Water Quality Assessment for the Tongue River Watershed, Montana

August 2, 2007

Appendices

FINAL DRAFT

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

Project Manager: Ron Steg

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A.0 MONTANA NARRATIVE WATER QUALITY STANDARDS

The narrative Montana water quality standards applicable to the 303(d) listed pollutants in the Tongue River watershed are provided below. The full set of standards for the State can be found in the Administrative Rules of Montana (ARM), Chapter 30, Subchapter 6. Numeric water quality standards, where applicable, are discussed in Appendix B.

17.30.624 B-2 CLASSIFICATION STANDARDS

(1) Waters classified B-2 are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) No person may violate the following specific water quality standards for waters classified B-2:

(f) No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(h) Concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient, or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7.

(i) Dischargers issued permits under ARM Title 17, chapter 30, subchapter 13, shall conform with ARM Title 17, chapter 30, subchapter 7, the nondegradation rules, and may not cause receiving water concentrations to exceed the applicable standards specified in department Circular DEQ-7 when stream flows equal or exceed the design flows specified in ARM 17.30.635(4).

(j) If site-specific criteria for aquatic life are adopted using the procedures given in 75-5-310, MCA, the criteria shall be used as water quality standards for the affected waters and as the basis for permit limits instead of the applicable standards in department Circular DEQ-7.

(k) In accordance with 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water as long as the minimum treatment requirements, adopted pursuant to 75-5-305, MCA, are met.

17.30.625 B-3 CLASSIFICATION STANDARDS

(1) Waters classified B-3 are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) No person may violate the following specific water quality standards for waters classified B-3:

(f) No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(h) Concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient, or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7.

(i) Dischargers issued permits under ARM Title 17, chapter 30, subchapter 13, shall conform with ARM Title 17, chapter 30, subchapter 7, the nondegradation rules, and may not cause receiving water concentrations to exceed the applicable standards specified in department Circular DEQ-7 when stream flows equal or exceed the design flows specified in ARM 17.30.635(4).

(j) If site-specific criteria for aquatic life are adopted using the procedures given in 75-5-310, MCA, the criteria shall be used as water quality standards for the affected waters and as the basis for permit limits instead of the applicable standards specified in department Circular DEQ-7.

(k) In accordance with 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water as long as the minimum treatment requirements, adopted pursuant to 75-5-305, MCA, are met.

17.30.629 C-3 CLASSIFICATION STANDARDS

(1) Waters classified C-3 are to be maintained suitable for bathing, swimming, and recreation, and growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply. Degradation which will impact established beneficial uses will not be allowed.

(2) No person may violate the following specific water quality standards for waters classified C-3:

(f) No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(h) Concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient, or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7.

(i) Dischargers issued permits under ARM Title 17, chapter 30, subchapter 13, shall conform with ARM Title 17, chapter 30, subchapter 7, the nondegradation rules, and may not cause receiving water concentrations to exceed the applicable standards specified in department Circular DEQ-7 when stream flows equal or exceed the design flows specified in ARM 17.30.635(4).

(j) If site-specific criteria for aquatic life are adopted using the procedures given in 75-5-310, MCA, the criteria shall be used as water quality standards for the affected waters and as the basis for permit limits instead of the applicable standards specified in department Circular DEQ-7.

(k) In accordance with 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water as long as the minimum treatment requirements, adopted pursuant to 75-5-305, MCA, are met.

17.30.637 GENERAL PROHIBITIONS

(1) State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will:

- (a) Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines;
- (b) Create floating debris, scum, a visible oil film (or be present in concentrations at or in excess of 10 milligrams per liter) or globules of grease or other floating materials;
- (c) Produce odors, colors or other conditions as to which create a nuisance or render undesirable tastes to fish flesh or make fish inedible;
- (d) Create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life; and
- (e) Create conditions which produce undesirable aquatic life.

(2) No wastes may be discharged and no activities conducted such that the wastes or activities, either alone or in combination with other wastes or activities, will violate, or can reasonably be expected to violate, any of the standards.

(3) Leaching pads, tailing ponds, or water, waste, or product holding facilities must be located, constructed, operated and maintained in such a manner and of such materials so as to prevent the discharge, seepage, drainage, infiltration, or flow which may result in the pollution of surface waters. The department may require that a monitoring system be installed and operated if the department determines that pollutants are likely to reach surface waters or present a substantial risk to public health.

(a) Complete plans and specifications for proposed leaching pads, tailing ponds, or water, waste, or product holding facilities utilized in the processing of ore must be submitted to the department no less than 180 days prior to the day on which it is desired to commence their operation.
(b) Leaching pads, tailing ponds, or water, waste, or product holding facilities operating as of the effective date of this rule must be operated and maintained in such a manner so as to prevent the discharge, seepage, drainage, infiltration or flow which may result in the pollution of surface waters.

(4) Dumping of snow from municipal and/or parking lot snow removal activities directly into surface waters or placing snow in a location where it is likely to cause pollution of surface waters is prohibited unless authorized in writing by the department.

(5) Until such time as minimum stream flows are established for dewatered streams, the minimum treatment requirements for discharges to dewatered receiving streams must be no less than the minimum treatment requirements set forth in ARM 17.30.635(2) and (3).

(6) Treatment requirements for discharges to ephemeral streams must be no less than the minimum treatment requirements set forth in ARM 17.30.635(2) and (3). Ephemeral streams are subject to ARM 17.30.635 through 17.30.637, 17.30.640, 17.30.641, 17.30.645 and 17.30.646 but not to the specific water quality standards of ARM 17.30.620 through 17.30.629.

(7) Pollution resulting from storm drainage, storm sewer discharges, and non-point sources, including irrigation practices, road building, construction, logging practices, over-grazing and other practices must be eliminated or minimized as ordered by the department.

(8) Application of pesticides in or adjacent to state surface waters must be in compliance with the labeled direction, and in accordance with provisions of the Montana Pesticides Act (Title 80, chapter 8, MCA) and the Federal Environmental Pesticides Control Act (7 USC 136, et seq., (Supp. 1973) as amended). Excess pesticides and pesticide containers must not be disposed of in a manner or in a location where they are likely to pollute surface waters.

(9) No pollutants may be discharged and no activities may be conducted which, either alone or in combination with other wastes or activities, result in the total dissolved gas pressure relative to the water surface exceeding 110 percent of saturation.

APPENDIX B –METHODOLOGY FOR APPLYING MONTANA'S WATER QUALITY STANDARDS

B.0 METHODOLOGY FOR APPLYING MONTANA'S WATER QUALITY STANDARDS

One of the primary goals of this water quality assessment was to provide a comparison of the available water quality data to the applicable Montana water quality standards. For pollutants with numeric criteria such as salinity, SAR, and metals, Montana's numeric criteria were used directly as a point of reference for this comparison. However, for pollutants with only narrative criteria such as chlorides, sulfates, sediment, nutrients and temperature, it was necessary to develop a suite of indicators representing the narrative criteria. These indicators were used as a point of reference for comparison of the available water quality data to the narrative standards.

The comparisons to Montana's water quality standards are presented for informational purposes only. The criteria and indicators are used only as a point of reference to facilitate the comparison. Water quality impairment decisions for the purpose of Clean Water Act Section 303(d) are not presented or implied and are the delegated responsibility of the States.

B.1 Tongue River Tributaries

The tributaries addressed in this appendix include Hanging Woman Creek, Otter Creek, and Pumpkin Creek. The characteristics of these water bodies differ considerably from the main stem of the Tongue River and the Tongue River Reservoir in terms of hydrologic response, physical size, and biota that inhabit them. This necessitates a unique approach for the tributaries. This section presents the criteria, indicators and methods used to apply Montana's water quality standards in the tributaries to the Tongue River.

B.1.1 Salinity and TDS

The State of Montana adopted maximum and average numeric criteria for salinity (as measured by electrical conductivity, EC, in µS/cm) on June 6, 2003 (Table B-1) (ARM 17.30.670). The Montana criteria are specified separately for the growing season (March 2–October 31) and non-growing season (November 1–March 1), although the seasonal values are identical for EC in the Tongue River tributaries. These values are used directly to measure agricultural beneficial use impairment.

Throughout this document, 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.

Table B-1. Montana's numeric salinity criteria for tributaries to the Tongue River.

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

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, or ≥4 data points per month) and whether or not the available data adequately 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 used in each of the subject water bodies. This analysis is presented in Appendix E. The specific approach for applying the monthly standard is presented in the main body of the document.

B.1.2 Sodium Adsorption Ratio

The State of Montana adopted maximum and average numeric criteria for sodium adsorption ratio (SAR) on June 6, 2003 (Table B-2) (ARM 17.30.670). Criteria vary by growing season (March 2–October 31) versus non-growing season (November 1–March 1). These values are used directly to measure agricultural beneficial use impairment.

Throughout this document, 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.

Table B-2. Montana's numeric SAR criteria for tributaries to the Tongue River.

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

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 adequately 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 used in each of the subject water bodies. This analysis is presented in Appendix E. The specific approach for applying the monthly standard is presented in the main body of the document.

B.1.3 Chlorides

Montana does not currently have numeric criteria for chlorides. The narrative standards applicable to chlorides are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,) (see Appendix A). The prohibition against the creation of "concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life" is generally the most relevant to chlorides. USEPA recommends chloride criteria for streams and rivers based on the aquatic toxicity of plant, fish, and invertebrate species (USEPA, 1988). Recommended aquatic life criteria are 860 mg/L (acute) and a 230 mg/L (chronic). These criteria are proposed as a basis of comparison for all streams in the Tongue River watershed. Chloride is also one component of the total dissolved solids (salinity) in a stream. Because of this, high chloride concentrations can also adversely affect agricultural beneficial uses. The USDA salinity lab reports an alfalfa chloride tolerance of 700 mg/L in the soil water (USDA, 2004). The chronic aquatic life recommendations are stricter and, therefore, have been used as a point of reference for comparison to the available water quality data.

B.1.4 Sulfates

Sulfate, often the dominant anion in southeast Montana streams (USGS, 2001; USGS, 2002), is one component of salinity (or total dissolved solids). The narrative standards applicable to sulfate (SO_4) are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of “concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life” is generally the most relevant to sulfates. Sulfates are generally a threat to agricultural uses because of the potential to increase stream salinity. However, sulfate itself generally does not threaten agricultural uses at concentrations commonly found in the natural environment (Eaton, 1942; Wickman and Vavrovsky, 2002). Sulfate can also provide fertility benefits to crops, and is often applied with fertilizers (Tisdale et al., 1993). Therefore, the salinity standards presented in Section B.1.1 are a considered a surrogate point of reference for sulfates for the purposes of this assessment.

B.1.5 Metals

Montana has numeric standards for most metals (contained in Montana DEQ Circular DEQ-7). There are three different numeric standards for each metal: acute and chronic toxicity aquatic life standards designed to protect aquatic life uses, and the human health standard, designed to protect drinking water uses (MDEQ, 2006b). Many of the aquatic life criteria for metals vary according to the hardness of the water. Table B-3 shows the aquatic life criteria as specified in DEQ-7. Table B-4 shows the acute and chronic aquatic life standards and the human health standards applicable to the metals of concern in the Tongue River watershed, re-expressed at average Tongue River hardness, where applicable. These numeric criteria will be directly applied to metals data in the Tongue River watershed (with hardness corrections as necessary, see Table B-4).

It should be noted that the metals criteria in DEQ-7 are based on “total recoverable” metals. However, few total recoverable metals data were available for the Tongue River watershed. Because of this, data reported as “total metals” are also included in the Assessment Report. As reported in 40 CFR Part 136.3 (Guidelines Establishing Test Procedures for the Analysis of Pollutants), the two methods are considered equivalent, although they differ slightly in the digestion process.

The procedures used to sample metals in the field and analyze metals in the laboratory have changed substantially over time. General speculation is that historical metals sampling results are often questionable because of possible contamination during collection and processing. New metals procedures set by USEPA and Montana DEQ have been implemented to ensure clean sampling results (USEPA, 1996). Analytical procedures in the laboratory now have better accuracy and lower detection limits. Because of these issues, only metals data collected after 1996 are analyzed in this report.

To maintain the highest level of quality, only data collected by USGS, Montana DEQ, and USEPA are used in these analyses. Data collected by private companies or landowners (having unknown quality assurance/quality control) are not used in this report.

Table B-3. Montana numeric aquatic life criteria for metals.

Parameter	Acute (µg/L)[a] at 25 mg/L hardness	Chronic (µg/L)[b] at 25 mg/L hardness
Arsenic (TR)	340	150
Cadmium (TR)	0.52[c]	0.097[c]
Chromium (III) (TR)	5.79[c]	27.7[c]
Copper (TR)	3.79[c]	2.85[c]
Iron (TR)	—	1,000
Lead (TR)	13.98[c]	0.545[c]
Nickel (TR)	145[c]	16.1[c]
Selenium (TR)	20	5
Silver (TR)	0.374[c]	—
Zinc (TR)	37[c]	37[c]

[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). Corrections to ambient hardness are provided in Appendix C.
TR – Total Recoverable.

Table B-4. Montana numeric criteria for metals at Tongue River average hardness.

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.

*B.1.6 **Sediment** (i.e., Siltation and Suspended solids)*

Sediment (i.e., coarse and fine bed sediment), siltation, and suspended solids are addressed via the narrative standards identified in Table B-5.

Table B-5. Applicable narrative standards for sediment related pollutants.

Administrative Rules	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-2, B-3, and C-3.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will:
17.30.637(1)(a)	Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
	The maximum allowable increase above naturally occurring turbidity is: 0 NTU for A-closed; 5 NTU for A-1, B-1, and C-1; 10 NTU for B-2, C-2, and C-3
17.30.602(17)	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971 are natural.
17.30.602(21)	“Reasonable land, soil, and water conservation practices” means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.

Streams in the Great Plains region of Montana have flashy flows and highly erodible soils (see the Status Report), both of which contribute to naturally high sediment in streams throughout the region. These factors result in streams that have naturally high sediment bedload, shifting channels, few riffles, silt and clay substrates, and turbid water (Moody et al., 1999; Pizzuto, 1994; Bramblett et al., 2004). Several species of fish in the region (paddlefish, sturgeon chub, sauger) are specifically adapted to warm, turbid waters, and provide evidence that the high sediment loads in southeast Montana prairie streams have existed for a long period of time (MFWP, 2003).

At the same time, there are anthropogenic sediment sources in most southeast Montana watersheds, which contribute some increment of additional sediment to streams. The combination of naturally high sediment loading and human-caused landscape alterations makes application of Montana’s narrative sediment criteria difficult because:

- In their natural condition, prairie streams have more fine sediments than streams in the mountains or foothills regions in Montana. 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 (Bramblett et al., 2004).
- 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. 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.

While research is ongoing in an attempt to resolve these issues, at the time of this report, there are no definitive indicators available for direct comparison to the narrative criteria in the Tongue River watershed. Therefore, a suite of indicators within the following four data type categories were compiled to create a measurable point of reference for the narrative sediment criteria:

- Physical Habitat and Channel Condition Data
- Biological Data
- In-stream chemistry data
- Information pertaining to the presence or absence of anthropogenic sources and/or the relative significance of anthropogenic sources.

The suite of sediment indicators is presented in Table B-6 and details regarding each of the indicators are discussed in the following sections.

Table B-6. Summary of sediment indicators for tributaries to the Tongue River.

Indicator	Point of Reference
Water Chemistry (SSC/TSS)	• Comparable to Regional Conditions • Stable conditions or improving trends • No localized sediment loading
Relative Bed Stability Index	> -2.2
Riparian and Bank Condition Index	> 61
NRCS Riparian Assessment Score	> 74% (Sustainable)
Rapid Habitat Assessments	> 76%
Human Influence Index (HII)	>614

B.1.6.1 NRCS Stream Corridor Assessment

The Natural Resources Conservation Service (NRCS) inventoried point, linear, and riparian features for Hanging Woman Creek, Otter Creek, Pumpkin Creek, and the Tongue River in Big Horn, Custer, Powder River, and Prairie Counties, Montana. These data were summarized in two reports: *Powder River and Tongue River Stream Corridor Assessment Montana Reaches Phase I – Rapid Aerial Assessment*, and *Tongue River Stream Corridor Assessment Montana Reaches Phase II – Physical Habitat Assessment* (NRCS, 2001; NRCS, 2002).

Data from the Phase I report were used to evaluate potential sources of sediment in the target watersheds. Data from Phase II were used to evaluate the condition of riparian corridors, stream banks, and channel morphology (physical habitat and channel condition data). NRCS assigned scores to various channel characteristics, including:

Incisement	Lateral Cutting	Sediment Balance
Soils	Binding Root Mass	Woody Establishment
% Utilization	Riparian/Wetland Characteristics	Floodplain
Irrigation Impacts	Land Use Activities	

Based on these scores and estimated stream potential, sites were classified as Sustainable, At Risk, and Not Sustainable. Class descriptions are shown below (NRCS, 2002).

- **Sustainable** (>74%) – the stream and associated riparian area had certain expected attributes – flood plain, adequate riparian vegetation, sufficient soil, and channel characteristics in place, and processes such as energy dissipation, sediment trapping, and biotic function were working together to make the system stable.

- **Not Sustainable** (50-74%) – the stream and riparian system clearly lacked adequate vegetation, channel characteristics, etc., and was not able to demonstrate any of the processes that would be expected in a stable system. Accelerated bank erosion, sediment deposition or another indicator of imbalance was present.

- **At Risk** (<50%) – most of the attributes and processes are in place and working. What was lacking, however, was critical to stability and function. For example, most of the criteria may have been scored adequate except that vegetative cover may have been determined to be inadequate (with respect to potential) to protect the area from high flows. In this case, the area received an “At Risk” rating.

A physical habitat assessment score of >74 percent or greater (sustainable) was used as the point of reference. It should be noted that some sites were classified as “At Risk” or “Not Sustainable” because of natural conditions (i.e., flooding, drought, soils, geology). NRCS noted where these sites occurred.

B.1.6.2 Suspended Sediment/Total Suspended Solids Data

Total suspended solids (TSS) and suspended sediment concentrations (SSC) were collected at various sites throughout the Tongue River watershed from 1971 to present. However, there are few appropriate reference streams to compare to measured data. For the Tongue River and Tongue River Reservoir, there are essentially no reference streams. TSS and SSC data are used as indicators in three different ways:

- Compare data for Hanging Woman Creek, Otter Creek, and Pumpkin Creek to other Great Plains wadable streams.
- Analyze data for temporal trends.
- Analyze data for spatial trends, or localized sediment loading throughout specific segments.

Ideally, data should be similar to reference conditions, should show stable or improving trends, and should show no indications of localized (human caused) sediment loading.

TSS and SSC measure suspended solids mass by different methods. SSC, which uses a larger sample volume, is generally considered the more accurate method of measuring suspended solids mass in a stream, particularly at higher flows, as TSS data tend to underestimate the concentration of sand-sized particles in the sample (Gray et al., 2000). However, for the purpose of this analysis, TSS and SSC data were analyzed together, as the data are only used to determine broad temporal and regional trends. Also, data were collected by a variety of different agencies using multiple sampling techniques (i.e., grab samples, depth-width integrated, storm event, etc.). Again, data were combined and analyzed together for the purpose of broad scale assessments.

B.1.6.3 Relative Bed Stability Index

The substrate of a stream channel is one of the most important physical components for organisms that inhabit a stream. A stream bottom with excessive amounts of fine sediment (in this case, sediment less than 2 millimeters in diameter) is likely to contain a degraded aquatic macroinvertebrate community (Waters, 1995). In turn, fish that rely on macroinvertebrates as a food source will also be affected. In the Montana Northern Plains, most streams have a low gradient and contain higher amounts of sand and fine material than steeper gradient, faster flowing streams. Still, gravel and cobble substrates are common in the slow flowing streams and are important aquatic habitats (Bramblett et al. 2004). When an increase in fine sediment occurs, the gravel and cobble substrates can be covered with sediment and habitat quality for the biota is diminished (Waters, 1995).

The relative bed stability (RBS) metric is used to determine if a stream had excessive sediment (Kaufmann et al., 2004). Basically, the metric compares the measured median substrate size in the streambed to the maximum substrate size carried during bankfull events. In other words, if a stream is capable of moving large boulders during bankfull flow events, yet the measured median substrate is fine silt, then the metric suggests that excessive sediment loading is present. The metric is calculated as the Log_{10} of the median substrate size (D_{50}) divided by the maximum substrate size carried at bankfull width (D_{cbf}).

$$RBS = Log_{10} \frac{D_{50}}{D_{cbf}}$$

Additional details about the RBS, and how to calculate the D_{cbf}, can be found in the USEPA document, *Quantifying Physical Habitat in Wadeable Streams* (Kaufmann et al., 1999).

Reference sites for southeast Montana Northern Plains streams were used to determine thresholds for streams in good, fair, and poor condition based on relative bed stability (USEPA, 2005). Based on comparisons to the reference sites, the following classes were developed for excess sediment using the relative bed stability metric:

- > -2.2 indicates a good condition
- -2.7 to -2.2 indicates a fair condition
- < -2.7 indicates a poor condition

These values are proposed as an indicator in the wadable streams in the Tongue River watershed (i.e., Hanging Woman Creek, Otter Creek, and Pumpkin Creek).

B.1.6.4 Riparian and Bank Condition Index

Qualitative estimates of bank condition and riparian vegetation were obtained at sites throughout southeast Montana as part of the Environmental Monitoring and Assessment Program (EMAP) and Regional Environmental Monitoring and Assessment Program (REMAP) programs. Several estimates, including bank stability and riparian vegetation, were combined to form a riparian and bank condition (RBC) index. RBC indexes were well correlated with stream impairment – “good” (high) RBC scores were generally correlated with few anthropogenic sources and good stream biology. The index was based on a scale of 0 to 100. Based on comparisons with the reference site scores, the following condition classes were developed (USEPA, 2005):

- >61 indicates good riparian and bank conditions,
- 49-60 indicates fair riparian and bank conditions,
- <48 indicates poor riparian and bank conditions.

These values are proposed as an indicator in the wadable streams in the Tongue River watershed (Hanging Woman Creek, Otter Creek, and Pumpkin Creek).

B.1.6.5 Rapid Habitat Assessments

Various studies throughout the Tongue River watershed have used the Montana DEQ Rapid Bioassessment Macroinvertebrate Protocols (Bukantis, 1997) or USEPA rapid habitat assessment protocols (Lazorchak et. al, 2001) to evaluate riparian and channel health. The following is a list of features evaluated as part of the rapid habitat assessments.

Riffle Development	Benthic Substrate	Embeddedness
Channel Alteration	Sediment Deposition	Channel Flow Status
Bank Stability	Bank Vegetation Protection	Riparian Vegetation Width

The following condition classes were adopted from Plafkin et. al, 1989.

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

Based on these condition classes, a rapid habitat assessment score of 76 percent or higher is proposed as the point of reference for this indicator.

B.1.6.6 Human Influence Index (HII)

Bramblett et al. (2004) developed a human influence index (HII) to systematically compare human disturbance among multiple watersheds. Variables were selected representing reach-level habitat and disturbance, landscape-level disturbance, and water chemistry that were potentially affected by human activities. The HII was created by first listing raw values of the human influence attributes for each reach, then calculating the rank of these raw values among all reaches, and finally summing the ranks to form the HII score for the sampling reach. The HII scores were then separated into thirds based on percentiles to form strata; good was the top third of HII scores, fair was the middle third of HII scores and poor was the bottom third of HII scores. Four reaches were randomly chosen from each stratum to form the validation data set. HII attributes included such variables as the Rapid Habitat Assessment score, channel dimensions, fish cover, mid-layer canopy cover, substrate measures, near sample site land use, and various chemical values. An HII value of 615 or greater (good category) is proposed as the point of reference for this indicator in the Tongue River tributaries.

B.1.6.7 Sediment Sources

A preliminary sediment source assessment was conducted for each stream to obtain a better understanding of anthropogenic sources and their relative importance in comparison to natural sources using a GIS application of the Universal Soil Loss Equation (USLE), bank erosion estimates, and other data available from literature or watershed studies.

Sediment Modeling (USLE)

Sediment loading from upland areas was estimated for the Tongue River watershed and tributaries using the Universal Soil Loss Equation (USDA, 1978). Data sources for the modeling were:

- Land Cover – Montana and Wyoming GAP Analysis
- Soils and Soil Properties – STATSGO Soils (USDA)
- Elevation and Slope – 30 meter Digital Elevation Models (DEM) (USGS)
- Equation Coefficients – "Design Hydrology and Sedimentology for Small Catchments," (Haan et. al., 1994)

This analysis is based on the following assumptions:

- All land cover classes from the GAP analysis occurring on slopes greater than 25 degrees were reclassified to "badlands". This assumption was made based on field reconnaissance and air photo review suggesting that vegetative cover was very sparse to nonexistent on steep slopes and these areas consisted of bare, exposed soil highly susceptible to erosion.
- The GAP land cover was assumed to be accurate and reflect current conditions.
- "Natural" conditions were assumed to reflect the absence of grazing and row crops, thus increasing the percent vegetative cover and decreasing C factors.
- Grazing was assumed to occur on all shrub, grassland, and riparian areas.

Two difference scenarios were modeled – existing conditions and "natural" (i.e., not grazed, no crops).

Bank Erosion

To estimate bank erosion, a simple analysis was performed using literature values and conservative assumptions. The amount of bank erosion was calculated based on riparian surveys (percent of stream with eroding banks), measurements of bank height, and estimates of erosion rates. Assuming an average bulk density of 60 pounds per cubic feet (Juvan, undated), the sediment loads from bank erosion could be estimated for each stream listed as impaired because of sediment, siltation, or total suspended solids.

B.1.7 Comparative Analysis of Tributary Water Quality Data

Appendix K compares water quality data in the 303(d) listed Tongue River tributaries to water quality data in other streams having similar watershed characteristics. Sufficient data were compiled to conduct this comparison for salinity (SC), SAR, TSS/SSC, nitrogen (various forms), phosphorus (various forms), dissolved oxygen, stream temperature, chlorides, chlorophyll-a, calcium, magnesium, sodium, sulfate, and turbidity. Streams had to have a watershed size of less than 2,000 square miles, had to be completely contained in the Great Plains ecoregion (i.e., not originating in the Big Horn Mountains), had to be near the Tongue River watershed, and generally had to have more than 50 sampling events at a single station over a period of 20 or more years. Twenty stations were identified from the USGS NWIS database based on these requirements, and data are presented in Appendix K.

No direct inferences are made about the condition of Tongue River watershed tributaries when evaluated with the other Great Plains streams, as many of the Great Plains streams are also listed on various 303(d) lists. The Great Plains streams simply serve as a starting point with which to compare water quality data, specifically for Hanging Woman Creek, Otter Creek, and Pumpkin Creek.

B.2 Main Stem Tongue River

As described in Section 1.1, the 303(d) listed causes of impairment for the mainstem of the Tongue River have included the following pollutants: metals, other inorganics (i.e., sulfates), salinity/TDS/chlorides, and suspended solids. This section presents the standards, indicators, and methods used to apply Montana's water quality standards for each of the above listed pollutants in the mainstem of the Tongue River. The proposed approach for metals, chlorides and other inorganics (i.e., sulfates) in the Tongue River is the same as described previously for the tributaries (refer to Sections B.1.3, B.1.4, and B.1.5).

B.2.1 Salinity

The State of Montana adopted maximum and average numeric criteria for salinity (as measured by electrical conductivity, EC, in µS/cm) on June 6, 2003 (Table B-7) (ARM 17.30.670). Criteria vary by growing season (March 2–October 31) versus non-growing season (November 1–March 1). These values are used directly to measure agricultural beneficial use impairment. The approach for applying the monthly average criteria is described above in Section B.1.1.

Throughout this document, 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.

Table B-7. Montana's numeric salinity criteria for the Tongue River.

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

B.2.2 Sodium Adsorption Ratio

The State of Montana adopted maximum and average numeric criteria for sodium adsorption ratio (SAR) on June 6, 2003 (Table B-8) (ARM 17.30.670). Criteria vary by growing season (March 2–October 31) versus non-growing season (November 1–March 1). These values are used directly to measure agricultural beneficial use impairment. The approach for applying the monthly average criteria is described above in Section B.1.2.

Throughout this document, 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.

Table B-8. Montana’s numeric SAR criteria for the Tongue River.

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

B.2.3 Sediment (i.e., Suspended Solids)

As described in Section B.1.6, sediment, suspended solids, and siltation are addressed by Montana’s narrative standards (see Table B-5). A suite of indicators within the following four data type categories were compiled to create a measurable point of reference for the narrative sediment criteria in the mainstem Tongue River:

- Physical Habitat and Channel Condition Data
- Biological Data
- In-stream chemistry data
- Information pertaining to the presence or absence of anthropogenic sources and/or the relative significance of anthropogenic sources.

Given the availability of data and the fact that the Tongue River is a 5^{th} order stream, the suite of sediment indicators used for the Tongue River differs from those presented previously for the tributaries. The suite of sediment indicators is presented in Table B-9. Details regarding each of the indicators were presented above in Section B.1.6.

Table B-9. Summary of sediment indicators for the Tongue River.

Indicators	Point of Reference
Water Chemistry (SSC/TSS)	• Comparable to Regional Conditions • Stable conditions or improving trends • No localized sediment loading
NRCS Riparian Assessment Score	> 74% (Sustainable)
Rapid Habitat Assessments	> 75%

B.2.4 Metals

The metals standards described in Section B.1.5 will also be applied to metals data in the Tongue River.

