and CBM is only a relatively small contributor (3 percent difference). The model suggests that without irrigation, total phosphorus loading would be higher than in the existing condition, although this phenomenon is assumed to be due to the associated flow alterations and not with any "treatment" of phosphorus by irrigation practices. Note that model uncertainty is discussed in the Modeling Report.

Table 7-9. Total modeled nutrient loads for various scenarios for the Tongue River watershed draining to the Tongue River Reservoir (modeling subbasin 3001).

Parameter	Existing Load (tons)	Natural		No Irrigation		No CBM		No WWTP	
		tons	% Δ	tons	% Δ	tons	% Δ	tons	% Δ
Total Nitrogen	945.8	739.5	-22%	895.2	-5%	867.7	-8%	891.9	-6%
Total Phosphorus	151.6	115.0	-24%	165.2	9%	147.3	-3%	107.3	-29%

No data are available on the extent of phosphorus recycling from the bottom of the reservoir. However, under certain conditions, bottom sediments can be important sources of phosphorus to the overlying waters of reservoirs, particularly if the reservoir is shallow or experiences period of low dissolved oxygen (Chapra, 1997). Under well-oxygenated conditions, phosphorus forms insoluble ferric hydroxide complexes and sediments out of the water column. Under low-oxygen conditions these complexes dissociate and phosphorus may be released from the sediment layer, entering the water column and contributing to loading (Chapra, 1997). Indicators of potential nutrient loading from sediment sources include probable high concentrations of phosphorus in the sediment and known low-oxygen conditions in the waterbody, or evidence of algal blooms following turnover.

The CE-QUAL-W2 reservoir model assumed a TP load equal to 0.015 times the SOD rate, or 18.75 mg-P/m^2/d from the bottom sediments for those days and in those areas where the reservoir becomes anoxic (oxygen less than 0.1 mg/L). Because profile data for nutrients in the reservoir were lacking, this rate could not be calibrated. In addition, much of this sediment phosphorus release will eventually be sorbed and recycled back to the sediments, and the release will not occur under aerobic conditions. The CE-QUAL-W2 parameter thus provides an approximate upper bound on the likely recycle rate of phosphorus from the sediments.

Another perspective on the *net* contribution of phosphorus recycling from the sediment can be obtained by applying the method of Nurnberg (1984; cited in Welch and Jacoby, 2004). This approach applies an empirical TP retention coefficient for oxic conditions without sediment regeneration of TP, based on flushing rate and average depth to the inflow TP, then uses the difference between predicted and observed inlake TP to estimate net sediment recycling. Specifically,

$$\mathbf{L_{int} = z\rho\ [TP - TP_i \cdot (1\text{-}R)],}$$

where L_{int} is the net internal loading rate, z is the mean depth, ρ is the flushing rate, TP is the inlake average TP concentration, TP_i is the influent average TP concentration, and R is the net recycle rate for oxic conditions, estimated as 15/(18 + zρ).

Using data from 2000-2006, the mean depth of the Tongue River Reservoir is 5.06 m, flushing rate 4.155 yr^{-1}, influent TP 56.66 µg/L, and inlake TP average 55.38 µg/L. Applying Nurnberg's method yields an estimated *net* sediment phosphorus recycle rate of 1.18 mg/P/m^2/d – as an average over all portions of the bottom sediment and all times of the year. The total resulting load is 4,308 kg/yr (4.75 tons/yr), which is much smaller than the existing external load – suggesting that net recycling from the sediment is likely of minor importance for the total P balance of the reservoir.

Shoreline erosion is an additional potential source of sediment and TP because of the frequently changing reservoir volumes and subsequent wetting and drying of the shoreline soils. No information is available with which to make an estimate of shoreline erosion.

7.4 Suspended Solids

As described in Section 7.0, the Tongue River Reservoir was listed as impaired for total suspended solids (TSS) on the 1996 303(d) list. The basis of this listing is unknown. Suspended solids were not identified as a cause of impairment on the 2006 303(d) list. This section presents an updated evaluation of the Tongue River Reservoir relative to siltation/suspended solids.

The analysis is divided into two sections: (1) an evaluation of measured data and; (2) analysis of sources.

7.4.1 Measured Data

All available SSC and TSS data for the Tongue River Reservoir are summarized in Table 7-10. Data collected in the Tongue River are presented in Section 3.4. Most concentrations in the reservoir are relatively low (less than 10 mg/L) and range from 2 to 121 mg/L. The median value of all samples is 8 mg/L.