B.3 Tongue River Reservoir

As described in Section 1.1, the 303(d) listed causes of impairment for the Tongue River Reservoir have included the following pollutants: nutrients, organic enrichment/dissolved oxygen, chlorophyll-a, and suspended solids (MDEQ, 1996, MDEQ, 2006). This section presents the criteria, indicators and methods used to apply Montana's water quality standards for each of the above listed pollutants, as well as salinity and SAR, in the Tongue River Reservoir.

B.3.1 Salinity

The State of Montana adopted maximum and average numeric criteria for salinity (as measured by electrical conductivity, EC, in µS/cm) on June 6, 2003 (Table B-10) (ARM 17.30.670). Criteria for the Tongue River Reservoir do not vary by growing season (March 2–October 31) versus non-growing season (November 1–March 1). These values are used directly to measure agricultural beneficial use impairment. The approach for applying the monthly average criteria is described above in Section B.1.1.

Table B-10. Montana's numeric salinity criteria for the Tongue River Reservoir.

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

B.3.2 Sodium Adsorption Ratio

The State of Montana adopted maximum and average numeric criteria for sodium adsorption ratio (SAR) on June 6, 2003 (Table B-11) (ARM 17.30.670). Criteria for the Tongue River Reservoir do not vary by growing season (March 2–October 31) versus non-growing season (November 1–March 1). These values are used directly to measure agricultural beneficial use impairment. The approach for applying the monthly average criteria is described above in Section B.1.2.

Table B-11. Montana's numeric SAR criteria for the Tongue River Reservoir.

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

B.3.3 Nutrients

Montana does not have numeric water quality criteria for nutrients (i.e., nitrogen and phosphorus); instead, the impacts of excess nutrient concentrations are addressed via narrative standards. Determining appropriate nutrient indicators for the Tongue River Reservoir is a complex undertaking due to the reservoir's unique features. The reservoir is not a natural lake; it is a part of the Tongue River that was flooded with the creation of the Tongue River Dam in 1940 (see Appendix H). The reservoir also has a relatively large ratio of watershed area to surface area (i.e., ratio of 308), which suggests that natural nutrient loadings to the reservoir would be larger than comparably-sized reservoirs or lakes with smaller upstream drainage areas (WOW, 2004). Finally, the reservoir's location and dam operations suggest that thermal stratification may be an important factor affecting its water quality (Wetzel, 2001).

Several potential nutrient indicators were identified through a literature review and modeling analysis. Indicators are summarized in Table B-12 and further discussed in the following sections. It should be noted, however, that regional or national standards developed for other reservoirs may not be appropriate to the Tongue River Reservoir because of the unique features described above. Indicator values should therefore be used with caution.

Table B-12. Preliminary nutrient indicators for the Tongue River Reservoir.

Source	TSI	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll-a (µg/L)
South Dakota Department of Environment and Natural Resources (SDDNER, 2005)	<58.5	<0.043	NA	<17.0
USEPA Nutrient Targets for Lakes and Reservoir in Ecoregion IV (USEPA, 2001)	NA	<0.020	< 0.44	< 2.0
Tongue River Modeling – "Natural Conditions"	NA	< 0.010	< 0.028	< 1.5

B.3.3.1 Modeling

A modeling approach was used to determine potential nutrient targets. The LSPC/HSPF watershed model was linked to the CE-QUAL-W2 lake model to simulate nutrient, dissolved oxygen, and chlorophyll-*a* concentrations in the reservoir (see the 2007 Modeling Report for additional information). The models were run for two scenarios – existing conditions and "natural" conditions (i.e., no anthropogenic sources of nutrients) – for the years 1997 through 2002. These years were chosen because they contained the most complete set of weather data (e.g., precipitation, wind speed, solar radiation) needed to run the W2 model.

Results from the natural scenario indicated that annual median chlorophyll-*a* concentrations at the surface of the reservoir near the dam during this period would range from 1.21 to 1.50 µg/L. The instantaneous maximum chlorophyll *a* concentration at this location was predicted to be 7.96 µg/L. Annual median total phosphorus concentrations under natural conditions were predicted to range from 5.3 to 10.0 µg/L with a long-term median of 9.6 µg/L. Annual median total nitrogen concentrations under natural conditions were predicted to range from 23.7 µg/L to 30.0 µg/L with a long-term median of 27.6 µg/L.

B.3.3.2 South Dakota Department of Environment and Natural Resources

Secchi disk transparency, chlorophyll *a*, and total phosphorus are often used to define the degree of eutrophication or trophic status of a lake (Carlson, 1977). 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 Dr. Robert Carlson (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. A target value of 58.5 for the Tongue River Reservoir was identified based on a statistical study of lakes in the Northwestern Great Plains ecoregion completed by the South Dakota Department of Environment and Natural Resources (SDDENR, 2005). Using the formulas below (obtained from Carlson, 1977), a TSI score of 58.5 translates into a total phosphorus target of 43 µg/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, 1997)

$$TSI(Chl) = 10 \times \left(6 - \frac{2.04 - 0.68(Ln(Chl))}{Ln2}\right)$$, where chlorophyll-*a* is in µg/L (Carlson, 1997)

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 is significant in the Tongue River Reservoir, the index is used to provide primarily a qualitative perspective on the condition of the reservoir.

B.3.3.3 USEPA Nutrient Targets

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). Because the approach is purely statistical, it does not guarantee that the targets are appropriate indices of support of beneficial uses; however, they are of value for a cross-sectional comparison.

B.3.4 Dissolved Oxygen

The numeric freshwater aquatic life standards for dissolved oxygen are presented in Table B-13 (MDEQ, 2006b). A table of fish spawning times and schedule for the presence of early life stages of fish that are likely to occur may be found at http://www.deq.state.mt.us/wqinfo/Standards/SpawningTimesFWP.pdf. The Montana dissolved oxygen standard is 5.0 mg/L as a 1-day minimum concentration and is used as a supplemental indicator to assess the nutrient impairment of the Tongue River Reservoir and also used directly to assess compliance with Montana’s DO standards.

Table B-13. Minimum Aquatic life standards (Class B2) for dissolved oxygen (mg/L).

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

[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.

B.3.5 Sediment (i.e., Suspended Solids)

Sediment (i.e., coarse and fine bed sediment), siltation, and suspended solids are addressed via the narrative standards identified in Table B-5.

Similar to nutrients, determining appropriate sediment indicators for the Tongue River Reservoir is a complex undertaking due to the reservoir's unique features and the lack of accepted target values for prairie lakes. In the absence of such accepted target values, a preliminary target for the Tongue River Reservoir has been adopted based on data collected from studies of water quality and fish response (Newcombe and MacDonald, 1991; Newcombe and Jensen, 1996). This research indicates that fish respond negatively when exposed to increasing concentrations of suspended sediments with increasing duration of exposure.

Newcombe and Jensen (1996) created a quantitative index, the "Severity of Ill Effects" scale (SEV), by which to define the qualitative fish responses to various sediment concentration-duration scenarios. The scale groups the responses into four major effect classes: nil effect, behavioral effects, sublethal effects and lethal effects. These were further categorized into a more detailed 15-point SEV scale and a regression model was developed to predict SEV based on various sediment doses. For adult freshwater nonsalmonids, long-term TSS concentrations below 20 mg/L are predicted to cause only behavioral effects and this value is proposed as a preliminary target for the Tongue River Reservoir.

B.4 References

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APPENDIX C –COEFFICIENTS FOR CALCULATING MONTANA METALS STANDARDS

C.0 COEFFICIENTS FOR CALCULATING MONTANA METALS STANDARDS.

The following formulas and table provide the coefficients necessary for calculating Montana's hardness dependant metals criteria. Values were obtained from Montana DEQ Circular DEQ-7 (Dated February 2006).

Acute Standard = exp.{a [ln(Hardness)] + b}

Chronic Standard = exp.{c [ln(Hardness)] + d}

Table C-1. Coefficients for calculating metals standards in Montana.

Parameter	Acute Coefficients		Chronic Coefficients	
	a	b	c	d
Cadmium	1.0166	-3.924	0.7409	-4.719
Copper	0.9422	-1.700	0.8545	-1.702
Chromium (III)	0.819	3.7256	0.819	0.6848
Lead	1.273	-1.46	1.273	-4.705
Nickel	0.846	2.255	0.846	0.0584
Silver	1.72	-6.52	—	—
Zinc	0.8473	0.884	0.8473	0.884

Note: If the hardness is < 25 mg/L as $CaCO_3$, the number 25 must be used in the calculation. If the hardness is greater than or equal to 400 mg/L as $CaCO_3$, 400 mg/L must be used in the calculation.

APPENDIX D – WYOMING AND NORTHERN CHEYENNE WATER QUALITY STANDARDS

D.0 WYOMING AND NORTHERN CHEYENNE WATER QUALITY STANDARDS

D.1 Wyoming Water Quality Standards

Wyoming classifies most of the major streams in the Tongue River drainage as Class 2AB streams (WDEQ, 2001). These streams are protected for drinking water, game fish, nongame fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value uses. The main stem of the Tongue River is a Class 2AB coldwater fishery stream. Other Class 2AB streams in Wyoming are Prairie Dog Creek and Goose Creek. Most of the tributaries to the Tongue River in Wyoming are classified as Class 3B streams and are protected for other aquatic life, recreation, wildlife, agriculture, industry, and scenic value uses.

D.1.1 Narrative Standards

Wyoming has narrative standards to protect all beneficial uses assigned to a waterbody, including industrial, agricultural, and aquatic life uses. Aquatic life uses are generally protected under Sections 28 and 32 of the standards which state that waters must be free of substances that "adversely alter the structure and function of indigenous or intentionally introduced aquatic communities", and no conditions may be produced which "cause undesirable aquatic life in a waterbody," (WDEQ, 2007). Agricultural uses of a waterbody are protected so that there shall be no "measurable decrease in crop or livestock production." Wyoming has chosen not to pursue numeric criteria for SAR and SC. SAR and SC impairments are determined by using the narrative standards and implementation procedures for determining those impairments. A summary of the Wyoming narrative standards is shown in Table D-1. All Wyoming standards can be accessed on the Internet at http://deq.state.wy.us.

D.1.2 Numeric Standards

Numeric surface water quality standards have been developed for the protection of beneficial uses in Wyoming waters. These standards apply to pollutants such as metals, fecal coliforms, pH, and other toxics (WDEQ, 2007). Unlike Montana, Wyoming's criteria for metals are expressed in the dissolved form, which constitutes the major bioavailable pool. Standards are summarized in Table D-2 and Table D-3.

Table D-1. Summary of the Wyoming narrative water quality standards.

Rule	Text	Affected Pollutants
Section 13	Except for those substances referenced in Sections 21 (e) and (f) of these regulations, toxic materials attributable to or influenced by the activities of man shall not be present in any Wyoming surface water in concentrations or combinations which constitute "pollution".	Metals
Section 15	In all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.	Total Suspended Solids Siltation
Section 16	In all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.	Total Suspended Solids Siltation
Section 19	All Wyoming surface waters which have the natural water quality potential for use as an industrial water supply shall be maintained at a quality which allows continued use of such waters for industrial purposes. Degradation of such waters shall not be of such an extent to cause a measurable increase in raw water treatment costs to the industrial user(s). Unless otherwise demonstrated, all Wyoming surface waters have the natural water quality potential for use as an industrial water supply.	All Parameters
Section 20	All Wyoming surface waters which have the natural water quality potential for use as an agricultural water supply shall be maintained at a quality which allows continued use of such waters for agricultural purposes. Degradation of such waters shall not be of such an extent to cause a measurable decrease in crop or livestock production. Unless otherwise demonstrated, all Wyoming surface waters have the natural water quality potential for use as an agricultural water supply.	Salinity SAR
Section 23	In all cold water fisheries and drinking water supplies (classes 1, 2AB, 2A, and 2B), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than ten (10) nephelometric turbidity units (NTUs). (b) In all warm water or nongame fisheries (classes 1, 2AB, 2B and 2C), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 15 NTUs.	Total Suspended Solids Siltation
Section 28	All Wyoming surface waters shall be free from substances and conditions or combinations thereof which are attributable to or influenced by the activities of man, in concentrations which produce undesirable aquatic life.	All Parameters
Section 32	Class 1, 2 and 3 waters of the state must be free from substances, whether attributable to human induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely alter the structure and function of indigenous or intentionally introduced aquatic communities.	All Parameters

Table D-2. Summary of the numeric Wyoming surface water quality standards.

Parameter	Aquatic Life (acute) (µg/L)[a]	Aquatic Life (chronic) (µg/L)[a]	Human Health (µg/L)[b]
Aluminum, *(pH 6.5-9.0 only)*	750	87	
Arsenic	340	150	7
Barium			2,000
Cadmium[c]	4.3	2.2	5
Chloride	860,000	230,000	
Chromium (III)[c]	569.8	74.1	100
Copper[c]	13.4	9	1,000
Iron	1,000	300	
Lead[c]	64.6	2.5	15
Manganese[c]	3,110	1,462	50
Nickel[c]	468.2	52.0	100
Silver[c]	3.4		
Zinc[c]	117.2	118.1	5,000
Fecal coliforms	During the entire year, fecal coliform concentrations shall not exceed a geometric mean of 200 organisms per 100 mL (based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period), nor shall the geometric mean of 3 separate samples collected within a 24-hour period exceed 400 organisms per 100 mL in any Wyoming surface water.		
pH	For all Wyoming surface waters, wastes attributable to or influenced by the activities of man shall not be present in amounts which will cause the pH to be less than 6.5 or greater than 9.0 standard units. For all Class 1, 2 and 3 waters, effluent attributable or influenced by human activities shall not be discharged in amounts which change the pH to levels which result in harmful acute or chronic effects to aquatic life, directly or in conjunction with other chemical constituents, or which would not fully support existing and designated uses.		

[a]Metals criteria are for dissolved metals.
[b]No 4-day (96-hour) or longer period average concentration may exceed these values.
[c]Hardness-dependent criteria. Value given is an example only and is based on a $CaCO_3$ hardness of 100 mg/L. Criteria for each case must be calculated using a formula (see Table D-4).

Table D-3. Minimum DO criteria[a] (mg/L) for Wyoming waters.

	Coldwater Criteria		Warmwater Criteria	
Period of Time	Early Life Stages[b,c]	Other Life Stages	Early Life Stages[c]	Other Life Stages
30-day mean	NA	6.5	NA	5.5
7-day mean	9.5 (6.5)	NA	6.0	NA
7-day mean minimum[d]	NA	5.0	NA	4.0
1-day minimum[d]	8.0 (5.0)	4.0	5.0	3.0

[a]These limitations apply to Class 1, 2A, 2B, and 2C waters only and in no case may be interpreted to require DO concentrations greater than 100 percent saturation at ambient temperature and elevation.
[b]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.
[c]Includes all embryonic and larval stages and all juvenile forms to 30 days after hatching.
[d]All minima should be considered as instantaneous concentrations to be achieved at all times.

Table D-4. Wyoming metals standards for hardness dependant parameters.*

Parameter	Acute	Chronic
Cadmium	e^ (1.128 [ln(hardness)]-3.6867)(CF)	e^ (0.7852 [ln(hardness)]-2.715)(CF)
Chromium (III)	e^ (0.8190 [ln(hardness)] +3.7256)(0.316)	e^ (0.8190 [ln(hardness)]+0.6848)(0.860)
Copper	e^ (0.9422 [ln(hardness)]-1.700)(0.960)	e^ (0.8545 [ln(hardness)]-1.702)(0.960)
Lead	e^ (1.273 [ln(hardness)]-1.460)(CF)	e^ (1.273 [ln(hardness)]-4.705)(CF)
Manganese	e^ (0.7693[ln(hardness)]+4.4995)	e^ (0.5434[ln(hardness)]+4.7850)
Nickel	e^ (0.8460 [ln(hardness)]+2.255)(0.998)	e^ (0.8460 [ln(hardness)]+0.0584)(0.997)
Silver	e^ (1.72 [ln(hardness)]-6.52)(0.85)	N/A
Zinc	e^ (0.8473 [ln(hardness)]+0.884)(0.978)	e^ (0.8473 [ln(hardness)]+0.884)(0.986)

*Hardness measured as mg/L $CaCO_3$. Hardness values used in these equations must be between 25 mg/L and 400 mg/L. For hardness values less than 25 mg/L, use 25. For hardness values greater than 400 mg/L use 400.

Conversion Factors: Aquatic life values for the above metals are based on dissolved amounts of each substance. Because the National Toxics Criteria (USEPA's Section 304(a) criteria) are expressed as "total recoverable" values, the application of a conversion factor is necessary to convert from "total recoverable" to "dissolved". Furthermore, the toxicity of the associated metals varies with hardness and the total recoverable value must be calculated based on the $CaCO_3$ hardness prior to multiplying by the conversion factor (CF).

D.2 Northern Cheyenne Tribal Standards

Based on the tribally adopted water quality standards (currently pending review by USEPA), the Tongue River is a beneficial use Class 1 coolwater stream from Cook Creek to the confluence with Logging Creek. From Logging Creek to the Northern Reservation border, the Tongue River is a Class 1 warmwater stream (NCEPD, 2002). Class 1 coolwater streams "provide for protection, propagation, and growth of coolwater fishes, as well as protection, growth, and propagation of associated aquatic life normally found where summer water temperatures do not often exceed 25 degrees Celsius." Class 1 warmwater streams "provide for protection, propagation, and growth of warmwater fishes, as well as protection, growth, and propagation of associated aquatic life normally found where summer water temperatures do not often exceed 35 degrees Celsius."

The Northern Cheyenne Tribe's narrative standards are similar to Montana's standards and address two basic concepts: (1) activities that would result in nuisance aquatic life are prohibited; and (2) no increases are allowed over naturally occurring conditions of sediment, settleable solids, oils, or floating solids, which are harmful to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

Numeric standards for the Tongue River watershed are shown in Table D-5 and Table D-6. The salinity (EC and TDS) standards are similar to the proposed Montana standards, but the SAR standards for the Tongue River and its tributaries are more stringent.

Table D-5. Northern Cheyenne surface water quality standards.

Parameter	Aquatic Life (acute) (µg/L)	Aquatic Life (chronic) (µg/L)	Human Health (µg/L)[a]
Aluminum (TR), (pH 6.5-9.0 only)	750	87	
Arsenic	340	150	18
Barium			1,000
Cadmium[b]	2.0	0.025	
Chloride	860,000	230,000	
Chromium (III)[b]	570	74	
Copper[b]	13	9.0	1,300
Iron		1,000	300
Lead[b]	65	2.5	
Nickel[b]	470	52	610
Selenium		5.0	170
Silver[b]	3.4	0.12	
Zinc[b]	120	120	9,100

[a]Maximum allowable concentration.
[b]Standard is dependent on the hardness of the water, measured as the concentration of $CaCO_3$ (mg/L). Values are shown at 100 mg/L hardness (see Appendix C for the coefficients to calculate the standard).
Note: TR – total recoverable.

Table D-6. Numeric standards for EC, TDS, and SAR for waters in the Northern Cheyenne Reservation.

	EC (µS/cm)	SAR	TDS (mg/L)
Southern Boundary			
Irrigation Period Average[a]	1,000	—	660
Year Round Maximum	2,000	2.0	1,320
Northern Boundary			
Irrigation Period Average[a]	1,500	—	990
Year Round Maximum	2,000	3.0	1,320
Tributaries			
Irrigation Period Average[a]	1,500	3.0	990
Year Round Maximum	2,000	3.0	1,320

[a]An "irrigation period average" is the 30-day average applicable during the period of active irrigation or water spreading, defined by the Tribe as April 1 through November 15, annually.

D.3 References

NCEPD. 2002. Northern Cheyenne Tribe of the Northern Cheyenne Indian Reservation – Surface Water Quality Standards (Draft Standards Submitted to USEPA on July 17, 2002).

WDEQ. 2001. Wyoming Surface Water Classification List (Dated June 21, 2001). Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

WDEQ. 2007. Water Quality Rules And Regulations – Chapter 1 – Wyoming Surface Water Quality Standards (Dated February 16, 2007). Wyoming Department of Environmental Quality. Cheyenne, Wyoming.

APPENDIX E – MONTHLY SC ANALYSIS

E.0 MONTHLY SC ANALYSIS

Montana has adopted instantaneous and monthly average salinity standards for the Tongue River and its tributaries. 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 from eight representative stations in the Tongue River, and one station each in Hanging Woman Creek, Otter Creek, and Pumpkin Creek 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 adequately represent the full range of flow conditions, and the current time period[a]. The selected stations are:

- Tongue River at Miles City – USGS Gage 06308500
- Tongue River above the T&Y Diversion Dam – USGS Gage 06307990
- Tongue River below the Brandenberg Bridge – USGS Gage 06307830
- Tongue River at the Birney Day School Bridge – USGS Gage 06307616
- Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500
- Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300
- Tongue River at Monarch, Wyoming – USGS Gage 06299980
- Tongue River at Dayton, Wyoming – USGS Gage 06298000
- Hanging Woman Creek near Birney, Montana – USGS Gage 06307600
- Otter Creek at Ashland, Montana – USGS Gage 06307740
- Pumpkin Creek near Miles City, Montana – USGS Gage 06308400

E.1 Salinity Standards

The monthly average salinity standards (measured as electrical conductivity, EC) for the mainstem Tongue River and tributaries in Montana are shown in Table E-1. The standard varies between the growing season and nongrowing season. While 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. All of the available USGS data is reported in SC rather than EC, and all salinity data will be reported as SC for the remainder of this document.

Table E-1. Monthly average salinity standards for the mainstem Tongue River and tributaries.

Waterbody	Season	Monthly Average EC Standard (µS/cm)
Mainstem Tongue River	Nongrowing Season (Nov 1 – Mar 1)	1,500
	Growing Season (Mar 2 – Oct 31)	1,000
Tributaries	Nongrowing Season (Nov 1 – Mar 1)	500
	Growing Season (Mar 2 – Oct 31)	500

[a] Throughout this document, 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.

E.2 Tongue River at Miles City Montana (06308500)

Both discrete and continuous SC data are available for the Tongue River at Miles City. Discrete data are instantaneous samples that were collected at varying frequencies since October 1, 1959. 627 discrete samples were collected between October 1, 1959 and September 20, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected during the growing season (i.e., mid March to November 1) at the Miles City gage between April 29, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as “average daily” SC values by USGS. There were 568 average daily values reported between April 29, 2004 and September 30, 2006.

Based on all of the available SC data at the Miles City gage, 423 months have at least one SC sample. Of those, 300 months have only 1 SC sample, 67 months have 2 samples, 22 months have 3 samples, and 34 months have 4 or more samples (Figure E-1). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006). There was also a period of more intense sampling between 1962 and 1970. Only one nongrowing season month had 4 or more samples (November 1968).

In the last 5 years (October 1, 2001 to September 30, 2006), 62 months had one or more SC samples. Of those, 32 months have only 1 SC sample, 7 months have 2 samples, 1 month has 3 samples, and 22 months have 4 or more samples (Figure E-1). All of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006).

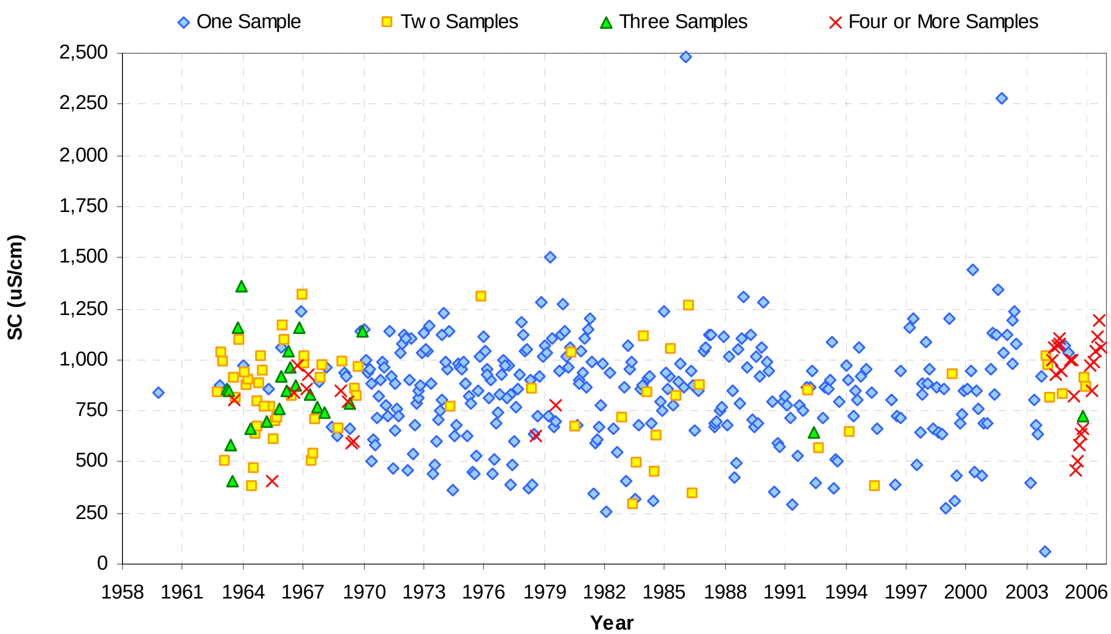

Figure E-1. Average monthly SC values and the number of SC samples collected each month at the Tongue River Miles City gage (Gage #06308500).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-2). In general, there are more exceedances of the standard in the past 5 years, and there are more exceedances when constricted to 4 or more sampling events per month. The most exceedances occurred in the past five years when 4 or more samples were available per month.

Table E-2. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at Miles City – USGS Gage 06308500.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 1, 1959 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	292	47	16.10%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	131	1	0.76%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	33	10	30.30%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	1	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	46	18	39.13%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	16	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	22	10	45.45%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	0	NA	NA

There is a documented inverse relationship between flow and SC in the Tongue River at Miles City (Figure E-2). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SC exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative of typical conditions.

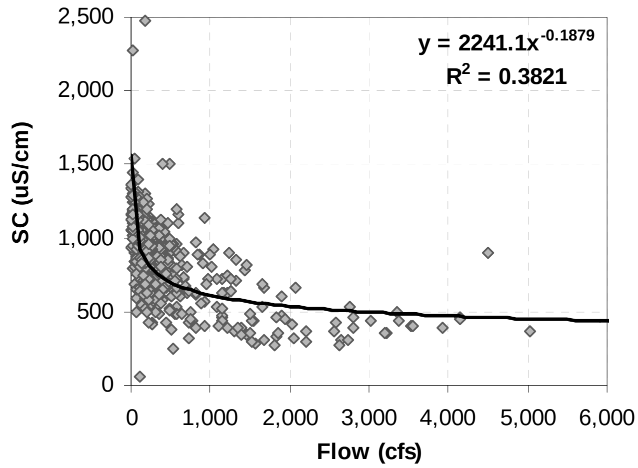

Figure E-2. SC versus flow for the Tongue River at Miles City, Montana. Entire period of record is shown.

Using the average daily flow data from the Miles City USGS gage, the total volume of water was calculated for each month in the station's period of record (January 1, 1940 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SC data for the past 5 years where there are four or more samples (Figure E-3). As expected, the monthly average SC appears to increase with decreasing flow, and no exceedances occur at flow percentiles greater than 20 percent. The data also suggest that the full range of flows during the past five years are well represented during the growing season, spanning 95 percent (1st to 96th flow percentile) of the flows ever recorded at Miles City. While it appears appropriate to evaluate the growing season using only months with four or more samples, there is insufficient data to adequately evaluate the non-growing season with four or more samples per month.

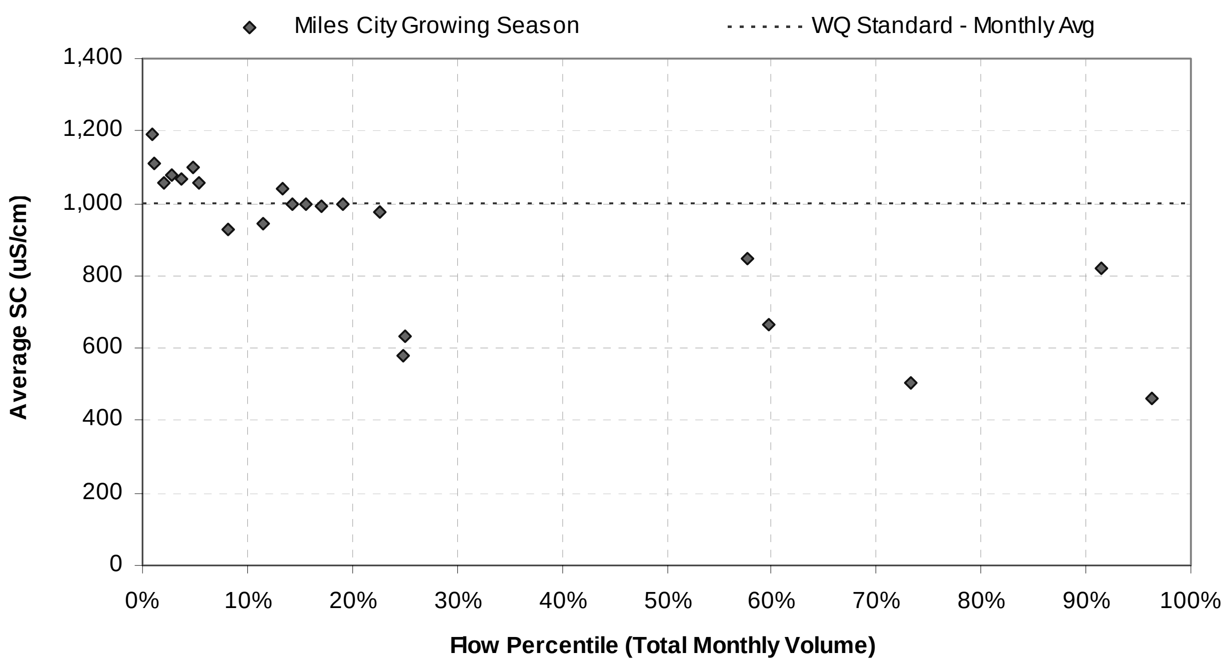

Figure E-3. Average monthly growing season SC values at Miles City (past five years only) versus flow percentile.

E.3 Tongue River above the T&Y Diversion Dam (06307990)

Both discrete and continuous SC data are available for the Tongue River above the T&Y Diversion Dam. Discrete data are instantaneous samples that were collected at a monthly frequency since November 1, 2004. 30 discrete samples were collected between November 1, 2004 and September 20, 2006.

Continuous SC data were collected during the growing season (i.e., mid March to November 1) at the gage upstream of the T&Y Diversion Dam between March 16, 2005 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as "average daily" SC values by USGS. There were 373 average daily values reported between March 16, 2005 and September 30, 2006.

Based on all of the available SC data at the gage upstream of the T&Y Diversion Dam, 22 months have at least one SC sample. Of those, 3 months have only 1 SC sample, 3 months have 2 samples, 0 months have 3 samples, and 16 months have 4 or more samples (Figure E-4). Most of the months with 4 or more samples were collected when the continuous data logger was operational (March 2005 to September 2006). None of the months in the nongrowing season had four or more samples. Since the USGS gage was installed in 2004, these statistics also apply as the last five years of data.

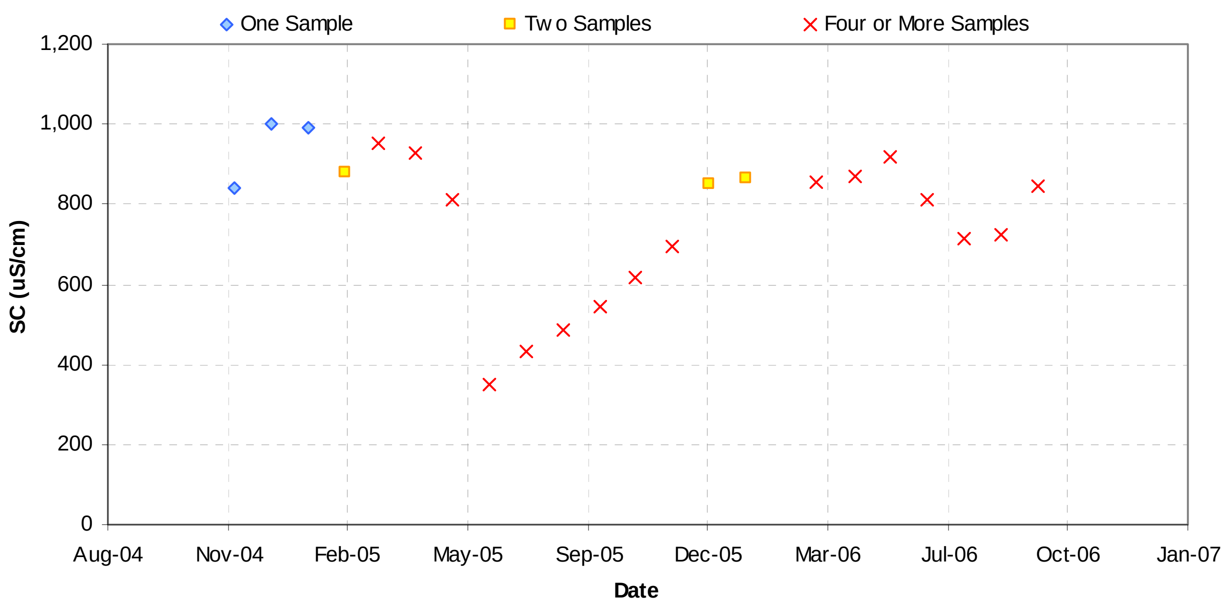

Figure E-4. Average monthly SC values and the number of SC samples collected each month at the Tongue River above the T&Y Diversion Dam (Gage #06307990).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-3). No exceedances of the monthly average salinity standard were observed at the Tongue River above the T&Y Diversion Dam. However, the period of record is limited at this gage (November 2004 to September 2006). The data also suggest that the range of flows during the past five years is not well represented during the growing season (Figure E-5). Several of the SC samples were taken in 2006, outside of the period of flow record. Non-growing season data also have insufficient data for conducting a representative evaluation when using only months with four or more samples.

Table E-3. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River above the T&Y Diversion Dam – USGS Gage 06307990.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – November 1, 2004 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	15	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	7	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	15	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	1	0	0.00%

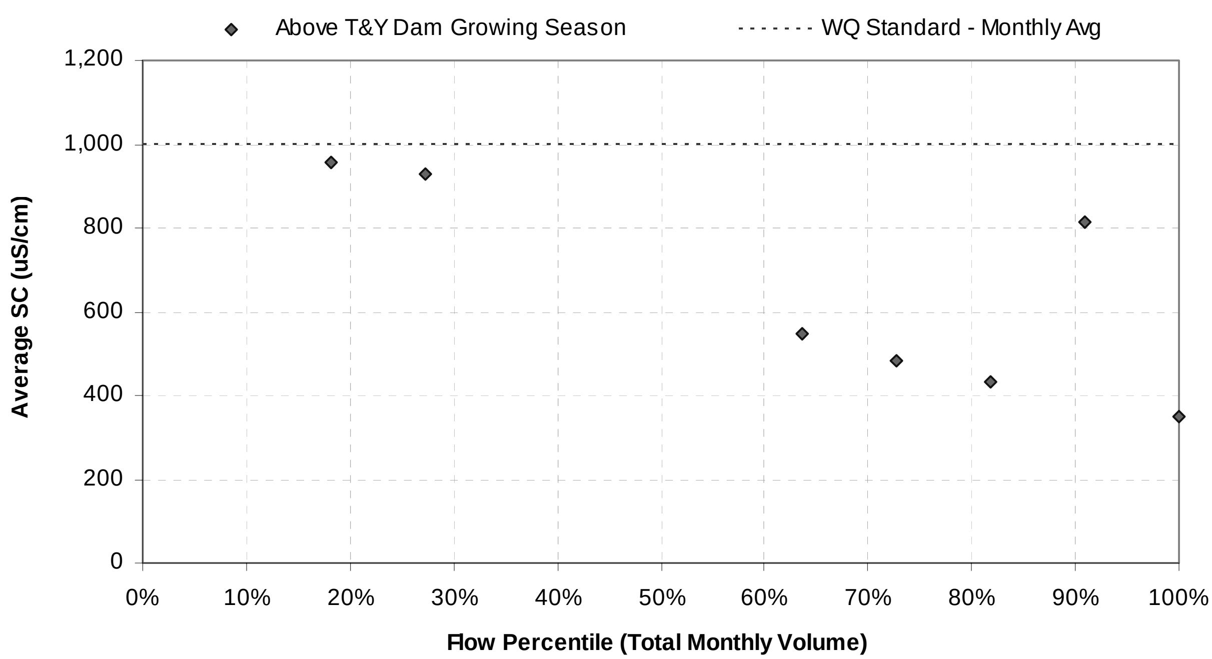

Figure E-5. Average monthly growing season SC values above the T&Y Diversion Dam (past five years only) versus flow percentile.

E.4 Tongue River at the Brandenberg Bridge (06307830)

Both discrete and continuous SC data are available for the Tongue River at the Brandenberg Bridge. Discrete data are instantaneous samples that were collected at varying frequencies since April 10, 1974. 97 discrete samples were collected between April 10, 1974 and August 15, 1985. Data were generally obtained once per month during that time period. No samples were collected between August 16, 1985 and June 12, 2000. Monthly to bi-monthly sampling (101 samples) was then reinstated between June 13, 2000 and September 30, 2006

Continuous SC data were collected at the Brandenberg Bridge gage between August 24, 2000 and September 30, 2006. Data were collected year-round until November 20, 2002. After November 2002, data were only collected during the growing season (March/April to October/November) of each year. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as "average daily" SC values by USGS. There were 1500 average daily values reported between August 24, 2000 and September 30, 2006.

Based on all of the available SC data at the Brandenberg Bridge gage, 168 months have at least one SC sample. Of those, 102 months have only 1 SC sample, 9 months have 2 samples, 0 months have 3 samples, and 57 months have 4 or more samples (Figure E-6). All of the months with 4 or more samples were collected when the continuous data logger was operational (August 24, 2000 and September 30, 2006). Only ten nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 58 months had one or more SC samples. Of those, 9 months have only 1 SC sample, 5 months have 2 samples, 0 months have 3 samples, and 44 months have 4 or more samples (Figure E-6).

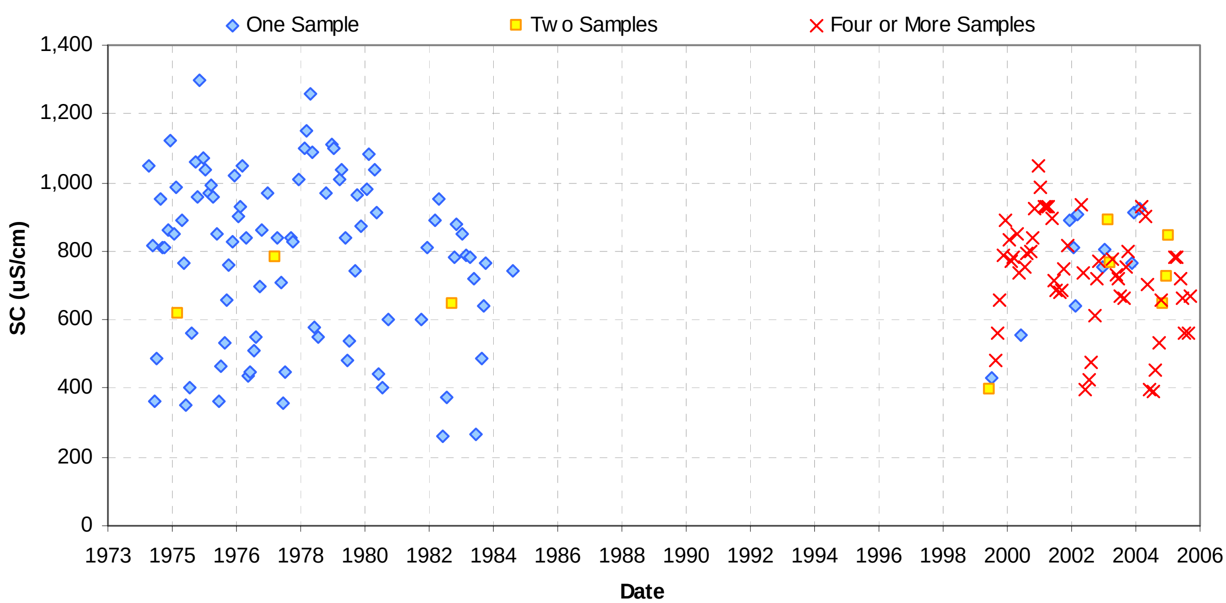

Figure E-6. Average monthly SC values and the number of SC samples collected each month at the Tongue River at the Brandenberg Bridge (Gage #06307830).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-4). Standards were only exceeded based on single samples (i.e., one sample per month) between 1974 and 1981. There have been no exceedances in the last five years and, as shown in Figure E-7. The months with four or more samples per month in the last five years appear to adequately represent the full range of flow conditions at this sample station.

Table E-4. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at the Brandenberg Bridge – USGS Gage 06307830.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – April 10, 1974 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	122	9	7.38%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	46	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	47	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	10	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	40	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	18	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	37	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	6	0	0.00%

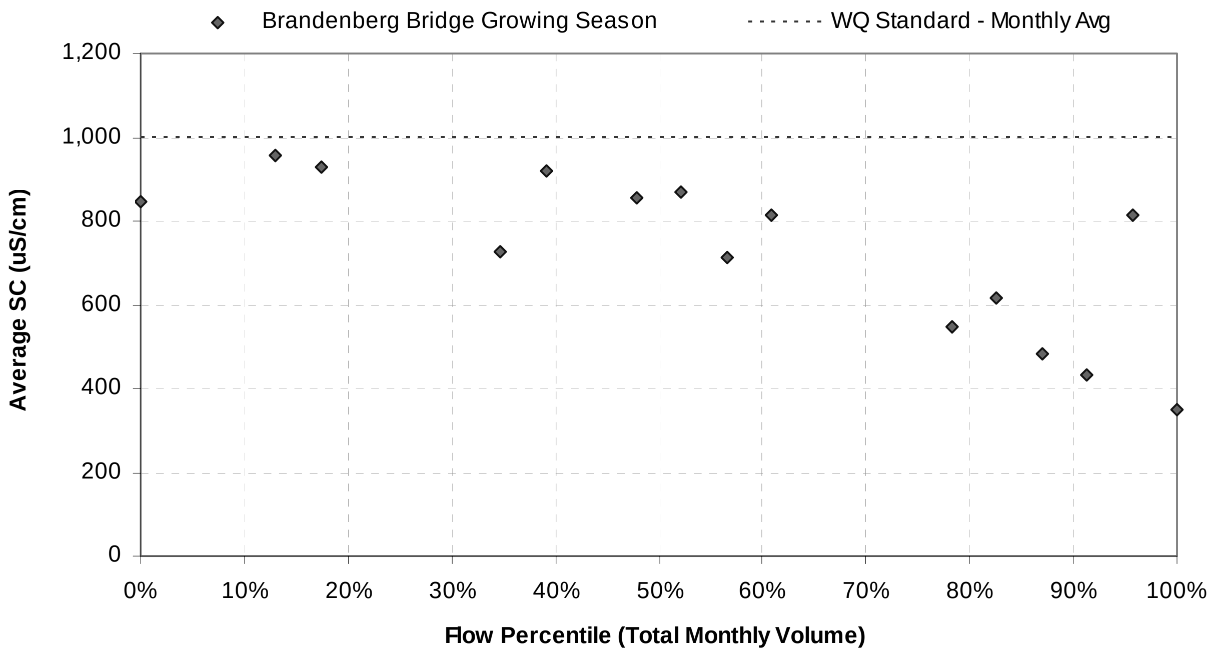

Figure E-7. Average monthly growing season SC values at the Brandenberg Bridge (past five years only) versus flow percentile (flow percentile based on the entire period of record for this station).

E.5 Tongue River at Birney Day School Bridge (06307616)

Both discrete and continuous SC data are available for the Tongue River at the Birney Day School Bridge. Discrete data are instantaneous samples that were collected at varying frequencies since October 2, 1979. 227 discrete samples were collected between October 2, 1979 and September 21, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Birney Day School gage between April 29, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as "average daily" SC values by USGS. There were 734 average daily values reported between April 29, 2004 and September 30, 2006.

Based on all of the available SC data at the Birney Day School Bridge gage, 200 months have at least one SC sample. Of those, 167 months have only 1 SC sample, 6 months have 2 samples, no months have 3 samples, and 27 months have 4 or more samples (Figure E-8). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006). Only five nongrowing season months had 4 or more samples (November 2004 and November 2005 through February 2006).

In the last 5 years (October 1, 2001 to September 30, 2006), 47 months had one or more SC samples. Of those, 18 months have only 1 SC sample, 2 months have 2 samples, zero months has 3 samples, and 27 months have 4 or more samples (Figure E-8). All of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006).

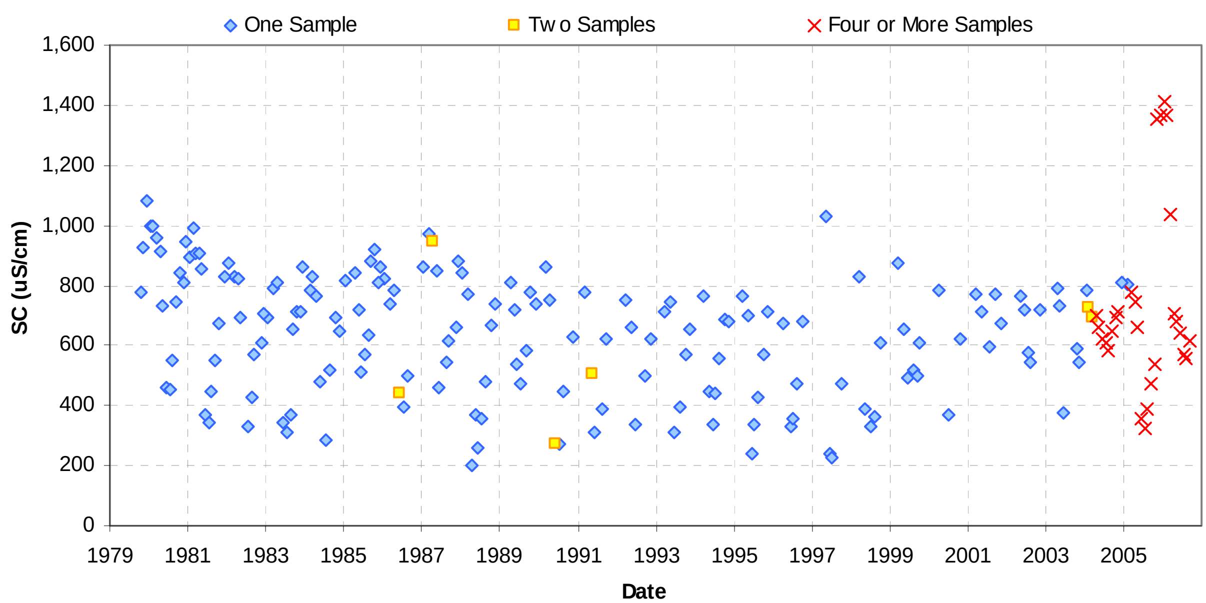

Figure E-8. Average monthly SC values and the number of SC samples collected each month at the Tongue River Birney Day School Bridge gage (Gage #06307616).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-5). In general, the frequency of exceedance of the standard in the past five years is similar to the entire period of record, and the frequency is greater with four or more sampling events per month. As shown in Figure E-9, the months with ≥ four samples per month in the last five years appear to adequately represent the full range of flow conditions at this sample station.

Table E-5. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at the Birney Day School Bridge – USGS Gage 06307616.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 2, 1979 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	156	2	1.28%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	44	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	22	1	4.45%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	5	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	31	1	3.22%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	12	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	22	1	4.45%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	5	0	0.00%

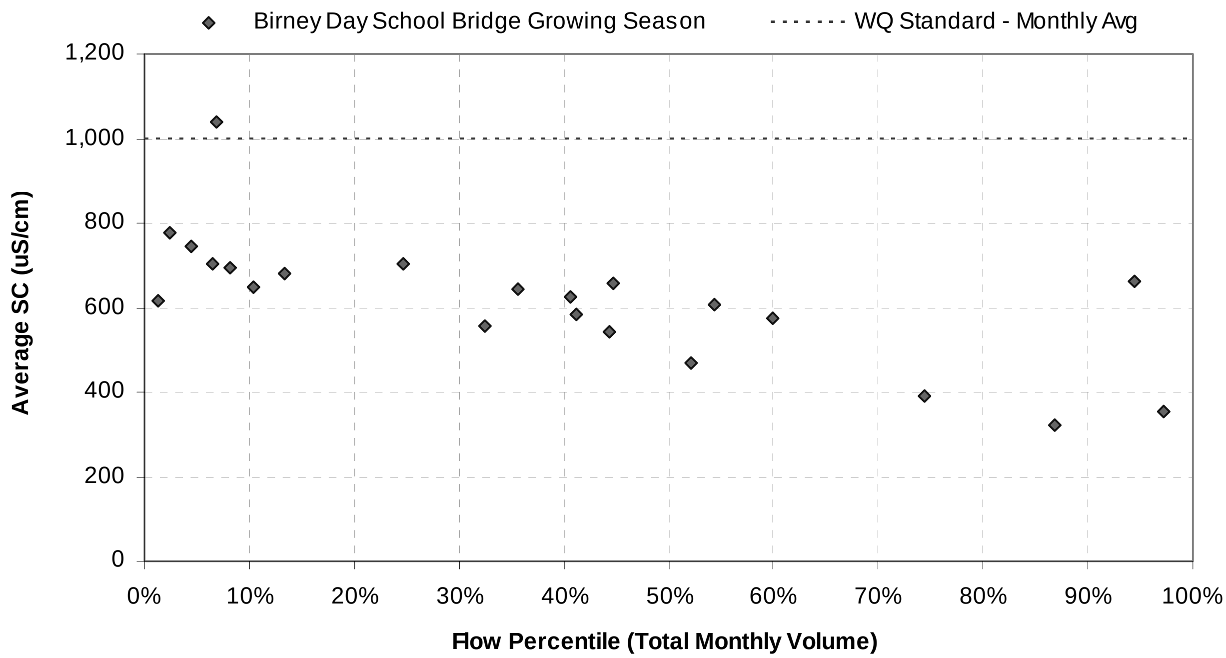

Figure E-9. Average monthly growing season SC values at the Birney Day School Bridge (past five years only) versus flow percentile (flow percentile for the entire period of record for this station).

E.6 Tongue River below the Tongue River Reservoir Dam (06307500)

Both discrete and continuous SC data are available for the Tongue River below the Tongue River Reservoir Dam. Discrete data are instantaneous samples that were collected at varying frequencies since October 7, 1975. 299 discrete samples were collected between October 7, 1975 and September 21, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Tongue River gage below the Tongue River Reservoir Dam from November 1, 1980 to December 31, 1986 and from May 1, 2004 to September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as “average daily” SC values by USGS. There were 2,047 average daily values reported from November 1, 1980 to December 31, 1986 and 780 average daily values reported from May 1, 2004 to September 30, 2006 for a total of 2,827 average daily SC values.

Based on all of the available SC data at the Tongue River gage below the Tongue River Reservoir Dam, 280 months have at least one SC sample. Of those, 164 months have only 1 SC sample, 16 months have 2 samples, 1 month has 3 samples, and 99 months have 4 or more samples (Figure E-10). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There was also a period of more intense sampling between 1980 and 1987. Thirty-two nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 46 months had one or more SC samples. Of those, 13 months have only 1 SC sample, 4 months have 2 samples, 1 month has 3 samples, and 28 months have 4 or more samples (Figure E-10).

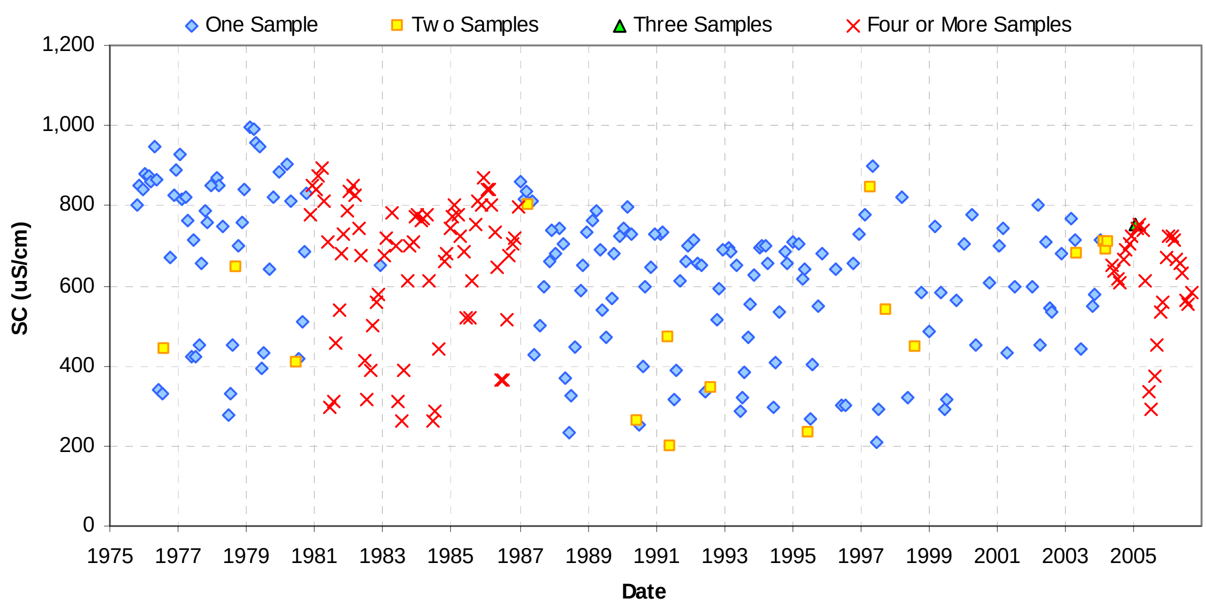

Figure E-10. Average monthly SC values and the number of SC samples collected each month at the Tongue River below the Tongue River Reservoir Dam gage (Gage #06307500).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-6). No exceedances of the monthly average standard have been observed under any of the conditions considered. As shown in Figure E-11, the months with ≥ four samples per month in the last five years appear to adequately represent the full range of flow conditions at this sample station.

Table E-6. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 7, 1975 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	196	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	84	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	67	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	32	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	33	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	13	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	21	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	7	0	0.00%

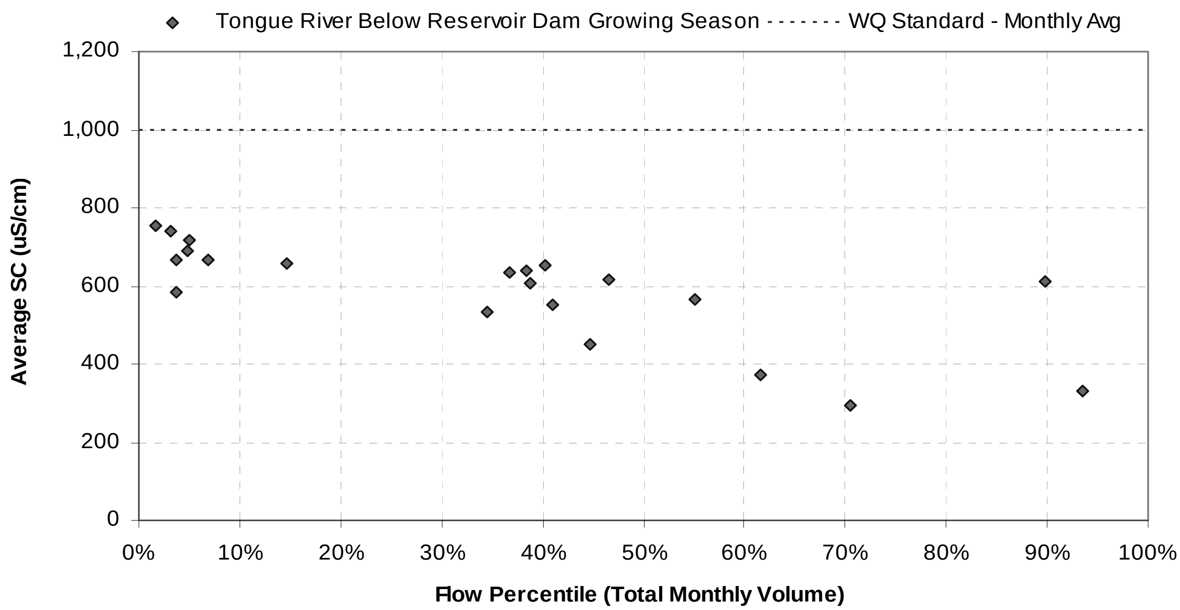

Figure E-11. Average monthly growing season SC values at the Tongue River below the Tongue River Reservoir Dam (past five years only) versus flow percentile.

E.7 Tongue River at the Montana-Wyoming State Line (06306300)

Both discrete and continuous SC data are available for the Tongue River at the Montana-Wyoming State Line. Discrete data are instantaneous samples that were collected at varying frequencies since October 16, 1985. 241 discrete samples were collected between October 16, 1985 and November 15, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Montana-Wyoming State Line gage between October 1, 1982 through December 31, 1986 and August 22, 2000 through September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as “average daily” SC values by USGS. There were 1,522 average daily values reported between October 1, 1982 and December 31, 1986 and 1,942 average daily values reported from August 22, 2000 to September 30, 2006 for a total of 3,464 average daily SC values.

Based on all of the available SC data at the Montana-Wyoming State Line gage, 222 months have at least one SC sample. Of those, 90 months have only 1 SC sample, 7 months have 2 samples, 4 months have 3 samples, and 121 months have 4 or more samples (Figure E-12). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2000 to September 2006). There was also a period of more intense sampling between 1982 and 1987. Thirty-eight nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 67 months had one or more SC samples. Of those, 7 months have only 1 SC sample, zero months have 2 samples, zero months have 3 samples, and 60 months have 4 or more samples (Figure E-12).