Concentrations near the dam are usually less than concentrations in the upstream (southern) portion of the reservoir. This may be due to the settling of the larger particles as they move downstream. DNRC reports that most large soil particles settle out prior to even reaching the reservoir and therefore sedimentation of the reservoir has not historically been a problem (Personal Communications, Kevin Smith, March 21, 2005). As shown in Section 3.4.3, approximately 72 percent of the suspended solids are settled out the Tongue River between the USGS gage at the state line (06306300) and downstream of the Tongue River Reservoir Dam (06307500).

Table 7-10. Summary of all available TSS data, Tongue River Reservoir (mg/L).

Station ID	Count	Average	Min	Max	Period of Record
198	15	6.4	2.0	14.4	1975-1976
137	3	22.0	2.0	42.0	1975
196	14	8.8	4.9	13.1	1975-1976
136	6	20.7	5.4	51.3	1976
Y15TRR01	8	10.0	10.0	10.0	2001
Y15TRR03	4	38.5	21.0	73.0	2001
Y15TRR02	6	22.8	10.0	50.0	2001
Y15TNGRR03	13	14.0	4.0	121.0	2003
Y15TNGRR02	12	6.4	4.0	23.0	2003
Y15TNGRR01	12	12.1	4.0	60.0	2003

Data collected by MDEQ and USEPA. Site locations are shown in Figure 7-1.

7.4.2 Sediment Sources

Soils in the Tongue River watershed are naturally highly erodible (see the Status Report; MDEQ, 2003). These attributes, in combination with semiarid conditions, flashy rain events, and sparse ground cover, result in naturally high sediment erosion. Buttes and badlands occur throughout the landscape, and saline or sodic soils limit plant growth in several areas.

Cattle are the predominant agricultural resource in the watershed (NASS, 2002) and it is well documented that cattle have the potential to impact the landscape, if not managed properly (Meehan, 1991). In the uplands, decreased ground cover, increased erosion, and the promotion of invasive species can occur from overgrazing. In the lowlands and stream valleys, cattle grazing can have direct impacts to the stream and riparian area (destabilized stream banks, lack of riparian cover, habitat degradation) (Meehan, 1991). However, the relative contribution of sediment to the stream is unknown.

Other potential sediment sources upstream of the Tongue River Reservoir may include unpaved roads, irrigated agriculture, various drainage features (return flows and irrigation dikes) that may alter both the flow and sediment dynamics in the system, and disturbed lands associated with the construction and operation of coal mines and coal bed methane development. Both water spreading and sprinkler irrigation are common throughout the mainstem of the Tongue River, but both are generally constructed to minimize water loss and erosion from a field (NRCS, 2002). Irrigation can affect flows and sediment supply in the stream, resulting in a lack of flushing flows and sediment imbalances. The effect of irrigation on in-stream sediment and sediment supply is unknown, and unquantifiable at the time of this report.

Another potential source of sediment loading to the reservoir is shoreline erosion. Shoreline erosion in a reservoir occurs when wave activity undercuts poorly consolidated soils and the higher slopes undergo mass movement into the water (Wetzel, 2001). This type of erosion is considered to potentially be significant in the Tongue River Reservoir because of (1) the large month-to-month variability in water volumes (which exposes large surface areas; see Appendix H); and (2) high winds that contribute to frequent wave activity. At the time of this report, no data have been collected with which to quantify the magnitude of shoreline erosion.

8.0 SUMMARY AND CONCLUSIONS

This document presents an assessment of water quality in the Tongue River, Tongue River Reservoir, and Hanging Woman, Otter, and Pumpkin Creeks. This assessment is based on data and information through September 2006 (this varies on a case-by-case basis depending upon data availability). The focus was on the listed pollutants and impaired beneficial uses from the 1996 and 2006 Montana 303(d) lists. Pollutants addressed included salinity, sodium adsorption ratio (SAR), metals, sulfates, sediment, nutrients, dissolved oxygen, and temperature. The primary purpose of this assessment was to compare the available water quality data to the applicable Montana water quality standards. This comparison has been made for informational purposes to provide watershed stakeholders and decision makers with baseline information regarding the current condition of the waters in the Tongue River Watershed. Formal interpretation of Montana's water quality standards and 303(d) impairment decisions are beyond the scope of these analyses and are not provided.

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