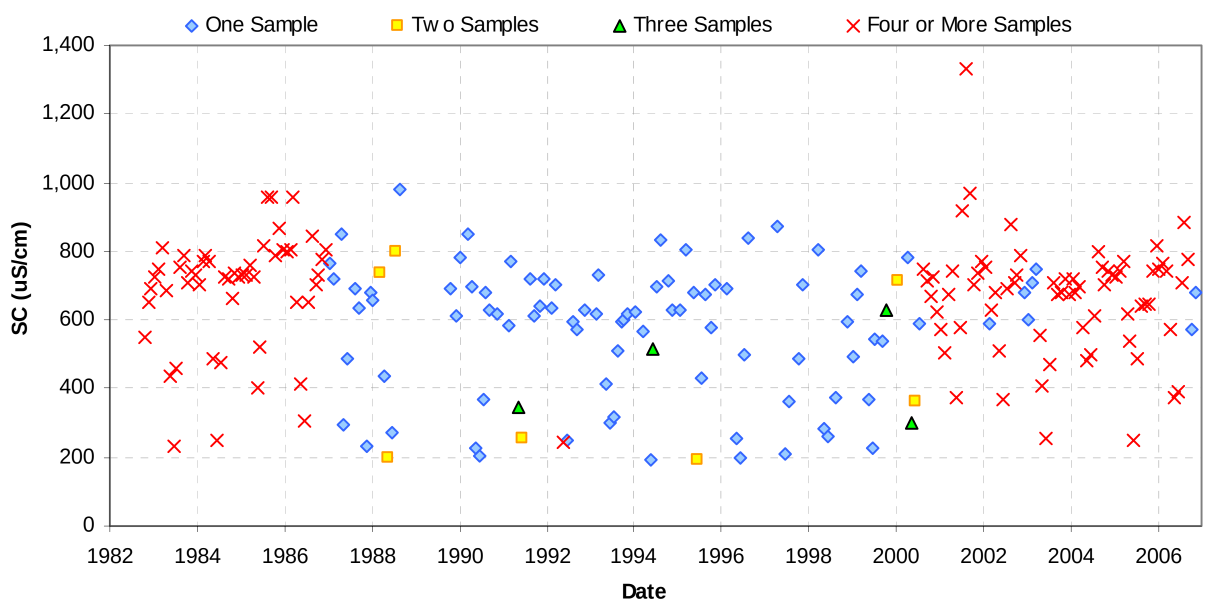

Figure E-12. Average monthly SC values and the number of SC samples collected each month at the Montana-Wyoming State Line (Gage #06306300).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-7). The monthly standard has only been exceeded once during the period of record, and that was during a low flow event (0^{th} percentile) in August of 2001. As shown in Figure E-13, the 39 months with four or more samples from the last five years appears to represent the full range of flow conditions at this station during the growing season.

Table E-7. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 16, 1985 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	154	1	0.65%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	68	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	84	1	1.19%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	38	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	41	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	21	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	39	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	16	0	0.00%

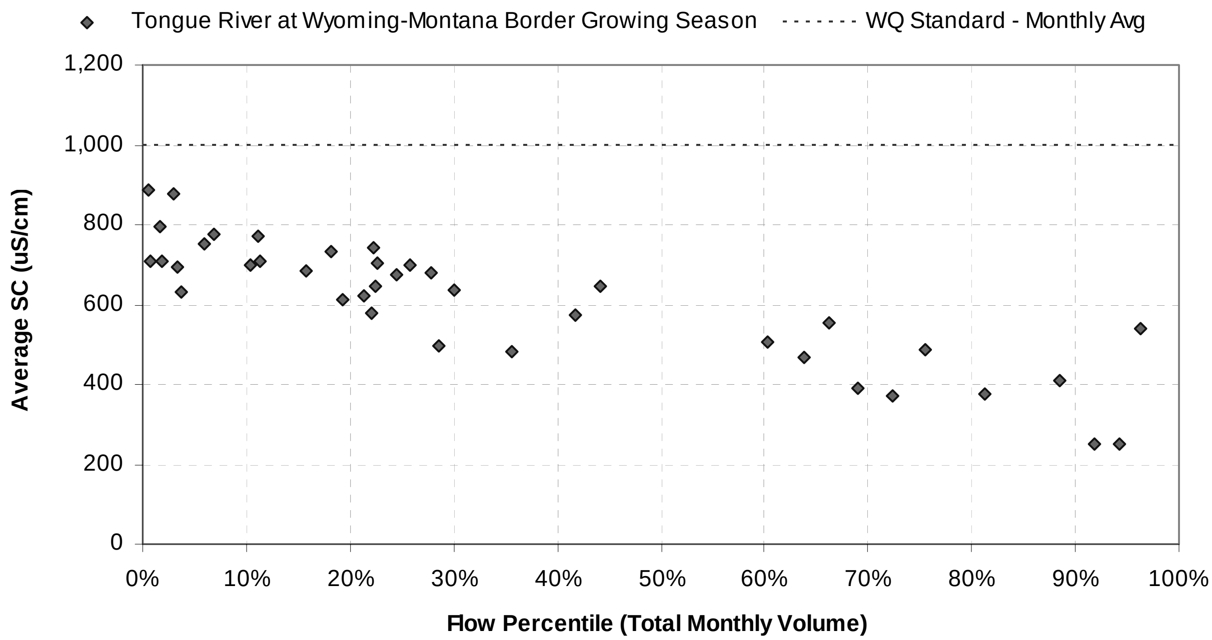

Figure E-13. Average monthly growing season SC values at the Montana-Wyoming State Line (past five years only) versus flow percentile.

E.8 Tongue River at Monarch, Wyoming (06299980)

Both discrete and continuous SC data are available for the Tongue River at Monarch. Discrete data are instantaneous samples that were collected at varying frequencies since April 3, 1974. 135 discrete samples were collected between April 3, 1974 and August 7, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Monarch gage between May 1, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SC at 15 minute intervals. The data were then reported as “average daily” SC values by USGS. There were 609 average daily values reported between May 1, 2004 and September 30, 2006.

Based on all of the available SC data at the Monarch gage, 115 months have at least one SC sample. Of those, 82 months have only 1 SC sample, 12 months have 2 samples, zero months have 3 samples, and 21 months have 4 or more samples (Figure E-14). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There was also a period of more intense sampling between 1974 and 1984. There were no nongrowing season months with 4 or more samples for this station.

In the last 5 years (October 1, 2001 to September 30, 2006), 31 months had one or more SC samples. Of those, 5 months have only 1 SC sample, 5 months have 2 samples, zero months have 3 samples, and 21 months have 4 or more samples (Figure E-14). All of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006).

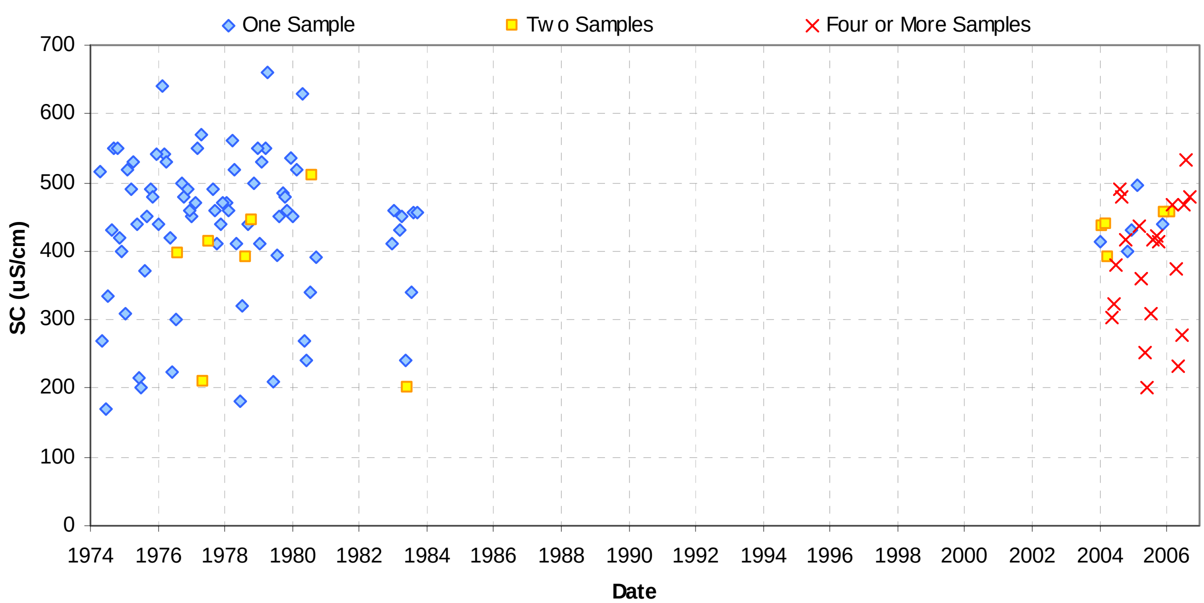

Figure E-14. Average monthly SC values and the number of SC samples collected each month at the Tongue River Monarch gage (Gage #06299980).

The calculated average monthly SC values were compared to Montana's average monthly SC standards[b]. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-8). There have been no SC exceedances at the Monarch gage station and with a maximum recorded value of 660 µS/cm, it is unlikely that the monthly standard would be exceeded. Recent data, however, are confined to the last two years and data are severely limited for the non-growing season.

Table E-8. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at Monarch – USGS Gage 06299980.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – April 3, 1974 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	81	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	34	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	21	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	0	0	0.00%
"Past 5 Years" – October 1, 2001 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	23	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	8	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	21	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	0	NA	NA

[b] 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.

E.9 Tongue River at Dayton, Wyoming (06298000)

Discrete SC data are available for the Tongue River at Dayton; however no continuous data are available for this station. Discrete data are instantaneous samples that were collected at varying frequencies since October 10, 1966. 216 discrete samples were collected between October 10, 1966 and August 14, 2002. Data were generally obtained once per month during that time period.

Based on all of the available SC data at the Dayton gage, 202 months have at least one SC sample. Of those, 189 months have only 1 SC sample, 12 months have 2 samples, 1 month has 3 samples, and no months have 4 or more samples (Figure E-15). In the last 5 years (October 1, 2001 to September 30, 2006), 1 month had only one SC sample.

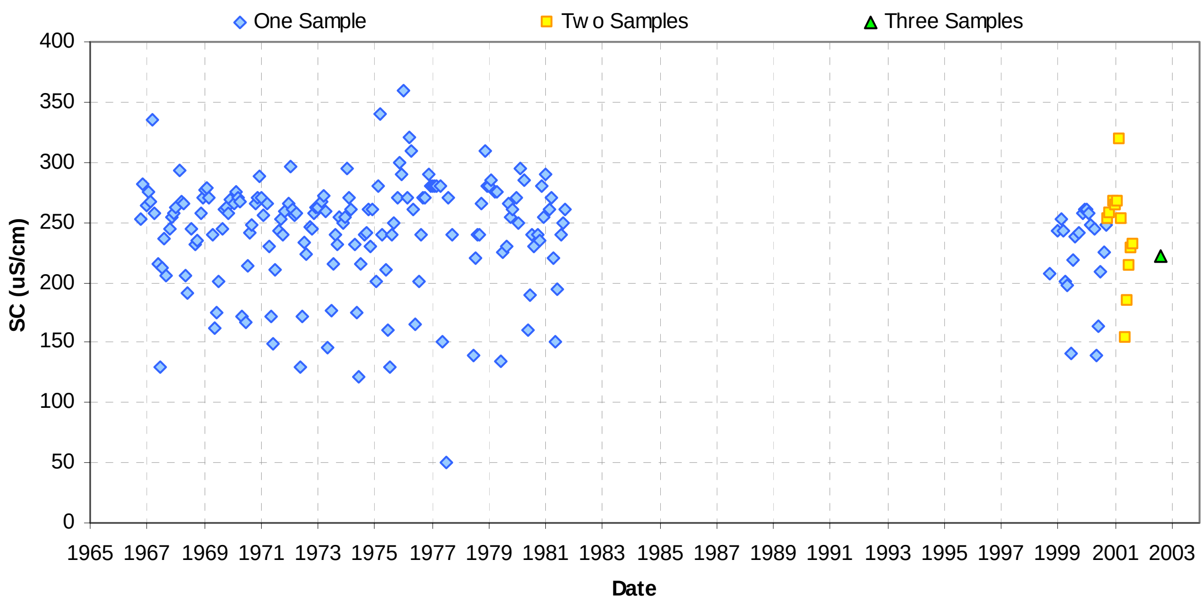

Figure E-15. Average monthly SC values and the number of SC samples collected each month at the Tongue River Dayton gage (Gage #06298000).

The calculated average monthly SC values were compared to Montana's average monthly SC standards[c]. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-9). This station has no more than 3 SC samples per month and only one sample within the last 5 years. There are no SC exceedances at the Dayton gage station, however, data for the recent time period are limited. Nonetheless, the maximum recorded SC at this station was 360 µS/cm, making exceedances unlikely at this station.

[c] 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.

Table E-9. Average monthly SC data and exceedances of the average monthly water quality standards for the Tongue River at Dayton – USGS Gage 06298000.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 10, 1966 to August 14, 2002	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 1000 µS/cm	136	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	66	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	0	NA	NA
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	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)	< 1000 µS/cm	1	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	0	NA	NA
	4 or more samples per month	Growing Season (March 2 to October 31)	< 1000 µS/cm	0	NA	NA
		Nongrowing Season (November 1 to March 1)	< 1500 µS/cm	0	NA	NA

E.10 Hanging Woman Creek (06307600)

Both discrete and continuous SC data are available for Hanging Woman Creek near Birney, Montana. Discrete data are instantaneous samples that were collected at varying frequencies since October 2, 1974. 225 discrete samples were collected between October 2, 1974 and June 6, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Hanging Woman Creek near Birney, Montana gage between November 1, 1980 and June 16, 2006. These data were collected by a probe placed in Hanging Woman Creek which recorded SC at 15 minute intervals. The data were then reported as "average daily" SC values by USGS. There were 1,935 average daily values reported between November 1, 1980 and June 16, 2006.

Based on all of the available SC data at the Birney, MT gage, 217 months have at least one SC sample. Of those, 133 months have only 1 SC sample, 10 months have 2 samples, 4 months have 3 samples, and 70 months have 4 or more samples (Figure E-16). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There was also a period of more intense sampling between 1980 and 1987. Twenty nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 26 months had one or more SC samples. Of those, 8 months have only 1 SC sample, 5 months have 2 samples, 1 month has 3 samples, and 12 months have 4 or more samples (Figure E-16).

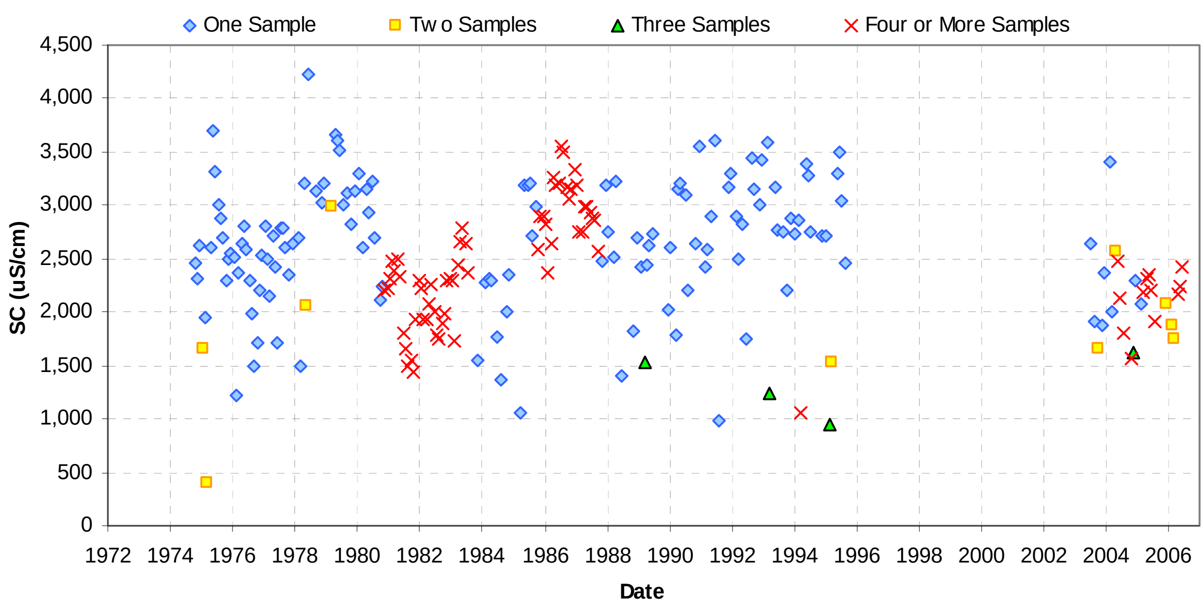

Figure E-16. Average monthly SC values and the number of SC samples collected each month at the Hanging Woman Creek gage near Birney, MT (Gage #06307600).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-10). Across all stratifications, all observed values (with one exception- 405 µS/cm in March of 1975) were found to exceed the average monthly standards. However, data are limited to only 30 percent of the full range of flows at this station (Figure E-18).

Table E-10. Average monthly SC data and exceedances of the average monthly water quality standards for Hanging Woman Creek at Birney, MT– USGS Gage 06307600.

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)	< 500 µS/cm	145	144	99.31%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	72	72	100%
	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	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	18	18	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	8	8	100%
	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

There is a documented inverse relationship between flow and SC in Hanging Woman Creak near Birney, Montana (Figure E-17). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SC exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

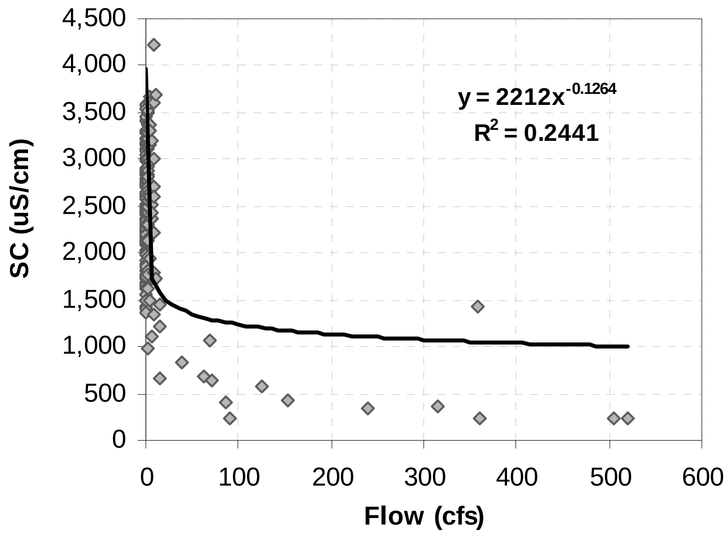

Figure E-17. SC versus flow for Hanging Woman Creek near Birney, Montana. Entire period of record is shown.

Using the average daily flow data from the Hanging Woman Creek USGS gage near Birney, the total volume of water was calculated for each month in the station's period of record (September 1, 1973 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SC data for the past 5 years where there are four or more samples (Figure E-18). As shown below, all 12 growing season samples are well above the standard, although all are for flows less than the 40th percentile. There are no months from the non-growing season with four or more samples per month, further limiting analyses.

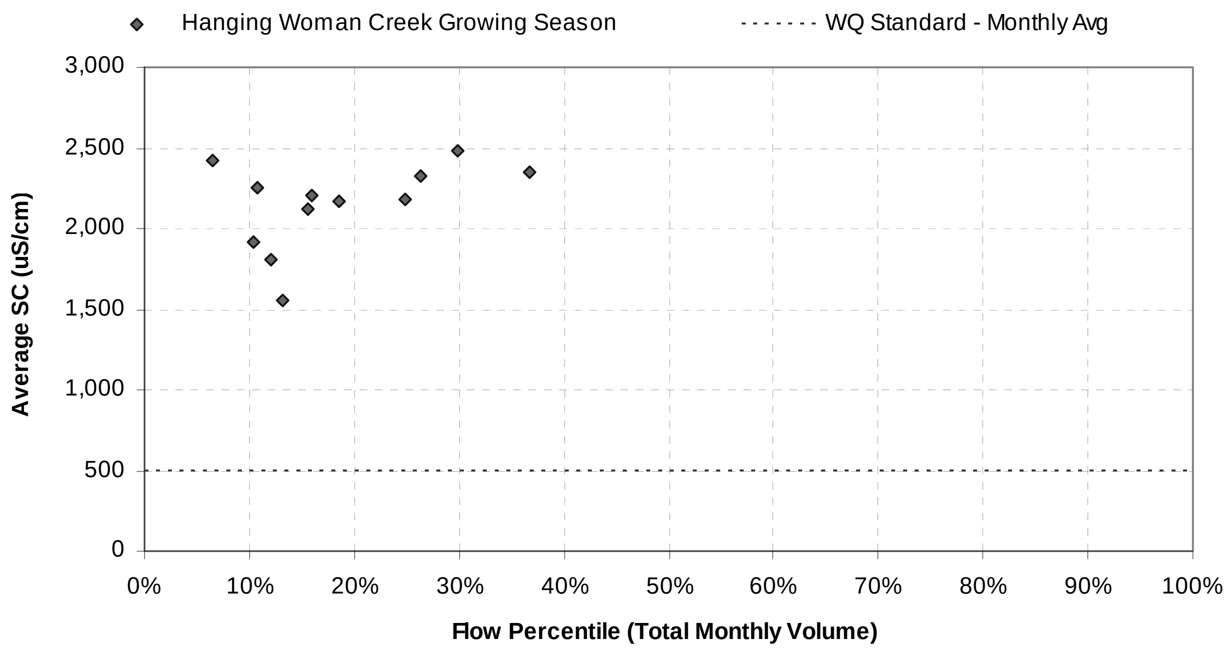

Figure E-18. Average monthly growing season SC values for Hanging Woman Creek near Birney, MT (past five years only) versus flow percentile.

E.11 Otter Creek (06307740)

Both discrete and continuous SC data are available for Otter Creek at Ashland, Montana. Discrete data are instantaneous samples that were collected at varying frequencies since October 2, 1974. 218 discrete samples were collected between October 2, 1974 and August 8, 2006. Data were generally obtained once per month during that time period.

Continuous SC data were collected year-round at the Otter Creek at Ashland, Montana gage between November 1, 1980 and September 30, 2006. These data were collected by a probe placed in Otter Creek which recorded SC at 15 minute intervals. The data were then reported as "average daily" SC values by USGS. There were 2,121 average daily values reported between November 1, 1980 and September 30, 2006.

Based on all of the available SC data at the Ashland, MT gage, 219 months have at least one SC sample. Of those, 132 months have only 1 SC sample, 11 months have 2 samples, no months have 3 samples, and 76 months have 4 or more samples (Figure E-19). Many of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There was also a period of more intense sampling between 1980 and 1986. Twenty nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 34 months had one or more SC samples. Of those, 10 months have only 1 SC sample, 4 months have 2 samples, no months have 3 samples, and 20 months have 4 or more samples (Figure E-19).

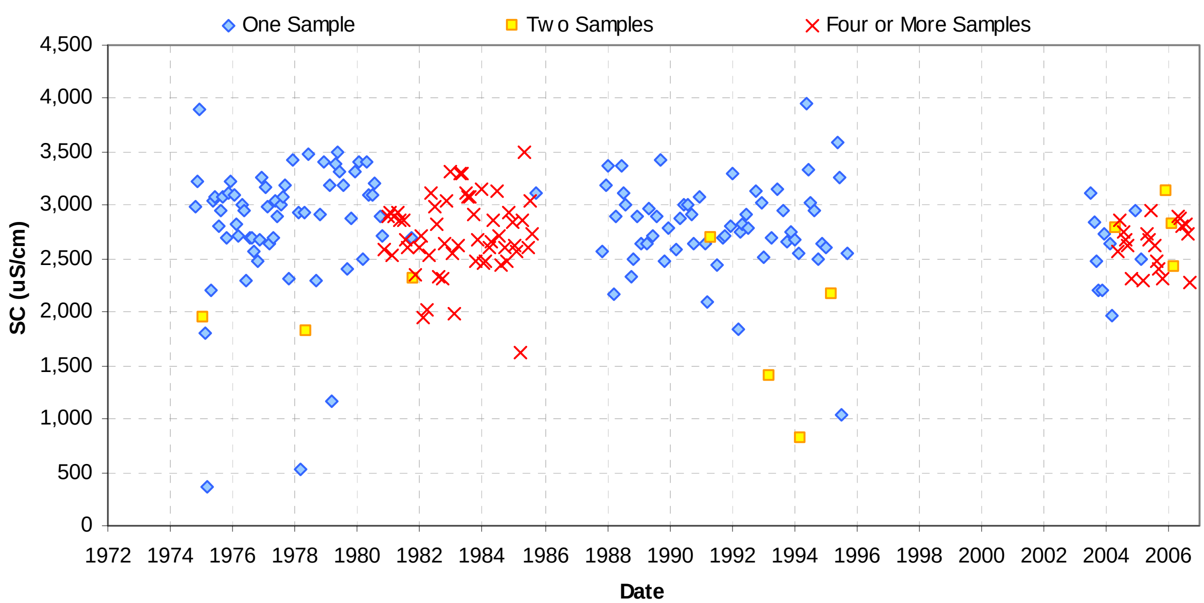

Figure E-19. Average monthly SC values and the number of SC samples collected each month at the Otter Creek gage near Ashland, MT (Gage #06307740).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-11). Across all stratifications, all observed values (with one exception- 370 µS/cm in March of 1975) were found to exceed the average monthly standards.

Table E-11. Average monthly SC data and exceedances of the average monthly water quality standards for Otter Creek at Ashland, MT– USGS Gage 06307740.

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)	< 500 µS/cm	155	154	99.35%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	64	64	100%
	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	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	27	27	100%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	7	7	100%
	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

There is a documented inverse relationship between flow and SC in Otter Creak near Ashland, MT (Figure E-20). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SC exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

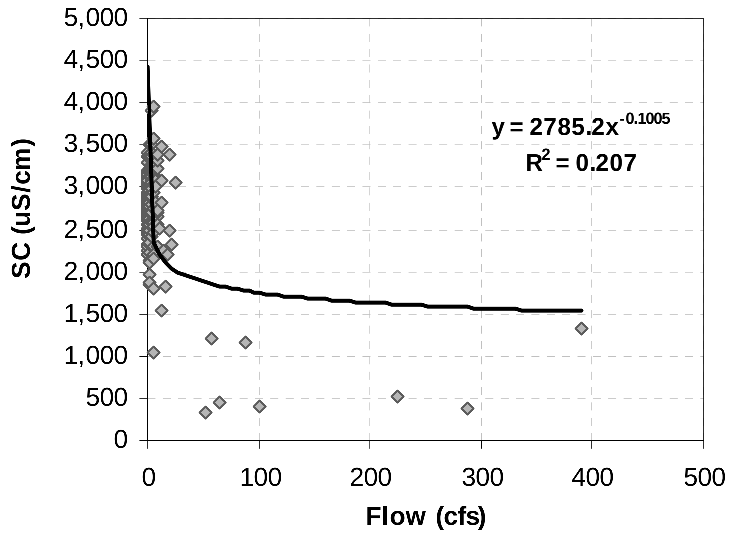

Figure E-20. SC versus flow for Otter Creek near Ashland, Montana. Entire period of record is shown.

Using the average daily flow data from the Otter Creek USGS gage near Ashland, the total volume of water was calculated for each month in the station's period of record (October 1, 1972 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SC data for the past 5 years where there are four or more samples (Figure E-21). As shown below, all 19 growing season samples are well above the standard. About 70 percent of the full flow range is covered by these data, with no flows greater than the 80th percentile represented. There are no months from the non-growing season with four or more samples per month, limiting analysis for that time period.

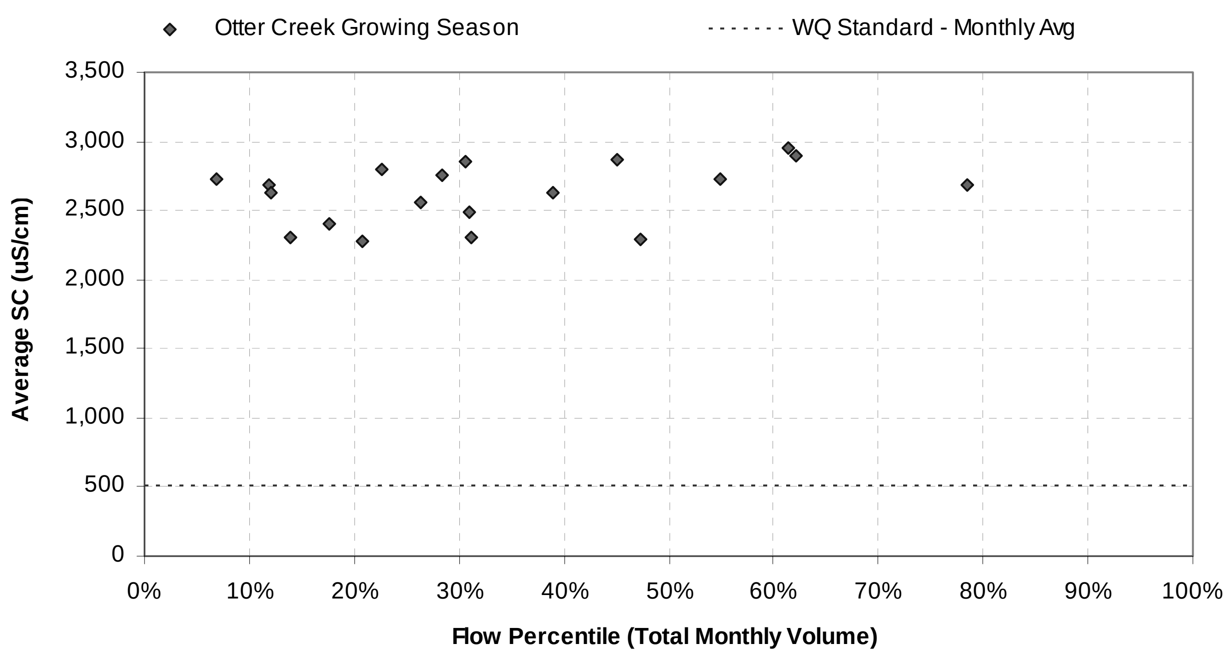

Figure E-21. Average monthly growing season SC values for Otter Creek near Ashland, MT (past five years only) versus flow percentile.

E.12 Pumpkin Creek (06308400)

Both discrete and continuous SC data are available for Pumpkin Creek at Miles City, Montana. Discrete data are instantaneous samples that were collected at varying frequencies since October 15, 1975. 88 discrete samples were collected between October 15, 1975 and September 20, 2006. Data were generally obtained once per month during that time period, mostly during the growing season.

Continuous SC data were collected year-round at the Miles City, Montana gage between March 10, 2004 and September 30, 2006. These data were collected by a probe placed in Pumpkin Creek which recorded SC at 15 minute intervals. The data were then reported as “average daily” SC values by USGS. There were 292 average daily values reported between March 10, 2004 and September 30, 2006.

Based on all of the available SC data at the Miles City, Montana gage, 74 months have at least one SC sample. Of those, 47 months have only 1 SC sample, 12 months have 2 samples, no months have 3 samples, and 15 months have 4 or more samples (Figure E-22). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (March 2004 to September 2006). There was also a period of sampling between 1975 and 1986. No months during the nongrowing season had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 21 months had one or more SC samples. Of those, 1 month has only 1 SC sample, 5 months have 2 samples, no months have 3 samples, and 15 months have 4 or more samples (Figure E-22).

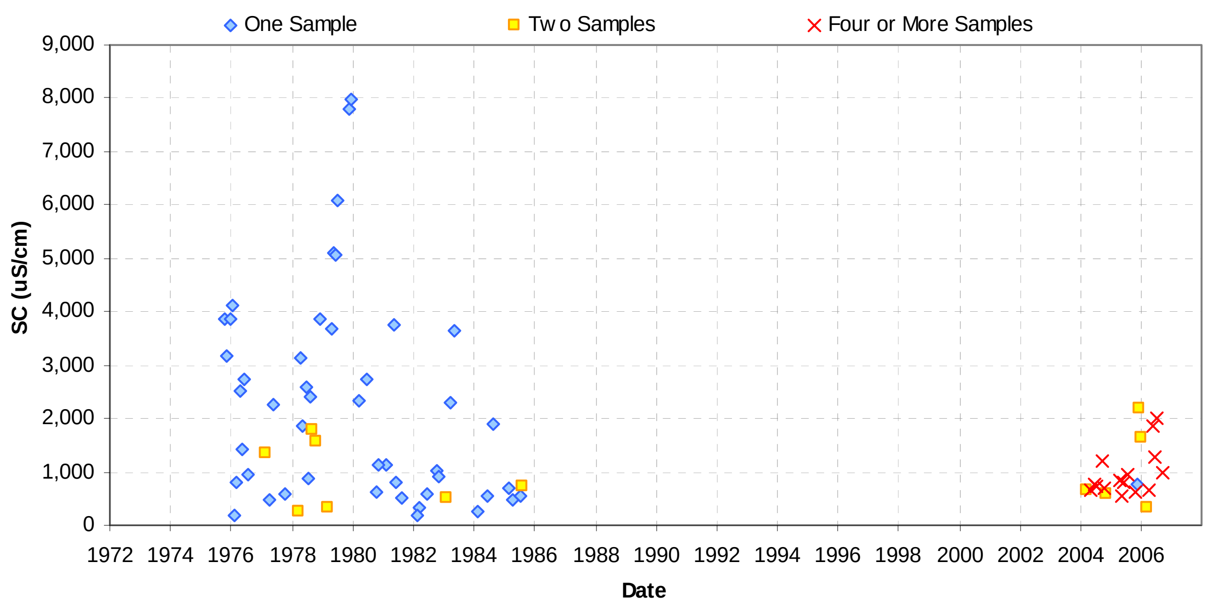

Figure E-22. Average monthly SC values and the number of SC samples collected each month at the Pumpkin Creek gage near Miles City, MT (Gage #06308400).

The calculated average monthly SC values were compared to the average monthly SC standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table E-12). Most of the observed stations were found to exceed the average monthly standards at the Pumpkin Creek, Miles City gage station. However, the data may only represent a portion of the full range of flow conditions.

Table E-12. Average monthly SC data and exceedances of the average monthly water quality standards for Pumpkin Creek at Miles City, MT– USGS Gage 06308400.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 15, 1975 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	55	49	89.09%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	19	16	84.21%
	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	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 500 µS/cm	17	16	94.12%
		Nongrowing Season (November 1 to March 1)	< 500 µS/cm	4	4	100%
	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

There is a documented inverse relationship between flow and SC in Pumpkin Creak near Miles City, Montana (Figure E-23). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SC exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

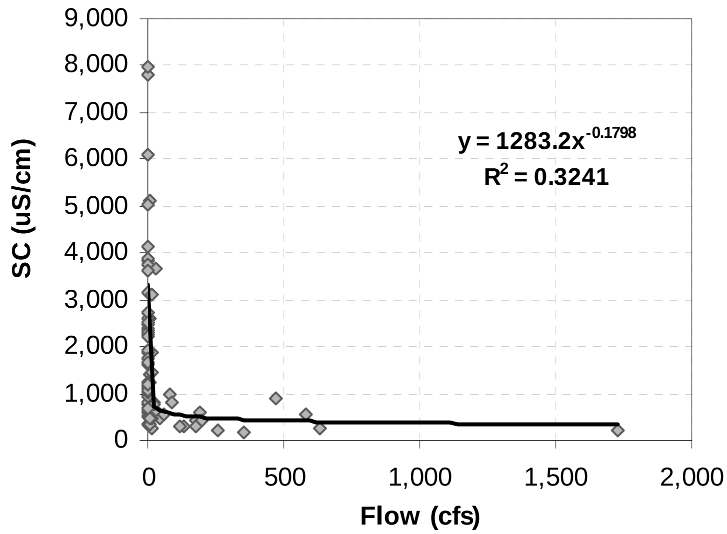

Figure E-23. SC versus flow for Pumpkin Creek near Miles City, Montana. Entire period of record is shown.

Using the average daily flow data from the Pumpkin Creek USGS gage near Miles City, the total volume of water was calculated for each month in the station's period of record (October 1, 1972 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SC data for the past 5 years where there are four or more samples (Figure E-24). As shown below, all 13 growing season samples from the last five years are well above the standard. Less than 50 percent of the full flow range is covered by these data, with no flows below the 50th percentile represented. There are no months from the non-growing season with four or more samples per month, further limiting analysis for that time period.

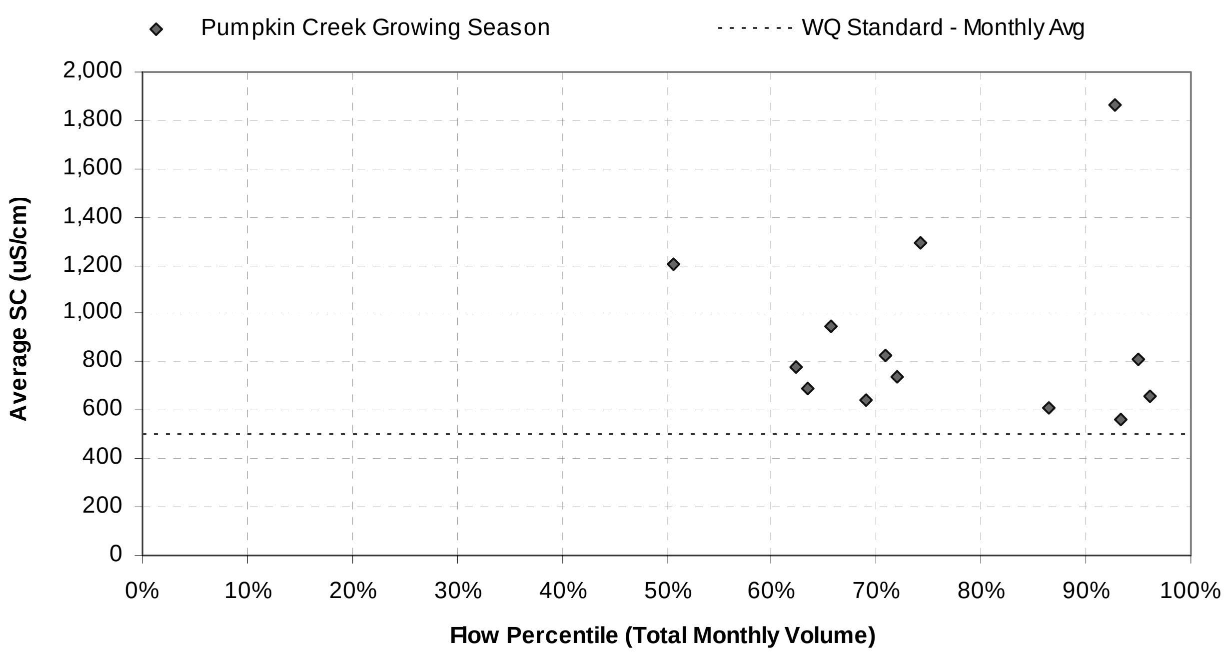

Figure E-24. Average monthly growing season SC values for Pumpkin Creek near Miles City, MT (past five years only) versus flow percentile.

E.13 Summary and Conclusions

A screening analysis was conducted to provide insight regarding potential alternatives for interpretation of Montana's monthly average salinity standard. The results of this analysis indicate that:

- The period of record varies from a maximum of approximately 47 years at Miles City, Montana (gage # 06308500) to a minimum of approximately two years above the T&Y Diversion Dam, Montana (gage #06307990).
- 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 collecting continuous SC data, there are few months with greater than one sample per month.
- Given the variability in SC on a monthly basis (an overall range of 38 to 7,990 µS/cm), 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) with the exception of Hanging Woman Creek and Pumpkin Creek.

APPENDIX F – MONTHLY SAR ANALYSIS

F.0 MONTHLY SAR ANALYSIS

Montana has adopted instantaneous and monthly average sodium adsorption ratio standards for the Tongue River and its tributaries. 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 from eight representative stations in the Tongue River, and one station each in Hanging Woman Creek, Otter Creek, and Pumpkin Creek 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 adequately represent the full range of flow conditions, and the current time period[d]. The selected stations are:

- Tongue River at Miles City – USGS Gage 06308500
- Tongue River above the T&Y Diversion Dam – USGS Gage 06307990
- Tongue River below the Brandenberg Bridge – USGS Gage 06307830
- Tongue River at the Birney Day School Bridge – USGS Gage 06307616
- Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500
- Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300
- Tongue River at Monarch, Wyoming – USGS Gage 06299980
- Tongue River at Dayton, Wyoming – USGS Gage 06298000
- Hanging Woman Creek near Birney, Montana – USGS Gage 06307600
- Otter Creek at Ashland, Montana – USGS Gage 06307740
- Pumpkin Creek near Miles City, Montana – USGS Gage 06308400

The monthly average SAR standards for the mainstem Tongue River and tributaries in Montana are shown in Table F-1. The standard varies between the growing season and nongrowing season. The State of Montana adopted average monthly numeric criteria for SAR on June 6, 2003. These values are used directly to measure agricultural beneficial use impairment.

Table F-1. Monthly average sodium adsorption ratio standards for the mainstem Tongue River and tributaries.

Waterbody	Season	Monthly Average SAR Standard (µS/cm)
Mainstem Tongue River	Nongrowing Season (Nov 1 – Mar 1)	5.0
	Growing Season (Mar 2 – Oct 31)	3.0
Tributaries	Nongrowing Season (Nov 1 – Mar 1)	5.0
	Growing Season (Mar 2 – Oct 31)	3.0

[d] Throughout this document, 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.

F.1 Tongue River at Miles City Montana (06308500)

Both discrete and continuous SAR data are available for the Tongue River at Miles City. Discrete data are instantaneous samples that were collected at varying frequencies since October 1, 1959. 481 discrete samples were collected between October 1, 1959 and August 21, 2006. Data were generally obtained once per month during that time period.

Continuous[e] SAR data were collected during the growing season (i.e., mid March to November 1) at the Miles City gage between April 29, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as "average daily" SAR values by USGS. There were 568 average daily values reported between April 29, 2004 and September 30, 2006.

Based on all of the available SAR data at the Miles City gage, 319 months have at least one SAR sample. Of those, 209 months have only 1 SAR sample, 53 months have 2 samples, 23 months have 3 samples, and 34 months have 4 or more samples (Figure F-1). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (April 2004 to September 2006). There was also a period of more intense sampling between 1962 and 1970. Only one nongrowing season month had 4 or more samples (November 1968).

In the last 5 years (October 1, 2001 to September 30, 2006), 35 months had one or more SAR samples. Of those, 7 months have only 1 SAR sample, 5 months have 2 samples, 1 month has 3 samples, and 22 months have 4 or more samples (Figure F-1).

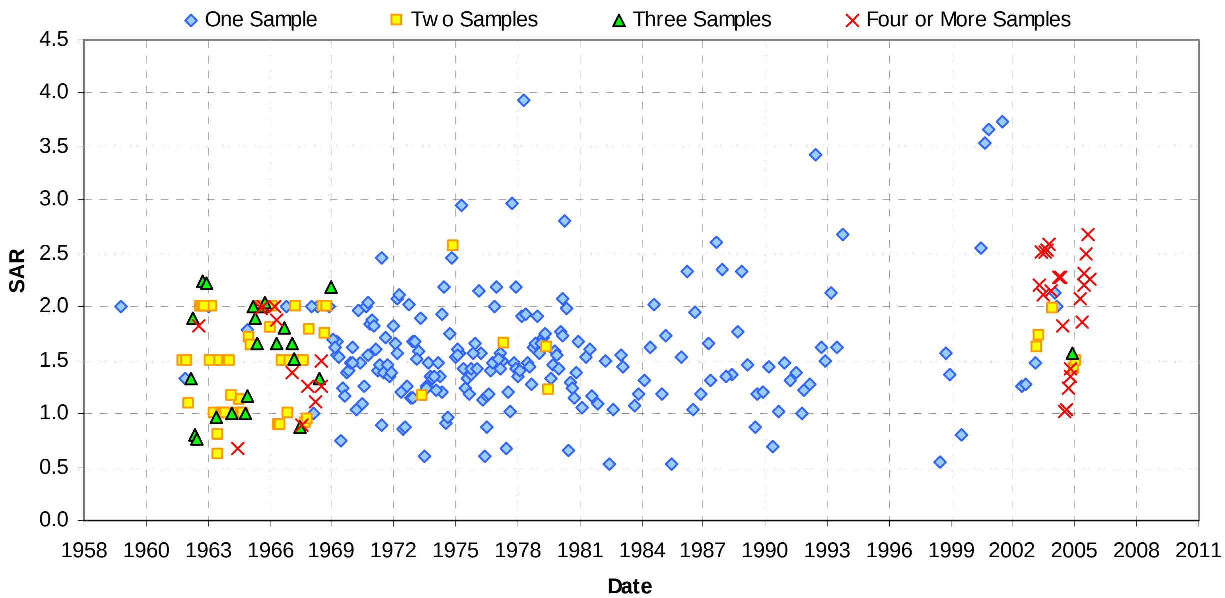

Figure F-1. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River Miles City gage (Gage #06308500).

[e] USGS estimated SAR from the continuous specific conductance (SC) data. See http://tonguerivermonitoring.cr.usgs.gov/SC_SAR_2006.htm for more details.

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-2). In general, there are more exceedances of the standard in the past 5 years, and there are more exceedances when analyzing 1 or more sampling events per month. The most exceedances occurred in the past five years when 1 or more samples were available per month.

Table F-2. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at Miles City – USGS Gage 06308500.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 1, 1959 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	215	5	2.33%
		Nongrowing Season (November 1 to March 1)	< 5.0	104	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	32	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	2	0	0.00%
"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	2	7.41%
		Nongrowing Season (November 1 to March 1)	< 5.0	8	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	22	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

There is a documented inverse relationship between flow and SAR in the Tongue River at Miles City (Figure F-2). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SAR exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative of typical conditions.

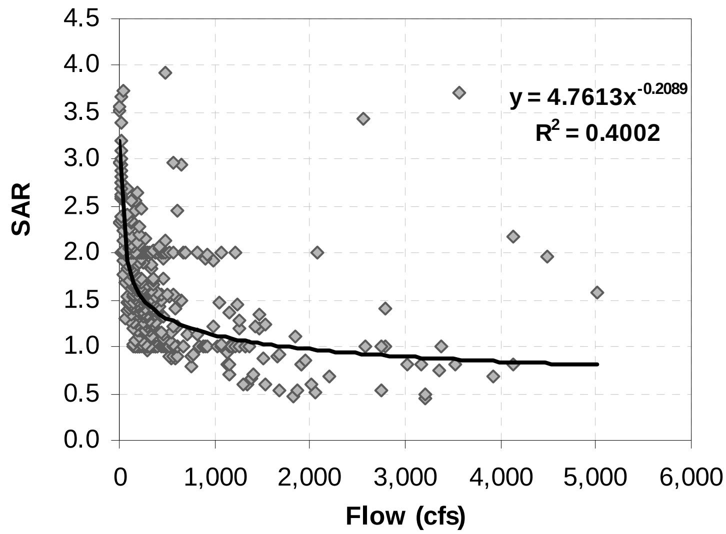

Figure F-2. SAR versus flow for the Tongue River at Miles City, Montana. Entire period of record is shown.

Using the average daily flow data from the Miles City USGS gage, the total volume of water was calculated for each month in the station's period of record (January 1, 1940 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SAR data for the past 5 years where there are four or more samples (Figure F-3). As expected, the monthly average SAR also appears to increase with decreasing flow, and no exceedances occur at flow percentiles greater than 10 percent. The data also suggest that the full range of flows during the past five years are well represented during the growing season, spanning 95 percent (1st to 96th flow percentile) of the flows ever recorded at Miles City. While it appears appropriate to evaluate the growing season using only months with four or more samples, there is insufficient data to adequately evaluate the non-growing season with four or more samples per month.

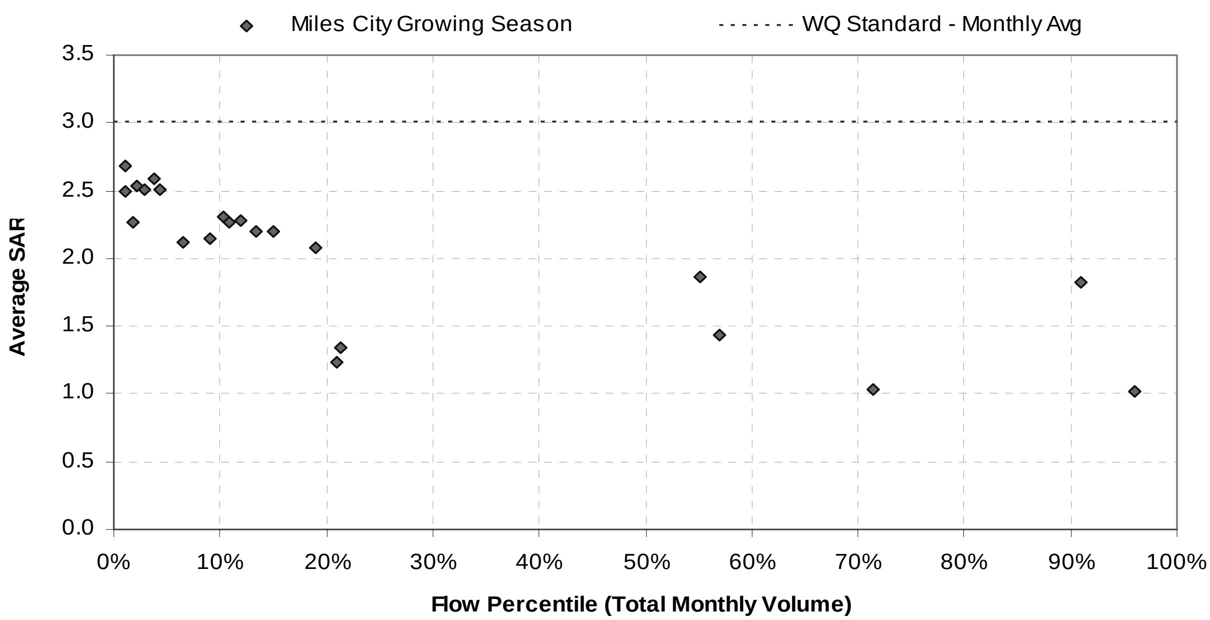

Figure F-3. Average monthly growing season SAR values at Miles City (past five years only) versus flow percentile.

F.2 Tongue River above the T&Y Diversion Dam (06307990)

Discrete SAR data are available for the Tongue River above the T&Y Diversion Dam; however no continuous SAR data are available for this station. Discrete data are instantaneous samples that were collected at a monthly frequency since November 1, 2004. 50 discrete samples were collected between November 1, 2004 and August 21, 2006. Discrete samples were generally obtained once per month.

Based on all of the available SAR data for the Tongue River above the T&Y Diversion Dam gage, 21 months have at least one SAR sample. Of those, 3 months have only 1 SAR sample, 12 months have 2 samples, 1 month has 3 samples, and 5 months have 4 or more samples (Figure F-4). All 21 SAR samples were collected within the last 5 years (October 1, 2001 to September 30, 2006) and 7 were collected during the nongrowing season.

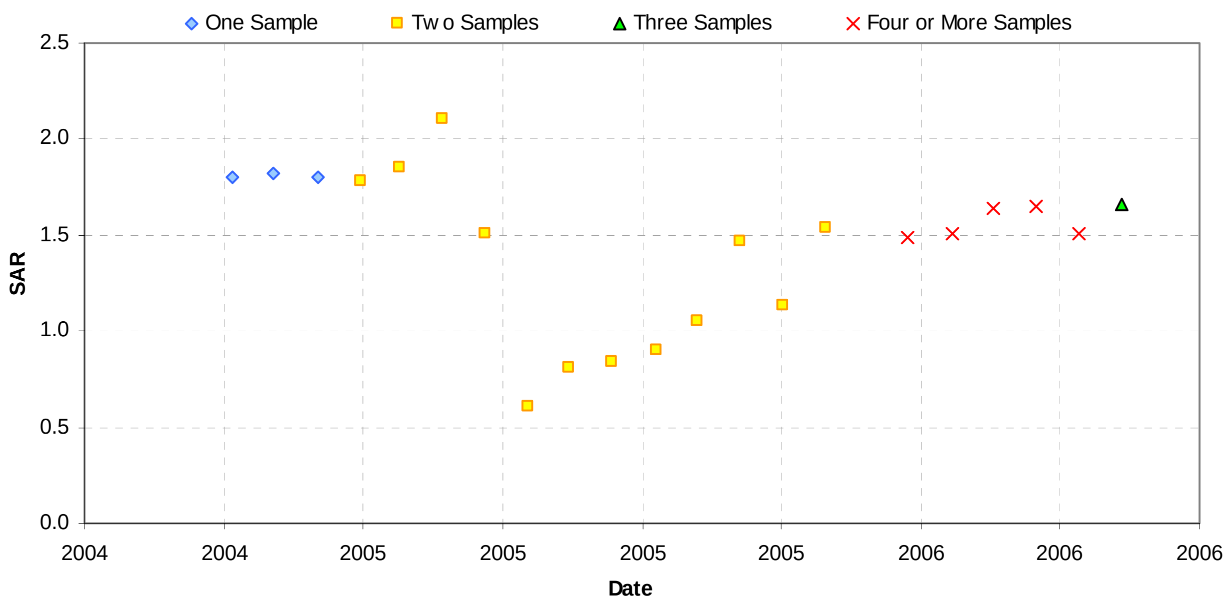

Figure F-4. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River above the T&Y Diversion Dam (Gage #06307990).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-3). No exceedances of the monthly average SAR standard were observed at the Tongue River above the T&Y Diversion Dam. However, the period of record is limited at this gage (November 2004 to September 2006), and may not adequately represent all hydrologic conditions. Additionally, monthly average SAR data with four or more samples from the past five years were all obtained in 2006, and the flow data only spans into 2005, so no figure could be generated to assess flow range conditions.

Table F-3. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at above the T&Y Diversion Dam – USGS Gage 06307990.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – November 1, 2004 to August 21, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	14	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	7	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	5	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

F.3 Tongue River at the Brandenberg Bridge (06307830)

Both discrete and continuous SAR data are available for the Tongue River at the Brandenberg Bridge. Discrete data are instantaneous samples that were collected at varying frequencies since October 1, 1974. 179 discrete samples were collected between October 1, 1974 and August 21, 2006. Data were generally obtained once per month during that time period. No samples were collected between September 16, 1981 and June 12, 2000. Monthly to bi-monthly sampling (108 samples) was then reinstated between June 13, 2000 and August 21, 2006.

Continuous SAR data were collected at the Brandenberg Bridge gage between October 1, 2003 and September 30, 2006. Data were primarily collected during the growing season. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as “average daily” SAR values by USGS. There were 594 average daily values reported between October 1, 2003 and September 30, 2006.

Based on all of the available SAR data at the Brandenberg Bridge gage, 143 months have at least one SAR sample. Of those, 112 months have only 1 SAR sample, 7 months have 2 samples, no months have 3 samples, and 24 months have 4 or more samples (Figure F-5). All of the months with 4 or more samples were collected when the continuous data logger was operational (October 1, 2003 and September 30, 2006). Only 1 nongrowing season month had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 58 months had one or more SAR samples. Of those, 29 months have only 1 SAR sample, 5 months have 2 samples, no months have 3 samples, and 24 months have 4 or more samples (Figure F-5).

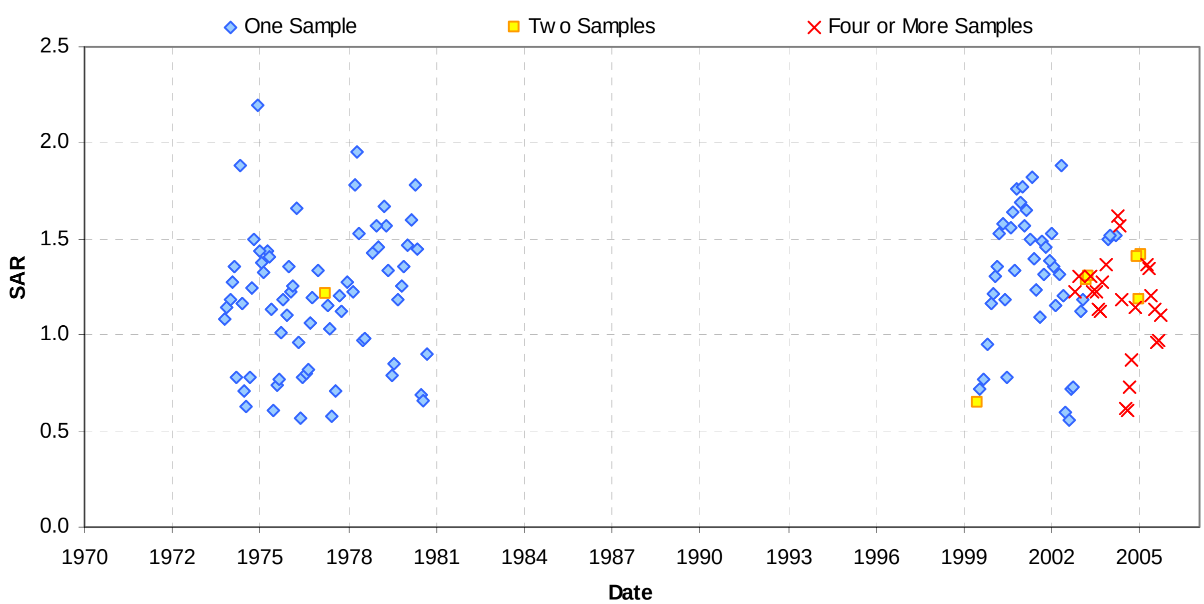

Figure F-5. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River at the Brandenberg Bridge (Gage #06307830).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-4). With a maximum recorded monthly SAR value of 2.19 from the Brandenberg Bridge site, it is unlikely that the water quality standard would be exceeded. The data do suggest that flows over the past 5 years are well represented (Figure F-6).

Table F-4. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at the Brandenberg Bridge – USGS Gage 06307830.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 1, 1974 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	101	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	42	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	23	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	1	0	0.00%

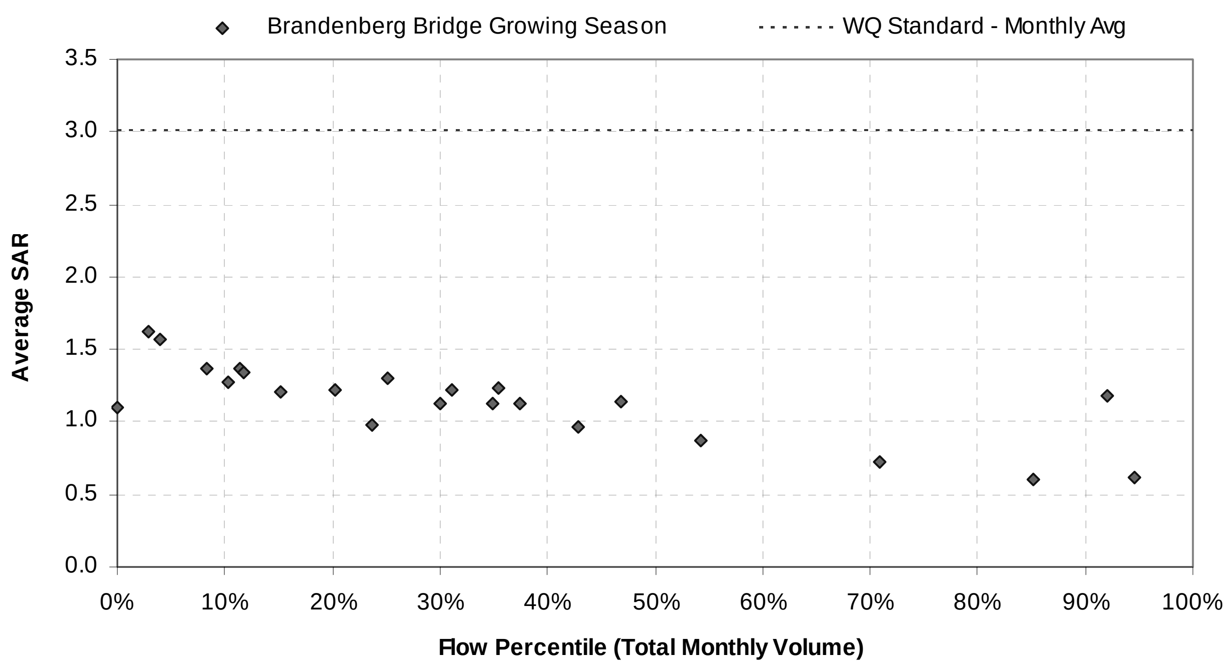

Figure F-6. Average monthly growing season SAR values at the Brandenberg Bridge (past five years only) versus flow percentile.

F.4 Tongue River at Birney Day School Bridge (06307616)

Discrete SAR data are available for the Tongue River at Birney Day School Bridge; however no continuous SAR data are available for this station. Discrete data are instantaneous samples that were collected at a monthly frequency since October 2, 1979. 159 discrete samples were collected between October 2, 1979 and August 21, 2006. Discrete samples were generally obtained once per month and in some cases bimonthly.

Based on all of the available SAR data for the Tongue River at Birney Day School Bridge gage, 123 months have at least one SAR sample. Of those, 98 months have only 1 SAR sample, 19 months have 2 samples, 1 month has 3 samples, and 5 months have 4 or more samples (Figure F-7). There were numerous monthly samplings from August 15, 1987 through June 15, 1993, then there is a break in samples until January 15, 2004 where monthly sampling begins again. 30 SAR samples were collected within the last 5 years (October 1, 2001 to September 30, 2006) and 8 of the recent samples were collected during the nongrowing season.

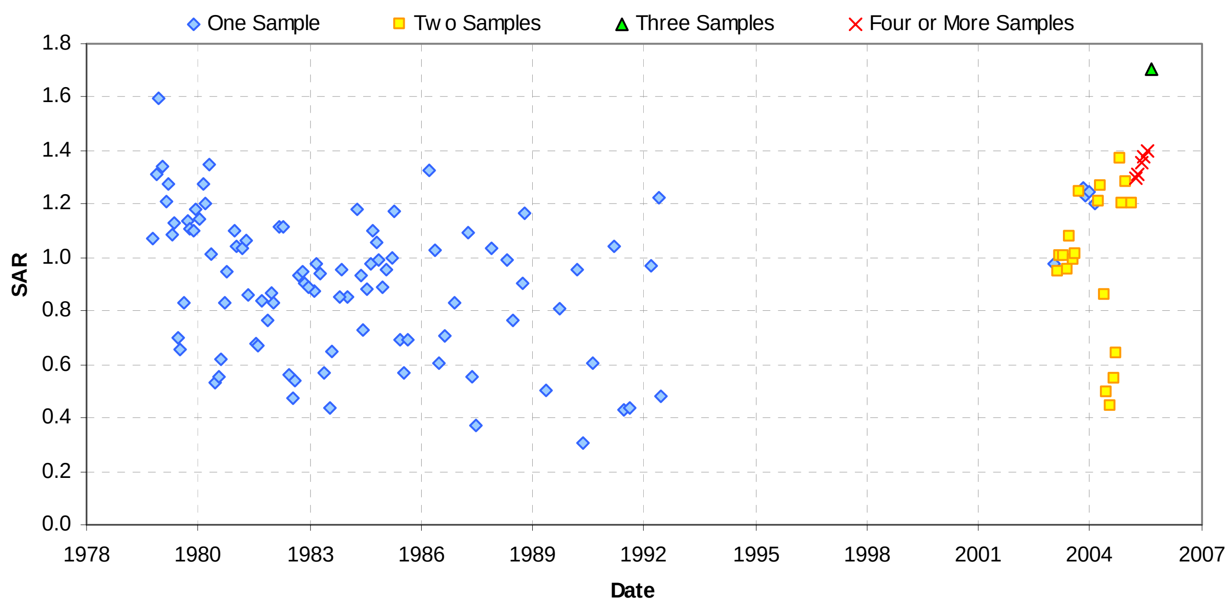

Figure F-7. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River Birney Day School Bridge gage (Gage #06307616).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-5). With a maximum SAR recorded value of 1.71 no exceedances are likely at this station. The data also suggest that only a minimal flow range is represented by the data collected at this station (Figure F-8) spanning only 53 percent of the full range of flows.

Table F-5. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at the Birney Day School Bridge – USGS Gage 06307616.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 2, 1979 to August 21, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	92	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	31	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	5	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

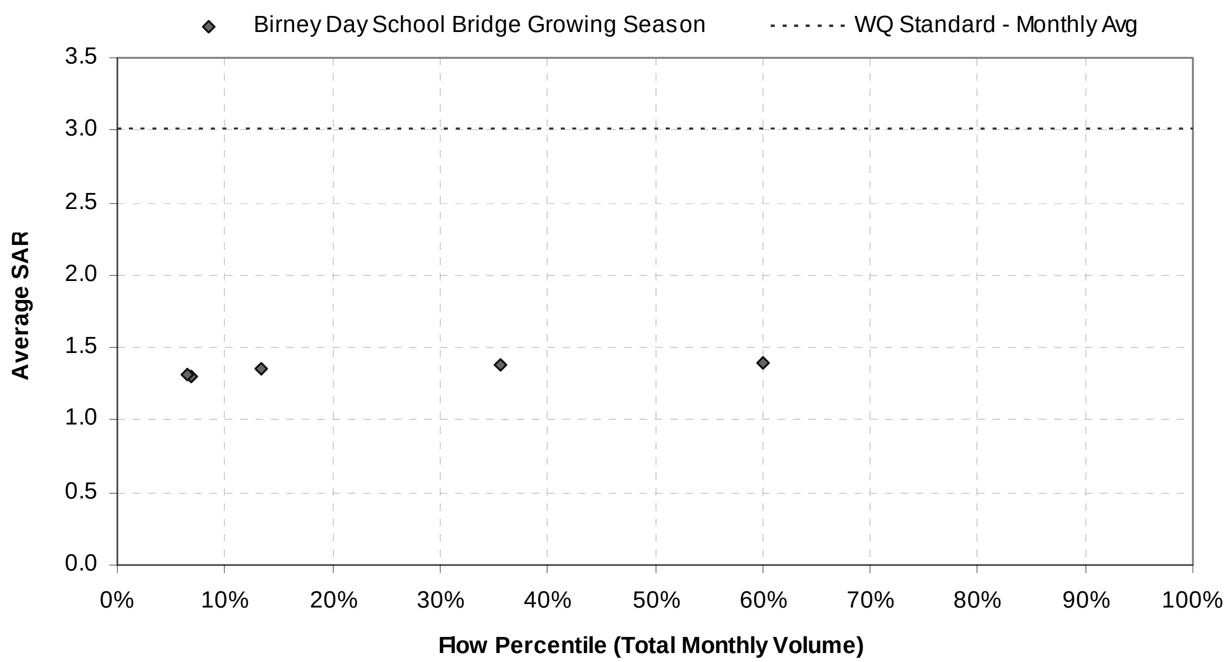

Figure F-8. Average monthly growing season SAR values at the Birney Day School Bridge (past five years only) versus flow percentile.

F.5 Tongue River below the Tongue River Reservoir Dam (06307500)

Discrete SAR data are available for the Tongue River below the Tongue River Reservoir Dam; however no continuous SAR data are available for this station. Discrete data are instantaneous samples that were collected at a monthly frequency since October 7, 1975. 251 discrete samples were collected between October 7, 1975 and August 21, 2006. Discrete samples were generally obtained once per month and in some cases bimonthly.

Based on all of the available SAR data for the Tongue River below the Tongue River Reservoir Dam gage, 208 months have at least one SAR sample. Of those, 176 months have only 1 SAR sample, 26 months have 2 samples, 1 month has 3 samples, and 5 months have 4 or more samples (Figure F-9). There were monthly samplings from October 15, 1975 through August 15, 1995. There are no samples until January 15, 2004 where monthly sampling begins again. 30 SAR samples were collected within the last 5 years (October 1, 2001 to September 30, 2006) and 8 of the recent samples were collected during the nongrowing season.

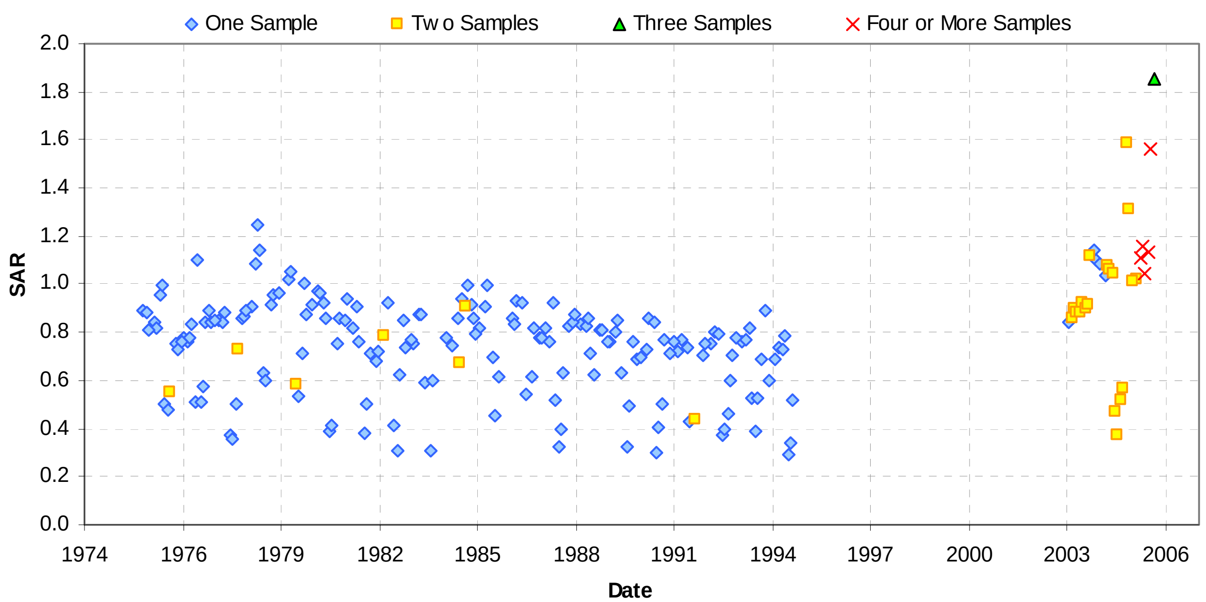

Figure F-9. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River below the Tongue River Reservoir Dam gage (Gage #06307500).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-6). There are no exceedances of the SAR standard at the Tongue River gage below the Tongue River Reservoir Dam and exceedances are unlikely as the maximum SAR value recorded was 1.86 at this station. However, the data suggest that only a minimal flow range is represented (Figure F-10), spanning 51 percent of the flows ever recorded at the Tongue River below the Tongue River Reservoir Dam.

Table F-6. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River below the Tongue River Reservoir Dam – USGS Gage 06307500.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 7, 1975 to August 21, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	149	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	59	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	5	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

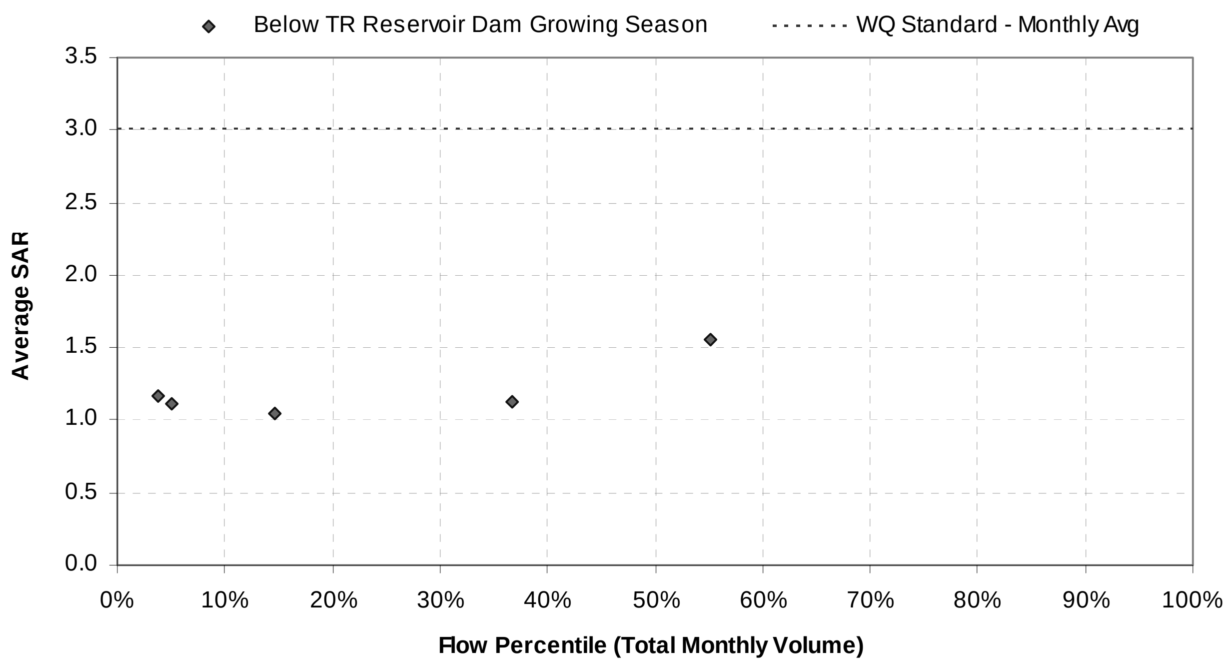

Figure F-10. Average monthly growing season SAR values below the Tongue River Reservoir Dam (past five years only) versus flow percentile.

F.6 Tongue River at the Montana-Wyoming State Line (06306300)

Both discrete and continuous SAR data are available for the Tongue River at the Montana-Wyoming State Line. Discrete data are instantaneous samples that were collected at varying frequencies since November 4, 1985. 241 discrete samples were collected between November 4, 1985 and August 22, 2006. Data were generally obtained once per month during that time period.

Continuous SAR data were collected year-round at the Montana-Wyoming State Line gage from August 22, 2000 to September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as “average daily” SAR values by USGS. There were 1,937 average daily SAR values reported from August 22, 2000 to September 30, 2006.

Based on all of the available SAR data at the Montana-Wyoming State Line gage, 99 months have at least one SAR sample. Of those, 27 months have only 1 SAR sample, 2 months have 2 samples, no months have 3 samples, and 70 months have 4 or more samples (Figure F-11). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (September 2000 to September 2006). 20 nongrowing season months had 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 60 months had one or more SAR samples. Of those, 5 months have only 1 SAR sample, no months have 2 samples, no months have 3 samples, and 55 months have 4 or more samples (Figure F-11).

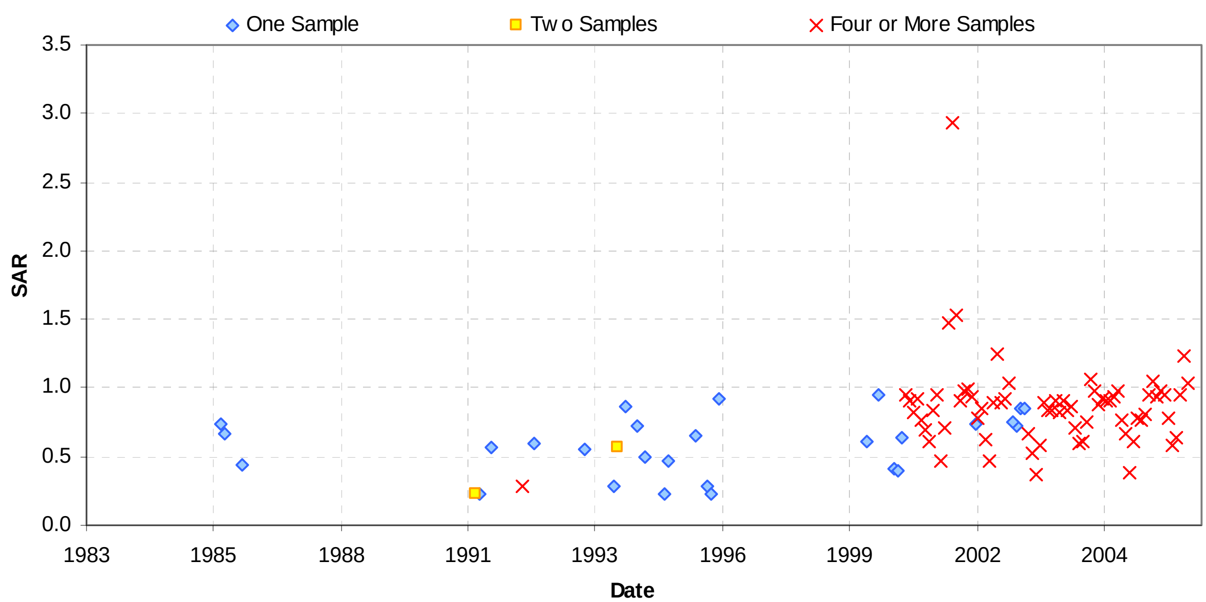

Figure F-11. Average monthly SAR values and the number of SAR samples collected each month at the Montana-Wyoming State Line (Gage #06306300).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-7). There are no exceedances at the Tongue River at the Montana-Wyoming state line station and the data suggest that the full range of flows during the past five years is well represented (Figure F-12). However, the period of record is limited at this gage (most data collected August 22, 2000 to September 30, 2006).

Table F-7. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at the Montana-Wyoming State Line – USGS Gage 06306300.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – November 4, 1985 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	69	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	30	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	50	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	20	0	0.00%

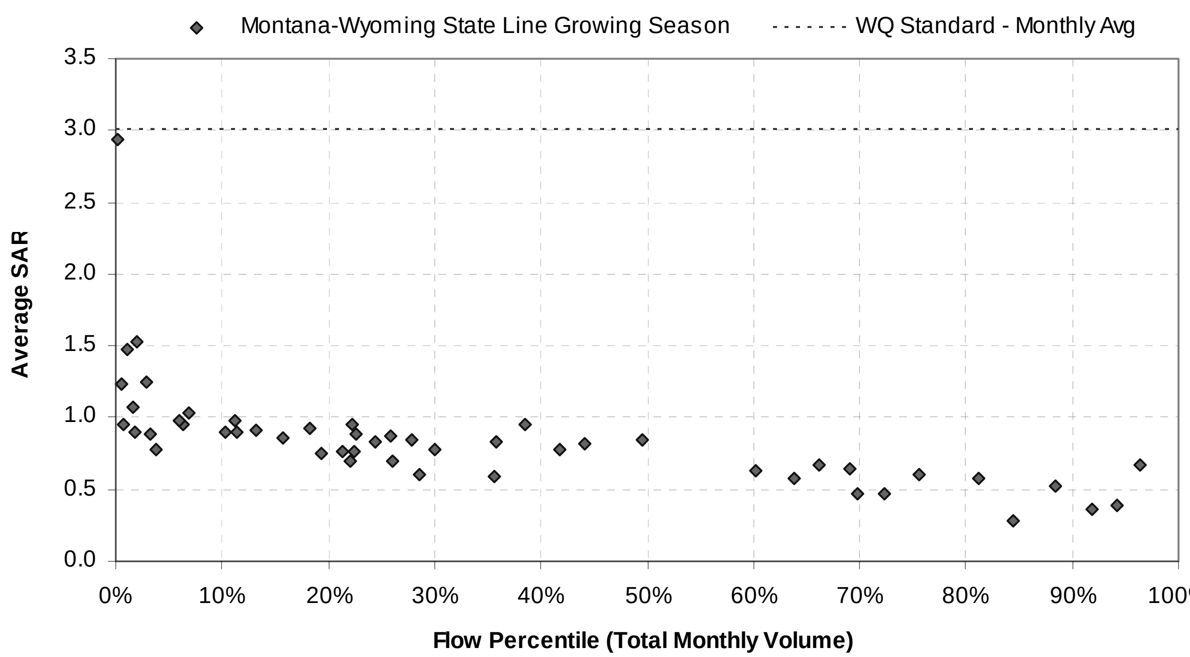

Figure F-12. Average monthly growing season SAR values at the Montana-Wyoming state line (past five years only) versus flow percentile.

F.7 Tongue River at Monarch, Wyoming (06299980)

Both discrete and continuous SAR data are available for the Tongue River at Monarch. Discrete data are instantaneous samples that were collected year-round since April 3, 1974. 133 discrete samples were collected between April 3, 1974 and August 7, 2006. Data were generally obtained once per month during that time period.

Continuous SAR data were collected year-round at the Monarch gage between May 1, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as "average daily" SAR values by USGS. There were 611 average daily values reported between May 1, 2004 and September 30, 2006.

Based on all of the available SAR data at the Monarch gage, 106 months have at least one SAR sample. Of those, 75 months have only 1 SAR sample, 9 months have 2 samples, 1 month has 3 samples, and 21 months have 4 or more samples (Figure F-13). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There was also a period of monthly sampling between 1974 and 1984. There were no nongrowing season months with 4 or more samples for this station.

In the last 5 years (October 1, 2001 to September 30, 2006), 31 months had one or more SAR samples. Of those, 4 months have only 1 SAR sample, 5 months have 2 samples, 1 month has 3 samples, and 21 months have 4 or more samples (Figure F-13). All of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006).

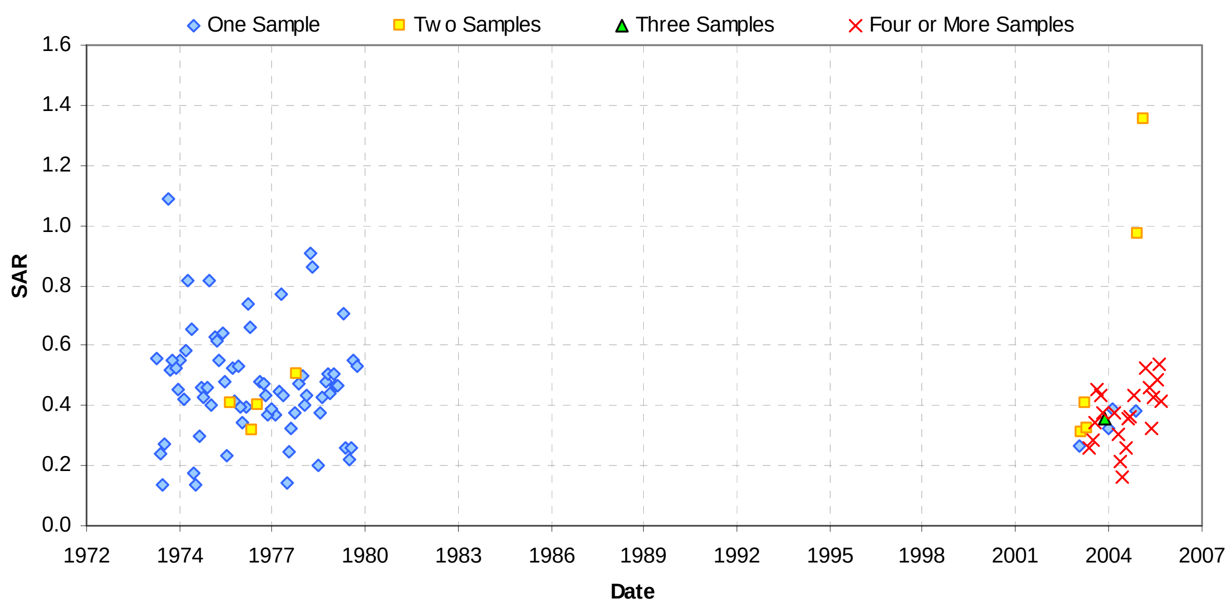

Figure F-13. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River Monarch gage (Gage #06299980).

The calculated average monthly SAR values were compared to Montana's average monthly SAR standards[f]. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-8). There are no SAR exceedances at the Monarch gage station. Though the period of record is limited at this gage (most data collected May 1, 2004 to September 30, 2006), the full range of flows during the past five years are well represented (Figure F-14).

Table F-8. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at Monarch – USGS Gage 06299980.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – April 3, 1974 to September 30, 2006	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	74	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	32	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	21	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

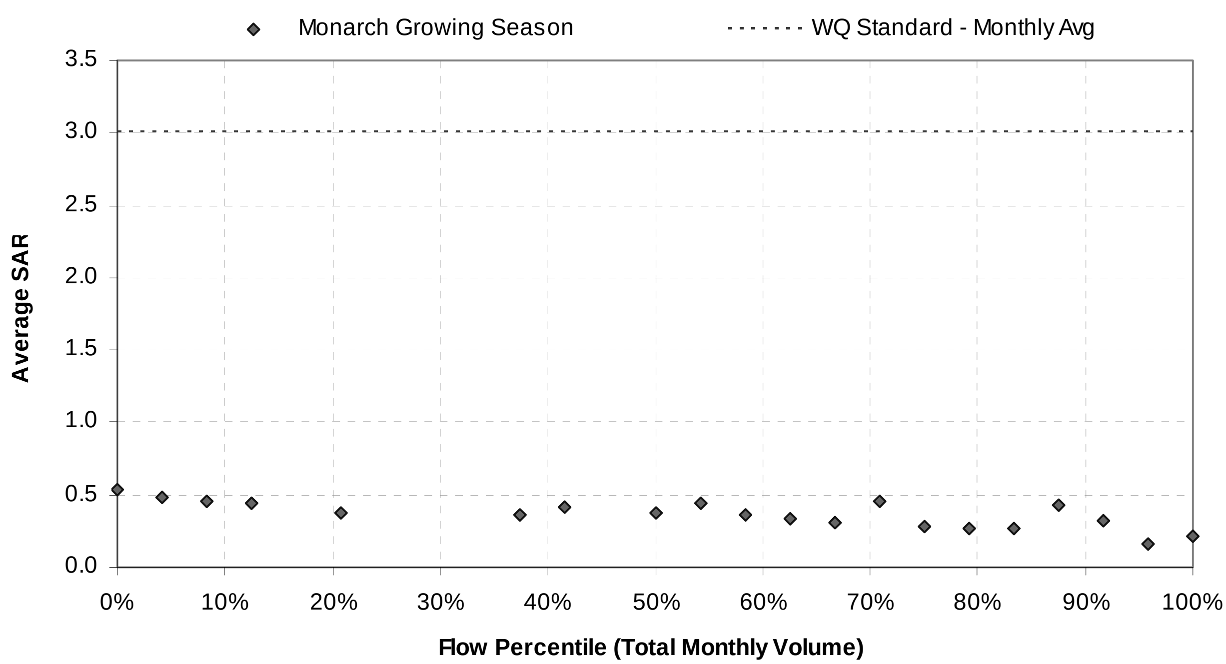

Figure F-14. Average monthly growing season SAR values at Monarch (past five years only) versus flow percentile.

[f] 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.

F.8 Tongue River at Dayton, Wyoming (06298000)

Discrete SAR data are available for the Tongue River at Dayton; however no continuous data are available for this station. Discrete data are instantaneous samples that were collected at varying frequencies since October 10, 1966. 221 discrete samples were collected between October 10, 1966 and August 14, 2002. Data were generally obtained once per month during that time period.

Based on all of the available SAR data at the Dayton gage, 207 months have at least one SAR sample. Of those, 195 months have only 1 SAR sample, 11 months have 2 samples, 1 month has 3 samples, and no months have 4 or more samples (Figure F-15). In the last 5 years (October 1, 2001 to September 30, 2006), 1 month had only one SAR sample.

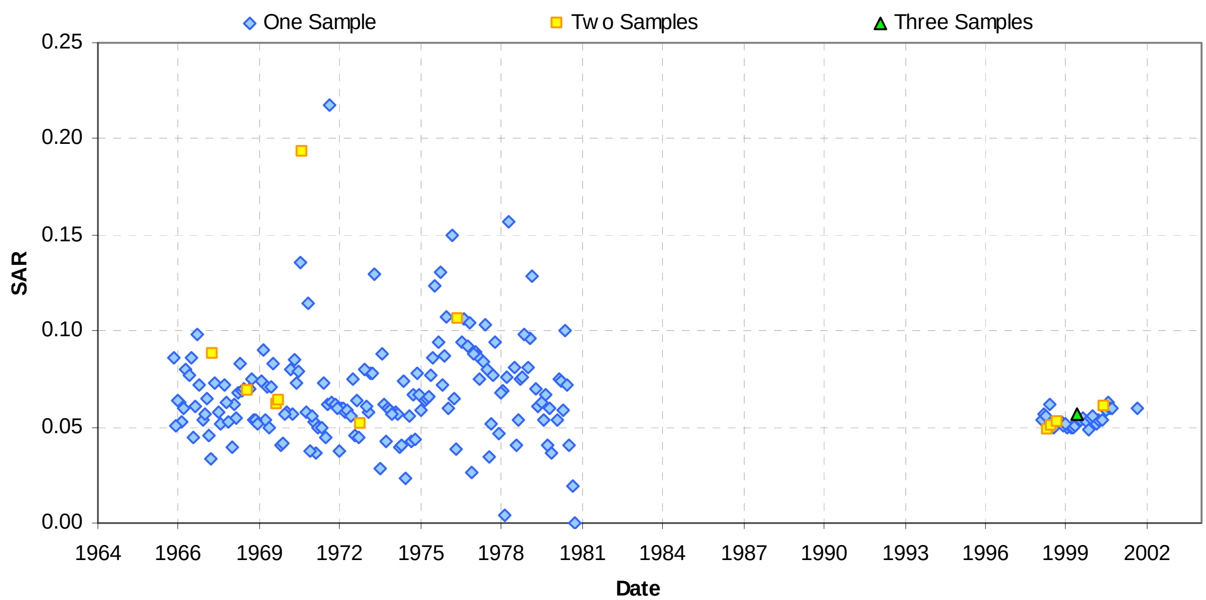

Figure F-15. Average monthly SAR values and the number of SAR samples collected each month at the Tongue River Dayton gage (Gage #06298000).

The calculated average monthly SAR values were compared to Montana's average monthly SAR standards[g]. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-9). This station has no more than 3 SAR samples per month and only one sample within the last 5 years. There are no exceedances at the Dayton gage station as there are very low recorded SAR values (0.31 as a maximum).

[g] 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.

Table F-9. Average monthly SAR data and exceedances of the average monthly water quality standards for the Tongue River at Dayton – USGS Gage 06298000.

Time Period	Sampling Frequency	Season	Numeric Standard	# Months with Samples	# Months Exceeding	% Months Exceeding
"All Data" – October 10, 1966 to August 14, 2002	**1 or more samples per month**	Growing Season (March 2 to October 31)	< 3.0	138	0	0.00%
		Nongrowing Season (November 1 to March 1)	< 5.0	69	0	0.00%
	4 or more samples per month	Growing Season (March 2 to October 31)	< 3.0	0	NA	NA
		Nongrowing Season (November 1 to March 1)	< 5.0	0	NA	NA

F.9 Hanging Woman Creek (06307600)

Both discrete and continuous SAR data are available for Hanging Woman Creek near Birney, Montana. Discrete data are instantaneous samples that were collected at varying frequencies since October 2, 1974. 185 discrete samples were collected between October 2, 1974 and June 6, 2006. Data were generally obtained once per month during that time period.

Continuous SAR data were collected during the growing season (i.e., mid March to November 1) at the gage near Birney, Montana between May 22, 2004 and June 16, 2006. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as "average daily" SAR values by USGS. There were 228 average daily values reported between May 22, 2004 and June 16, 2006.

Based on all of the available SAR data at the gage near Birney, 166 months have at least one SAR sample. Of those, 147 months have only 1 SAR sample, 8 months have 2 samples, no months have 3 samples, and 11 months have 4 or more samples (Figure F-16). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to June 2006). There are no nongrowing season months with 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 25 months had one or more SAR samples. Of those, 10 months have only 1 SAR sample, 4 months have 2 samples, no months have 3 samples, and 11 months have 4 or more samples (Figure F-16).

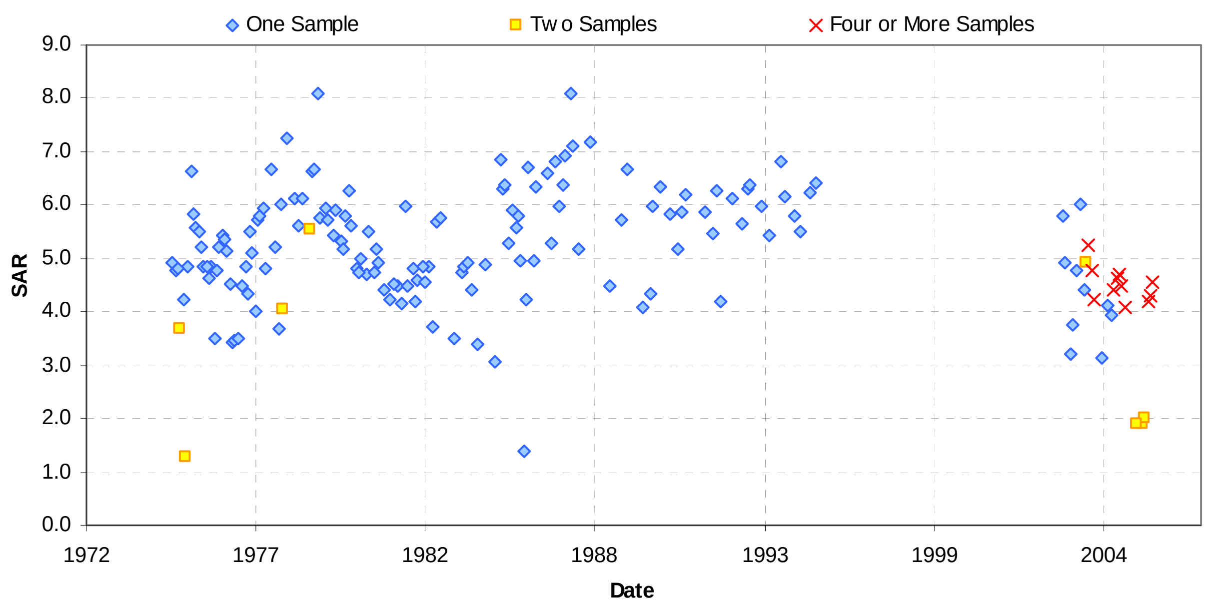

Figure F-16. Average monthly SAR values and the number of SAR samples collected each month at the Hanging Woman Creek near Birney, MT gage (Gage #06307600).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-10). At this Hanging Woman Creek station, all but 5 recorded monthly average SAR values were found to exceed the water quality standard. Most exceedances occurred during the growing season when 4 or more samples were available per month.

Table F-10. Average monthly SAR data and exceedances of the average monthly water quality standards for Hanging Woman Creek near Birney, MT – USGS Gage 06307600.

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

There is a documented inverse relationship between flow and SAR in Hanging Woman Creek near Birney (Figure F-17). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SAR exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

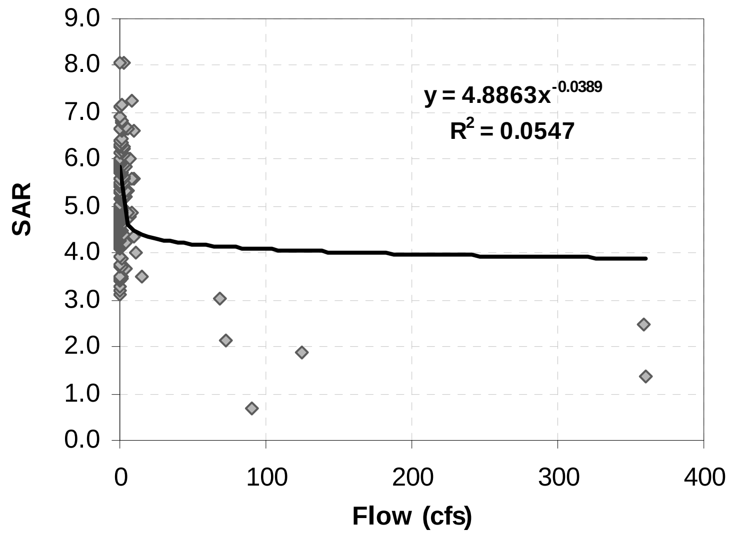

Figure F-17. SAR versus flow for Hanging Woman Creek near Birney, Montana. Entire period of record is shown.

Using the average daily flow data from the USGS gage near Birney, the total volume of water was calculated for each month in the station's period of record (September 1, 1973 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SAR data for the past 5 years where there are four or more samples (Figure F-18). The data suggest that the full range of flows during the past five years are not well represented during the growing season (less than 40 percent of the full range of flows at this station). The analyses of both the growing and nongrowing seasons are severely limited by the available data.

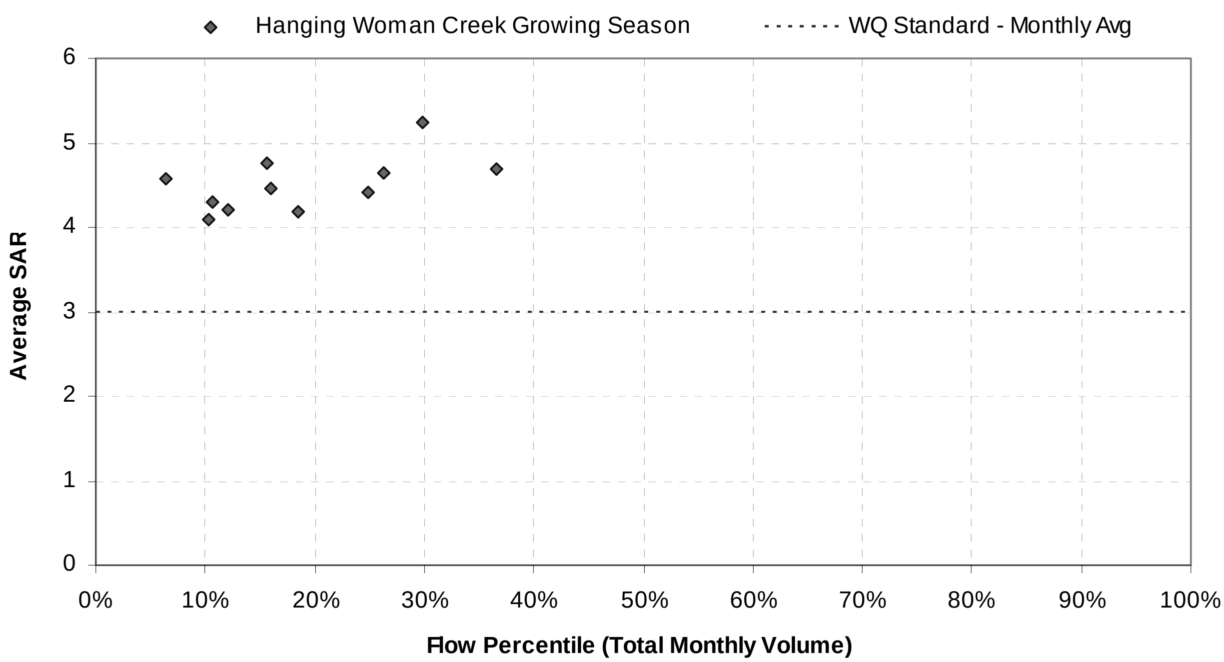

Figure F-18. Average monthly growing season SAR values near Birney (past five years only) versus flow percentile.

F.10 Otter Creek (06307740)

Both discrete and continuous SAR data are available for Otter Creek at Ashland, Montana. Discrete data are instantaneous samples that were collected at varying frequencies since October 2, 1974. 193 discrete samples were collected between October 2, 1974 and August 8, 2006. Data were generally obtained once per month during that time period.

Continuous SAR data were collected during the growing season (i.e., mid March to November 1) at the Ashland gage between May 25, 2004 and September 30, 2006. These data were collected by a probe placed in the Tongue River which recorded SAR at 15 minute intervals. The data were then reported as "average daily" SAR values by USGS. There were 484 average daily values reported between May 25, 2004 and September 30, 2006.

Based on all of the available SAR data at the Ashland gage, 172 months have at least one SAR sample. Of those, 144 months have only 1 SAR sample, 8 months have 2 samples, no months have 3 samples, and 20 months have 4 or more samples (Figure F-19). Most of the months with 4 or more samples were collected when the continuous data loggers were operational (May 2004 to September 2006). There are no nongrowing season months with 4 or more samples.

In the last 5 years (October 1, 2001 to September 30, 2006), 34 months had one or more SAR samples. Of those, 10 months have only 1 SAR sample, 4 months have 2 samples, no months have 3 samples, and 20 months have 4 or more samples (Figure F-19).

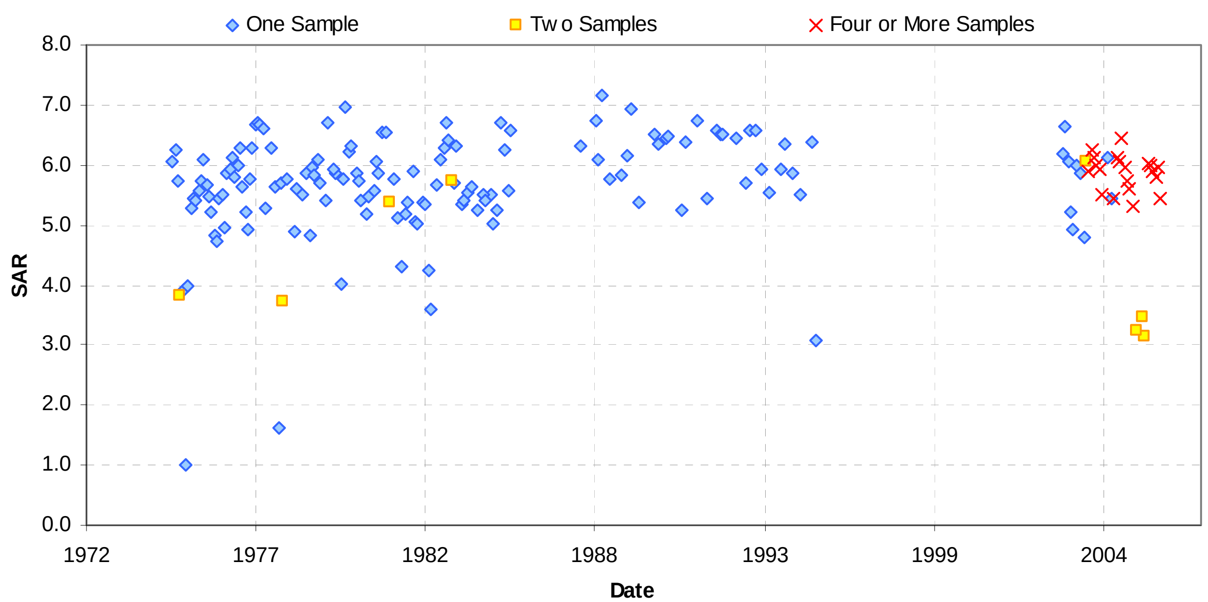

Figure F-19. Average monthly SAR values and the number of SAR samples collected each month at the Otter Creek Ashland gage (Gage #06307740).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-11). At this Otter Creek station, all recorded monthly average SAR values were found to exceed the water quality standard, with the exception of two values (1.00 and 1.62, both in March of 1975 and 1978, respectively).

Table F-11. Average monthly SAR data and exceedances of the average monthly water quality standards for Otter Creek at Ashland– USGS Gage 06307740.

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

There is a documented inverse relationship between flow and SAR in Otter Creek at Ashland (Figure F-20). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SAR exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

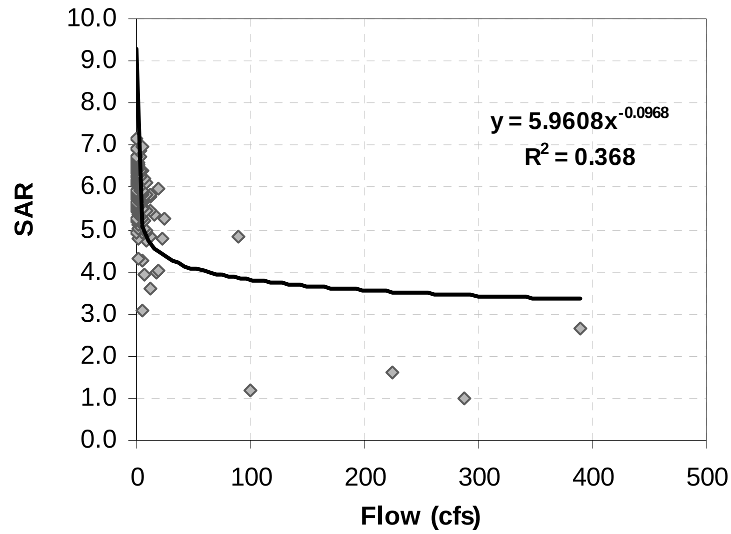

Figure F-20. SAR versus flow for Otter Creek at Ashland, Montana. Entire period of record is shown.

Using the average daily flow data from the Ashland USGS gage, the total volume of water was calculated for each month in the station's period of record (October 1, 1972 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SAR data for the past 5 years where there are four or more samples (Figure F-21). The data also suggest that the full range of flows during the past five years are relatively well represented during the growing season, spanning 77 percent (7th to 78th flow percentile) of the flows ever recorded at Ashland. While it appears appropriate to evaluate the growing season using only months with four or more samples, there is insufficient data to adequately evaluate the non-growing season with four or more samples per month.

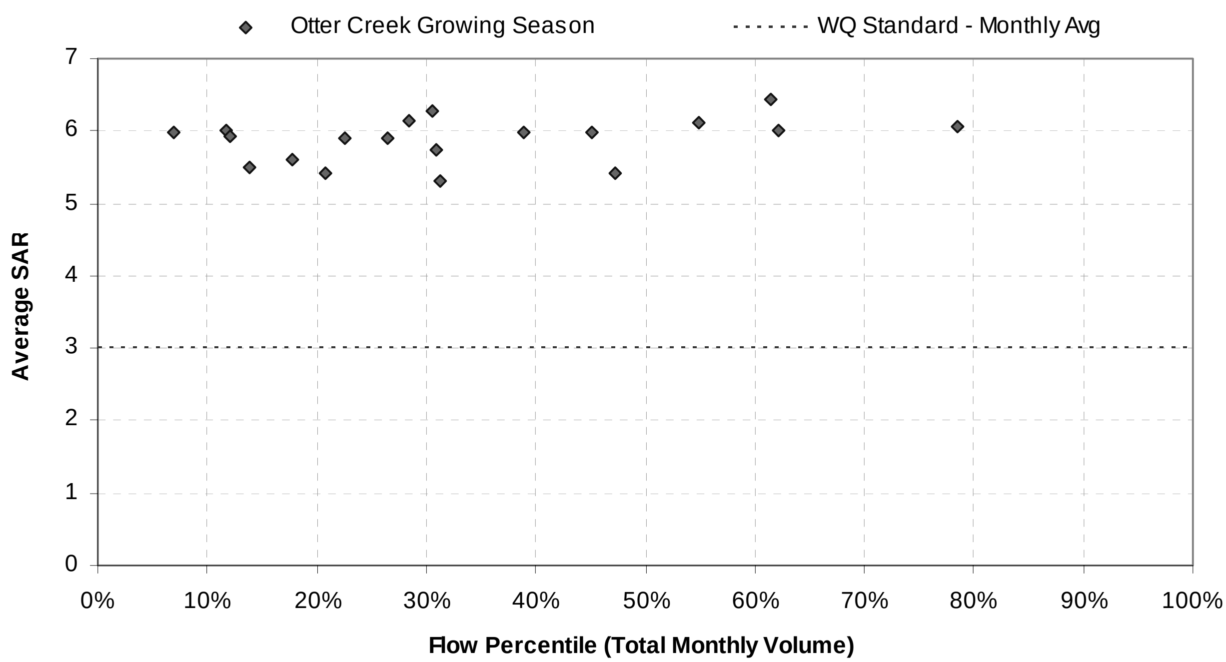

Figure F-21. Average monthly growing season SAR values at Ashland (past five years only) versus flow percentile.

F.11 Pumpkin Creek (06308400)

Discrete SAR data are available for Pumpkin Creek near Miles City; however no continuous data are available for this station. Discrete data are instantaneous samples that were collected at varying frequencies since October 15, 1975. 93 discrete samples were collected between October 15, 1975 and June 21, 2006. Data were generally obtained once per month during that time period. Sampling occurred between October 1975 and August 1985, and again between March 2004 and June 2006.

Based on all of the available SC data at the Pumpkin Creek gage, 68 months have at least one SAR sample. Of those, 53 months have only 1 SAR sample, 11 months have 2 samples, no months have 3 samples, and 4 months have 4 or more samples (Figure F-22). In the last 5 years (October 1, 2001 to September 30, 2006), 17 months had at least one SC sample. Of those, 6 months have only 1 SAR sample, 7 months have 2 samples, no months have 3 samples, and 4 months have 4 or more samples (Figure F-22). Only 3 months had nongrowing season data, none of which had more than 2 samples.

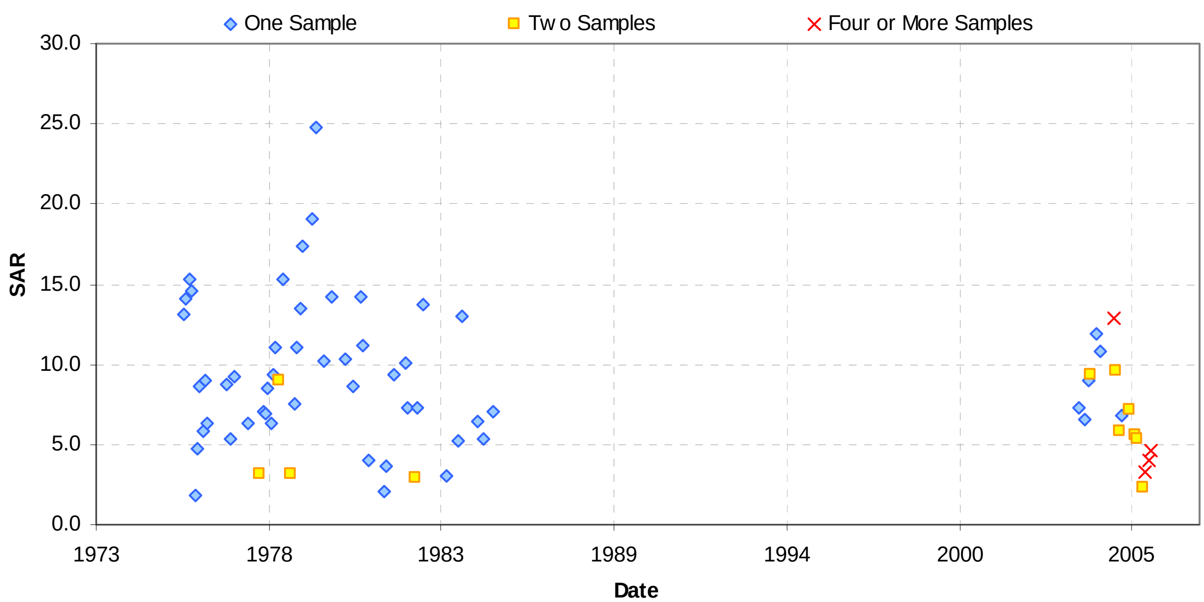

Figure F-22. Average monthly SAR values and the number of SAR samples collected each month at the Pumpkin Creek Miles City gage (Gage #06308400).

The calculated average monthly SAR values were compared to the average monthly SAR standards. In comparing values to the standards, data were stratified by time period, sampling frequency, and season to show the variations in exceedances depending on the chosen stratification level (Table F-12). All but four recorded values at this site exceed SAR water quality standards.

Table F-12. Average monthly SAR data and exceedances of the average monthly water quality standards for Pumpkin Creek near Miles City – USGS Gage 06308400.

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 September 30, 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

There is a documented inverse relationship between flow and SAR in Pumpkin Creek near Miles City (Figure F-23). This relationship, combined with the ongoing drought in southeast Montana (1999-present), suggests that SAR exceedances observed in the past five years may be a function of low flow and therefore, the last five years may not be representative.

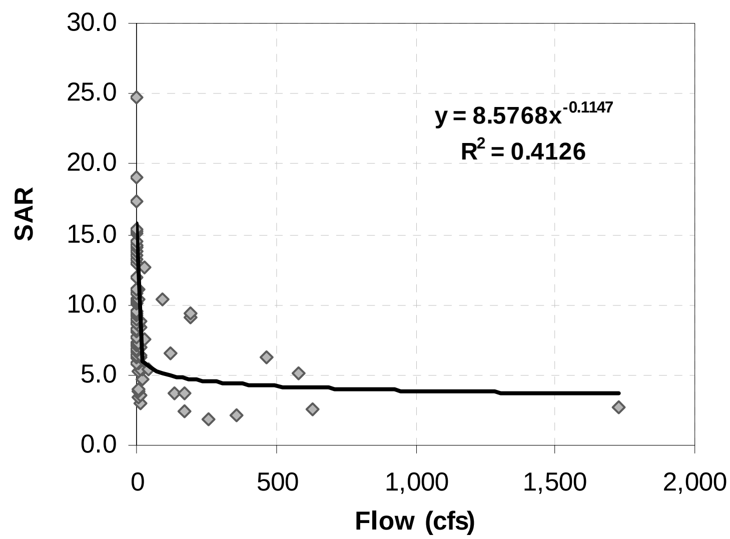

Figure F-23. SAR versus flow for Pumpkin Creek near Miles City, Montana. Entire period of record is shown.

Using the average daily flow data from the Pumpkin Creek near Miles City USGS gage, the total volume of water was calculated for each month in the station's period of record (October 1, 1972 to September 30, 2006). The flow percentile for each month was then calculated and plotted with the monthly average growing season SAR data for the past 5 years where there are four or more samples (Figure F-24). The data suggest that the full range of flows during the past five years are not well represented during the growing season, spanning only about 30 percent of the flows ever recorded at Miles City. Both growing and nongrowing seasons are limited in both the available SAR data and the corresponding flow range coverage.

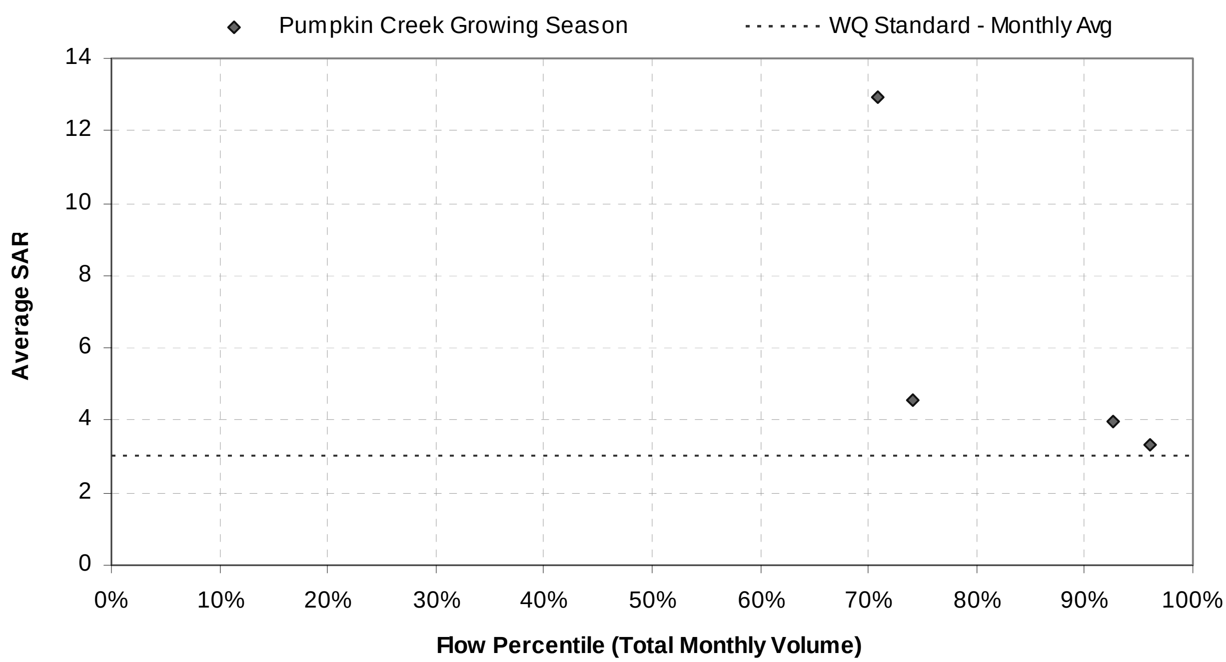

Figure F-24. Average monthly growing season SAR values near Miles City (past five years only) versus flow percentile.

F.12 Summary and Conclusions

A screening analysis was conducted to provide insight regarding potential alternatives for interpretation of Montana's monthly average sodium adsorption ratio standard. The results of this analysis indicate that:

- The period of record varies from a maximum of approximately 47 years at Miles City, Montana (gage # 06308500) to a minimum of approximately two years above the T&Y Diversion Dam, Montana (gage # 06307990).
- 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 collection continuous SAR data, there are few months with greater than one sample per month.
- Given the variability in SAR on a monthly basis (an overall range of 0 to 24.754 in SAR values), 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), with a few exceptions (Tongue River below the Reservoir Dam, Tongue River at the Birney Day School Bridge, Hanging Woman Creek, and Pumpkin Creek).

APPENDIX G – GROUNDWATER CONCENTRATIONS IN HANGING WOMAN CREEK, OTTER CREEK, AND PUMPKIN CREEK WATERSHEDS

G.0 GROUNDWATER CONCENTRATIONS IN HANGING WOMAN CREEK, OTTER CREEK, AND PUMPKIN CREEK WATERSHEDS

This appendix presents a summary of groundwater quality data in the Hanging Woman Creek, Otter Creek, and Pumpkin Creek watersheds to provide context for the discussions of water quality in the main report. Information about local geology, soils, and groundwater quality was obtained from existing USGS and NCRS studies. Groundwater data in the three watersheds were also downloaded from the USGS National Water Information System (NWIS) database (available at http://waterdata.usgs.gov/nwis) and from the Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) database (available at http://mbmggwic.mtech.edu/).

G.1 Hanging Woman Creek

G.1.1 Salinity

Geology and soils in the Hanging Woman Creek watershed are naturally high in salinity. Soil survey data indicates that some soil salinity naturally exceeds 10,000 µS/cm in this region (USDA, 2007a; USDA, 2007b). NRCS noted that saline soils and seeps were common in the upstream reaches of Hanging Woman Creek, as evidenced by alkali deposits, pan spots, exposure of salt bearing shales, salt crusts, and greasewood (NRCS, 2002).

Salt deposits and saline seeps in Hanging Woman Creek near the Montana-Wyoming border (Photo by NRCS, June 2002).

The Hanging Woman Creek watershed has large coal reserves. Several of the stream valleys dissect the coal seems, resulting in high salinity soils and springs originating from the coal aquifers (USGS, 1983; USGS, 1984; USGS, 1989). The Anderson coal bed is especially high in salinity, with an average TDS concentration of 8,700 mg/L (approximately equal to 12,000 µS/cm SC) (USGS, 1983). These coal beds are located in the upstream reaches of Hanging Woman Creek, where the stream exhibits high salinity. The high salinity soils noted by NRCS are also in this region. Salinity in the streams and groundwater tend to decrease in a downstream direction (USGS, 1989). This correlation between the geology, soils, and water chemistry all suggest that salinity concentrations are naturally high in Hanging Woman Creek due to localized geology and groundwater contributions.

Data from MBMG and USGS shows that salinity is high throughout most of the aquifers in the Hanging Woman Creek watershed, and is generally higher than the average in-stream salinity (Table G-1). Average SC concentrations for the quaternary alluvial aquifer, Tongue River Member aquifer, and the Wasatch Formation aquifer were 5,345 µS/cm, 3,940 µS/cm, and 3,126 µS/cm, respectively.

Table G-1. Summary of groundwater specific conductance data in the Hanging Woman Creek watershed (µS/cm).

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium (Quaternary)	156	5,345	2,700	14,800	2,363	1977-1987
Spring	7	1,729	313	4,204	1,349	1973-1982
Tongue River Member (of Ft Union Fm.)	228	3,940	313	10,500	2,329	1973-1986
Wasatch Formation	5	3,126	1,830	5,880	1,737	1961-1976

Data obtained from USGS and MBMG.

G.1.2 SAR

Geology and soils in the Hanging Woman Creek watershed are naturally high in sodium, resulting in naturally high SAR. The watershed has large coal reserves, which often have sodium rich coal bed aquifers. Where coal beds are at or near the surface, soils and surface water are naturally high in sodium and SAR. Like salinity, SAR values are high in the southern portion of the watershed (see Figure 2-24 in the 2003 Tongue River Status Report [MDEQ, 2003]), and tend to decrease in a downstream direction. USGS reported that SARs ranged from 41 to 61 in the Canyon and Deitz coal bed aquifers, and ranged from 50 to 56 in the Anderson coal bed aquifers (USGS, 1983; USGS, 1984). Soil survey data indicates that some soil SARs naturally exceed 15 in this region (USDA, 2007a; USDA, 2007b). Data from the Montana Bureau of Mines and Geology and USGS NWIS shows that SAR is high in aquifers near coal beds (i.e., Tongue River Member), and SAR is low in the alluvial and sandstone aquifers not containing coal (i.e., alluvium, Wasatch Formation) (Table G-2).

Table G-2. Summary of groundwater SAR in the Hanging Woman Creek watershed.

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium	61	7.08	1.52	14.2	2.3	1923-1987
Wasatch Formation	1	2.28	2.28	2.28	NA	1973
Tongue River Member (of Ft Union Fm.)	81	27.22	0.37	71.24	20.67	1973-1986
Springs	8	3.13	0.58	6.78	2.67	1923-1982

Data obtained from USGS and MBMG.

G.2 Otter Creek

G.2.1 Salinity

The Otter Creek watershed has large coal reserves (USGS, 1984b; USGS 1985). Water in alluvial aquifers typically contains TDS values ranging from 1,770 to 12,600 mg/L (USGS, 1983; USGS, 1985). These coal beds are located throughout the watershed, and are slightly more concentrated in the upstream reaches of Otter Creek (USGS, 1988). This correlation between the geology, soils, and water chemistry all suggests that salinity concentrations are naturally high in Otter Creek due to localized geology and groundwater contributions. Dilution, as well as the lack of coal beds near the mouth of the creek, helps to decrease salinity in a downstream direction.

Data from the Montana Bureau of Mines and Geology and USGS shows that salinity is high throughout most of the aquifers in the Otter Creek watershed, and is generally higher than the average in-stream salinity (Table G-3). Average SC concentrations for the quaternary alluvial aquifer, Tongue River Member aquifer, and the Wasatch Formation aquifer were 3,946 µS/cm, 3,004 µS/cm, and 2,980 µS/cm, respectively.

Table G-3. Summary of groundwater specific conductance data in the Otter Creek watershed.

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium (Pleistocene)	1	3,641	3,641	3,641	NA	1974
Alluvium (Quaternary)	236	3,916	373	14,000	1,912	1973-1988
Lebo Shale Member (Of Ft Union Fm.)	2	1,635	1,570	1,700	92	1973
Spring	56	3,078	373	8,400	1,723	1973-1984
Tongue River Member (Of Ft Union Fm.)	452	3,004	400	8,600	1,521	1973-1988
Tullock Member (Of Ft Union Fm.)	27	2,355	1,471	3,480	487	1973-1980
Wasatch Formation	3	2,980	2,140	4,500	1,319	1974

Data obtained from USGS and MBMG.

G.2.2 SAR

Geology and soils in the Otter Creek watershed are naturally high in sodium, resulting in naturally high SAR (USGS, 1984b; USGS 1985). The watershed has large coal reserves, which often have sodium rich coal bed aquifers. Where coal beds are at or near the surface, soils and surface water are naturally high in sodium and SAR. USGS reported that SARs ranged from 41 to 61 in the Canyon and Deitz coal bed aquifers, and ranged from 50 to 56 in the Anderson coal bed aquifers (USGS, 1983). Soil survey data indicates that some soil SARs naturally exceed 15 in this region (USDA, 2003). Data from the Montana Bureau of Mines and Geology and USGS NWIS shows that SAR is high in aquifers near coal beds (i.e., Tongue River Member), and SAR is low in the alluvial and sandstone aquifers not containing coal (Table G-4).

Table G-4. Summary of groundwater SAR in the Otter Creek watershed.

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium (Pleistocene)	1	5.68	5.68	5.68	NA	1974
Alluvium (Quaternary)	175	5.97	0.76	17.86	2.71	1973-1988
Judith River Formation (Of Montana Group)	2	106.2	104.42	107.98	2.52	1956
Lebo Shale Member (Of Ft Union Fm.)	2	37.35	29.19	45.51	11.54	1973
Minnelusa Sandstone Or Formation	2	80.72	48.59	112.85	45.44	1961-1964
Mission Canyon Limestone (Of Madison Group)	2	4.18	1.79	6.56	3.37	1962-1964
Shannon Sandstone Mbr. (Of Cody Or Steele Sh)	4	124.13	94.46	158.42	26.33	1956
Spring	56	6.68	0.54	38.37	7.64	1973-1984
Tongue River Member (Of Ft Union Fm.)	375	22.38	0.54	74.26	18.57	1923-1988
Tullock Member (Of Ft Union Fm.)	24	66.25	13.63	109.12	22.39	1973-1980
Wasatch Formation	3	1.48	0.76	2.91	1.24	1974

Data obtained from USGS and MBMG.

G.3 Pumpkin Creek

G.3.1 Salinity

The Pumpkin Creek watershed has large coal reserves, primarily in the headwaters region upstream of monitoring station 06308160, and in the Little Pumpkin Creek watershed (Bergantino et al., 1980; Bergantino et al., 1981). Data from the Montana Bureau of Mines and Geology and USGS shows that salinity is high throughout most of the aquifers in the Pumpkin Creek watershed, and is generally similar to the average in-stream salinity (Table G-5). This suggests that water in Pumpkin Creek is primarily sustained by groundwater and springs, and receives little dilution from precipitation. Average SC concentrations for the quaternary alluvial aquifer and the Tongue River Member aquifer were 3,813 µS/cm, and 2,916 µS/cm, respectively.

Table G-5. Summary of groundwater salinity (SC) in the Pumpkin Creek watershed.

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium (Quaternary)	2	3,813	3,520	4,105	414	1976-1977
Fox Hills-Hell Creek Aquifer	2	1,305	1,230	1,380	106	1976-1977
Hell Creek Formation	6	1,447	1,234	1,700	191	1976-1977
Lebo Shale Member (Of Ft Union Fm.)	10	2,369	990	2,950	626	1976
Spring	3	1,168	640	2,181	878	1974-1977
Tongue River Member (of Ft Union Fm.)	52	2,916	720	5,345	1,333	1974-1994
Tullock Member (of Ft Union Fm.)	7	2,959	1,305	4,782	1,024	1976

Data obtained from USGS and MBMG.

G.3.2 SAR

The Pumpkin Creek watershed has large coal reserves, primarily in the headwaters region upstream of monitoring station 06308160, and in the Little Pumpkin Creek watershed (Bergantino et al., 1980; Bergantino et al., 1981). Data from the Montana Bureau of Mines and Geology and USGS shows that SAR is high throughout most of the aquifers in the Pumpkin Creek watershed, although SAR values in the alluvium are generally low and similar to in-stream values (Table G-6). This suggests that water in Pumpkin Creek is primarily sustained by alluvial groundwater and springs, and receives little dilution from precipitation. SAR values in the coal aquifers in Pumpkin Creek (Tongue River Member, Lebo Shale Member) are much higher, having averages as high has 120.7 (Eagle Sandstone). Average SAR concentrations for the quaternary alluvial aquifer and the Tongue River Member aquifer were 6.3, while the average SAR in the Tongue River Member was 18.9.

Table G-6. Summary of groundwater SAR in the Pumpkin Creek watershed.

Aquifer	Count	Average	Minimum	Maximum	St Dev	Period of Record
Alluvium (Quaternary)	2	6.3	6.3	6.4	0.1	1976-1977
Eagle Sandstone	3	120.7	119.4	123.3	2.2	1955
Fox Hills-Hell Creek Aquifer	2	63.2	52.3	74.0	15.3	1976-1977
Hell Creek Formation	6	58.8	45.8	73.1	11.1	1976-1977
Lebo Shale Member (of Ft Union Fm.)	10	32.2	2.5	61.5	26.8	1976
Parkman Sandstone (of Montana Group)	1	71.6	71.6	71.6	NA	1955
Red Bird Siltstone Member (of Pierre Shale)	1	65.7	65.7	65.7	NA	1955
Shannon Sandstone Member	9	112.5	60.1	130.7	26.2	1955-1956
Spring	3	2.2	0.4	5.8	3.1	1974-1977
Tongue River Member (of Ft Union Fm.)	49	18.9	0.4	57.2	17.3	1974-1994
Tullock Member (of Ft Union Fm.)	7	33.4	17.2	58.1	16.4	1976-1976

Data obtained from USGS and MBMG.

G.4 References

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APPENDIX H – HYDROLOGY OF THE TONGUE RIVER WATERSHED

H.0 HYDROLOGY OF THE TONGUE RIVER WATERSHED

H.1 Introduction

This appendix presents a summary of precipitation and stream flows in the Tongue River watershed to provide context for the discussions of water quality in the main report.

H.2 Precipitation

Precipitation data are available from over 50 weather stations within and near the Tongue River watershed. For the purpose of this report, five stations were chosen to provide a simple overview of precipitation in the watershed: Burgess Junction (WY), Dome Lake (WY), Sheridan (WY), Ashland (MT), and Miles City (MT). These stations were selected because they represent the three major regions of the Tongue River watershed: mountains (Burgess Junction and Dome Lake), transition from mountains to prairie (Sheridan), and prairie (Ashland and Miles City). It should be noted that additional stations were used in the LSPC modeling (see the Modeling Report for a discussion of these stations). Average yearly precipitation in the watershed ranges from over 30 inches per year in the Bighorn Mountains to less than 13 inches per year near Ashland, Montana (Table H-1). Figure H-1 shows that mountain precipitation varied between 20 and 37 inches per year, while prairie precipitation varied between 5 and 24 inches per year (Figure H-2).

Low precipitation years (generally defined as less than 10 inches of precipitation) are common throughout the period of record at the Miles City and Sheridan precipitation gages (see Figure H-2). Historically, these low precipitation years were then followed by years of above average precipitation. The past several years (1999 to 2006) are unique because they have been consecutive low precipitation years, resulting in a prolonged period of drought. Since 1998, seven out of the past eight years (as measured at Sheridan) have been below the long-term average of 14.6 inches per year. At Miles City, six of the past eight years have been below average (average of 13.4 inches per year). Additional details about the documented ongoing drought that started in 1999 are presented in Section H.4.

Table H-1. Summary of yearly precipitation data at selected stations in the Tongue River watershed.

Station	Type	Period of Record	Average	Median	Min	Max	Range	5-Yr Avg[1]
Burgess Junction	Mountain	1989-2006	26.9	27.3	19.7	31.4	11.7	26.3
Dome Lake	Mountain	1989-2006	30.1	29.4	24.5	37.1	12.6	29.5
Sheridan	Prairie	1950-2006	14.6	14.6	8.2	23.8	15.6	13.2
Ashland	Prairie	1950-2006	12.8	12.7	7.5	20.2	12.7	12.6
Miles City	Prairie	1950-2006	13.4	13.2	5.3	20.3	15.0	12.0

[1]Years 2002-2006.

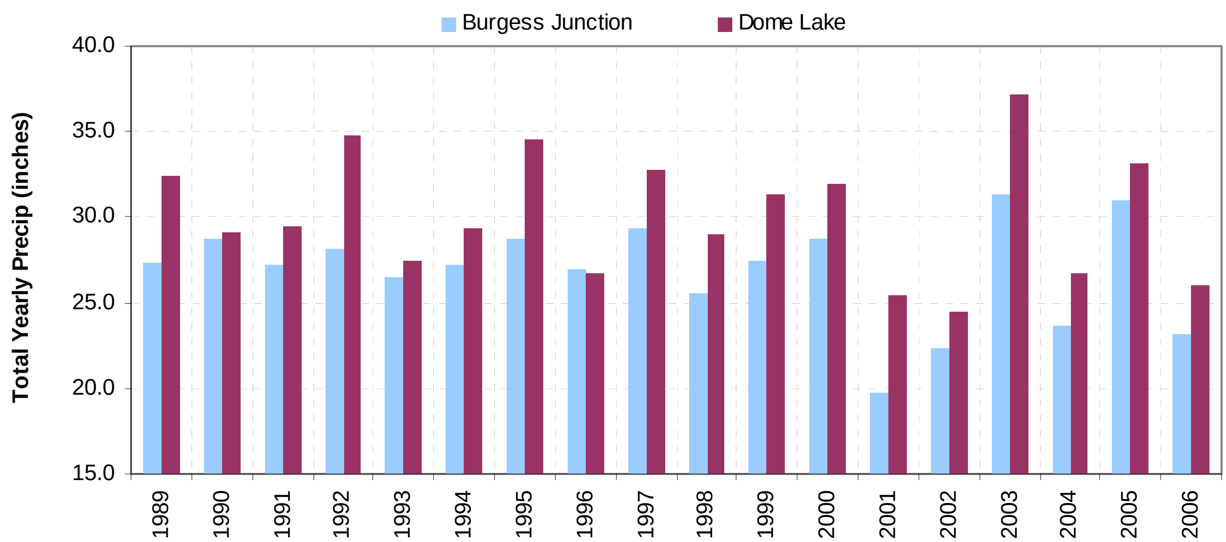

Figure H-1. Total yearly precipitation at two mountain gages in the Tongue River watershed.

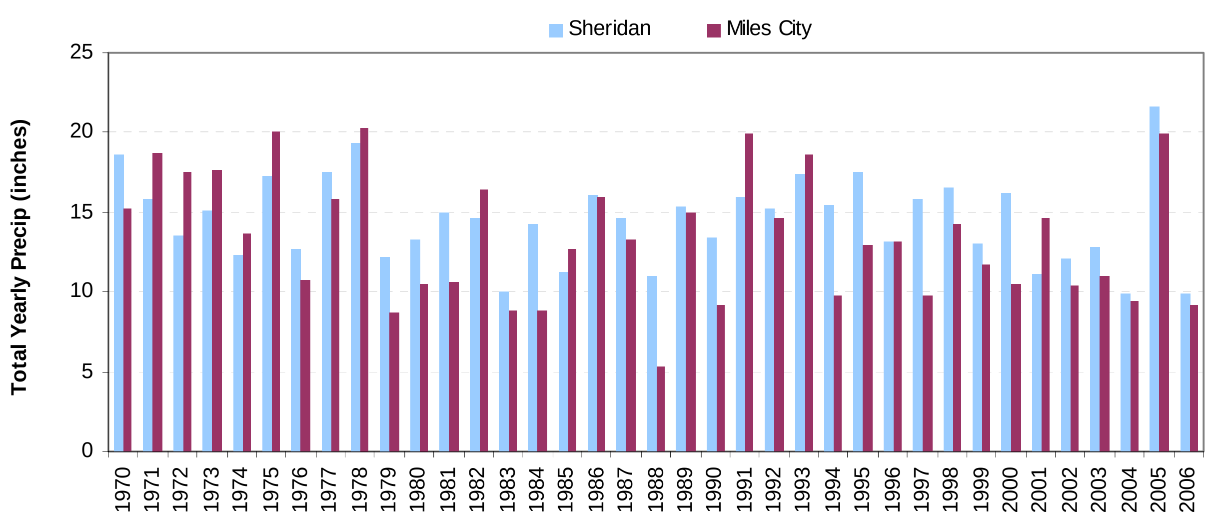

Figure H-2. Total yearly precipitation at two prairie gages in the Tongue River watershed.

H.3 Stream Flow

The USGS National Water Information System (NWIS) online database has continuous flow data for 54 gages in the Tongue River watershed. The period of record ranges from May 1, 1903 to the present. Gages are located on the mainstem Tongue River, most of the major tributaries (e.g., Goose Creek, Prairie Dog Creek, Hanging Woman Creek, Otter Creek), and in both high altitude mountain streams and low altitude prairie streams. The continuous flow gages summarized in Table H-2 and shown in Figure H-3 were selected to provide a general understanding of flow in the Tongue River watershed from the headwaters to the mouth. The following sections summarize stream flows from the headwaters to the Tongue River Reservoir (Section H.3.1), within the Tongue River Reservoir (Section H.3.2), and from the Tongue River Reservoir Dam to the mouth (Section H.3.3).

Table H-2. Summary of selected USGS continuous flow gages in the Tongue River watershed.

Station ID	Site Name	Latitude	Longitude	Altitude (ft)	Drainage Area (mi^2)	Period of Record[1]
06298000	Tongue River near Dayton, WY	44.84941	-107.30453	4,060	206	1918-Present
06299500	Wolf Creek at Wolf, WY	44.77247	-107.23424	4,525	38	1945-Present
06299980	Tongue River at Monarch, WY	44.90025	-107.02090	3,620	478	2004-Present
06302000	Big Goose Creek near Sheridan, WY	44.70219	-107.18146	4,505	120	1930-2000
06303500	Little Goose Creek In Canyon, Near Big Horn, WY	44.59608	-107.04007	4,860	52	1941-Present
06305700	Goose Creek near Acme, WY	44.88636	-106.98896	3,620	413	1984-Present
06306100	Squirrel Creek near Decker, MT	45.05136	-106.92729	3,680	34	1975-1985
06306250	Prairie Dog Creek near Acme, WY	44.98386	-106.83979	3,450	358	1970-Present
06306300	Tongue River at State Line near Decker, MT	45.00886	-106.83618	3,429	1,453	1960-Present
06307500	Tongue River at Tongue River Reservoir Dam near Decker, MT	45.14137	-106.77145	3,344	1,770	1939-Present
06307600	Hanging Woman Creek near Birney, MT	45.29555	-106.50393	3,150	470	1973-Present
06307616	Tongue River at Birney Day School Bridge near Birney, MT	45.41166	-106.45781	3,060	2,621	1979-Present
06307740	Otter Creek at Ashland, MT	45.58389	-106.25529	2,917	707	1972-Present
06307830	Tongue River below Brandenberg Bridge near Ashland MT	45.83972	-106.21973	2,760	3,948	1973-Present
06308400	Pumpkin Creek near Miles City, MT	46.22834	-105.69055	2,490	697	1972-Present
06308500	Tongue River at Miles City, MT	46.38472	-105.84528	2,360	5,379	1938-Present

[1]Period of record for the continuous flow recorders only.

Figure H-3. Selected USGS continuous flow gages in the Tongue River watershed.

H.3.1 Headwaters to the Tongue River Reservoir

It is important to understand the topography of the Tongue River watershed because it directly relates to stream flow. The headwaters of the Tongue River are located in the Bighorn Mountains, which are part of the larger Middle Rocky Mountains ecoregion. In the Tongue River watershed, the mountains rise up from the Great Plains (elevation of 3,000 to 5,000 feet near Sheridan, Wyoming) to a peak of 11,500 feet at the headwaters of Big Goose Creek (Figure H-4). Approximately 9 percent of the Tongue River watershed is located in the Bighorn Mountains.

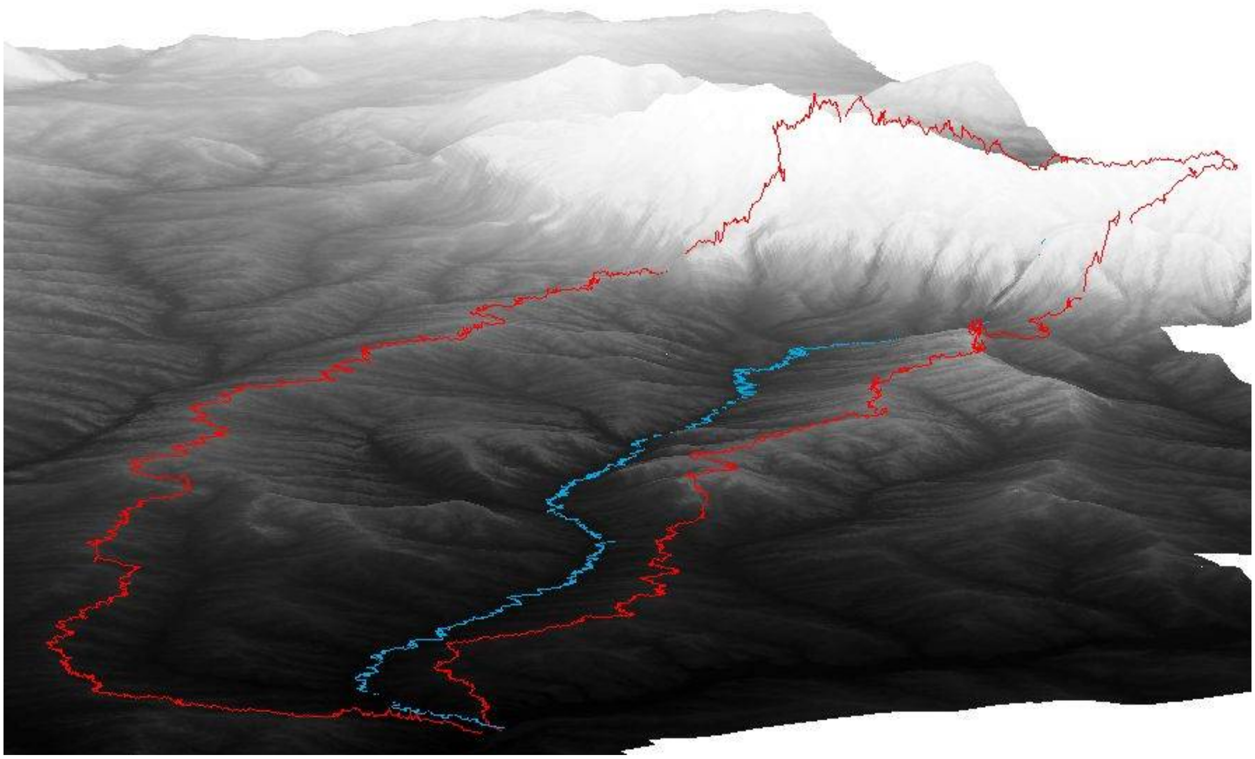

Figure H-4. 3D elevation model of the Tongue River watershed.

Precipitation and snowmelt from the Bighorn Mountains first flows into multiple small, high altitude tributaries and lakes. Some of the water is stored in high altitude reservoirs, which are regulated to store and release water for downstream irrigators. The multiple high altitude tributaries eventually flow into four streams that deliver water out of the Bighorn Mountains and into the prairie region near Sheridan, Wyoming. The four streams are the Tongue River, Wolf Creek, Big Goose Creek, and Little Goose Creek. USGS maintains continuous flow gages on each of these streams just downstream of the mountains (Figure H-3 shows the location of the gages, and flow data are summarized in Table H-3). Except for the Tongue River at Dayton, USGS currently maintains the gages from April 1 to September 30 of each year. As shown in Figure H-5, each stream exhibits a typical mountain snowmelt hydrograph, with peak flows in June and base flows in the winter months. The most water flows out of the mountains through the Tongue River (average flow of 174 cfs), and the least amount through Wolf Creek (average flow of 36 cfs). The regulation of the high altitude reservoirs is most evident in the falling limb of the Little Goose Creek hydrograph which, unlike the other hydrographs, shows sustained flows in July and August.

Table H-3. Summary of flows in four mountain streams.

Station Name	Station ID	Count	Average (cfs)	Median (cfs)	Minimum (cfs)	Maximum (cfs)	5-Year Average (cfs)[1]	Period of Record
Tongue River near Dayton, WY	06298000	27,727	174	72	18	2,590	110	1918-1929; 1940-Present
Wolf Creek at Wolf, WY	06299500	15,750	36	12	2	601	36	1945-Present
Big Goose Creek near Sheridan, WY	06302000	20,503	92	25	2	2,050	NA	1930-Present
Little Goose Creek in Canyon, near Big Horn, WY	06303500	17,302	81	53	3	837	86	1941-Present

[1]October 1, 2001-September 30, 2006. No data were available for Big Goose Creek in the past 5 years.

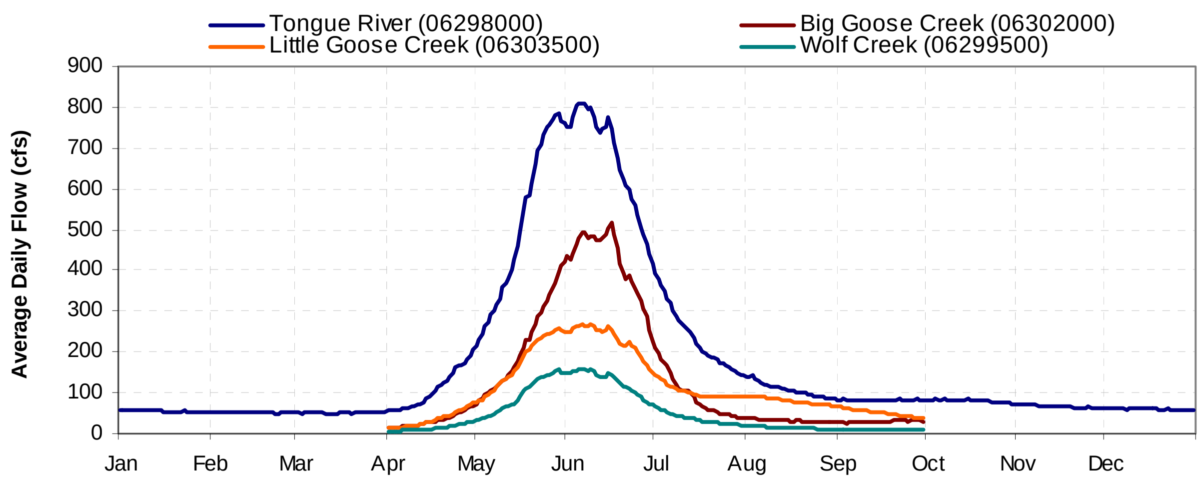

Figure H-5. Average daily flows in four mountain streams in the Tongue River watershed upstream of the Tongue River Reservoir (entire period of record is shown).

Prairie tributaries upstream of the Tongue River Reservoir also contribute flow to the Tongue River, but the relative contribution is small when compared to flow from the mountains. Major prairie tributaries upstream of the Tongue River Reservoir include Prairie Dog Creek, Badger Creek, Squirrel Creek, and Youngs Creek. Figure H-6 shows the average daily flows for Prairie Dog Creek near Acme, Wyoming (USGS Gage 06306250) and Squirrel Creek near Decker, Montana (USGS Gage 06306100). Flow at the Prairie Dog Creek gage is not typical of prairie streams in the Tongue River watershed because it receives an average flow of 62 cubic feet per second during the growing season from a diversion from the Powder River watershed. This results in an average flow of 35.8 cubic feet per second, as opposed to 0.9 cfs observed at the Squirrel Creek gage (Table H-4). Additional details for the Powder River diversion are included in the Modeling Report. No continuous flow gages were available for Badger Creek or Young's Creek.

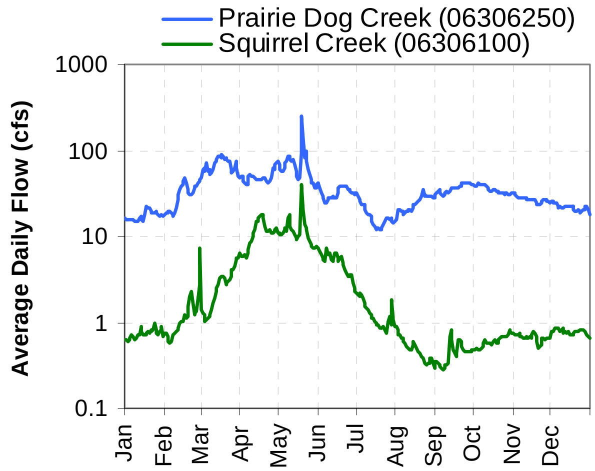

Figure H-6. Average daily flow for Prairie Dog Creek and Squirrel Creek.

Table H-4. Summary of flows in Prairie Dog Creek and Squirrel Creek.

Station Name	Station ID	Count	Average (cfs)	Median (cfs)	Minimum (cfs)	Maximum (cfs)	5-Year Avg (cfs)[1]	Period of Record
Squirrel Creek near Decker, MT	06306100	3,744	3.1	0.9	0.0	323	NA	1975-1985
Prairie Dog Creek near Acme, WY	06306250	5,507	35.8	25.0	0.0	3,090	21.1	1970-1979; 2000-Present

[1]October 1, 2001-September 30, 2006. No data were available for Squirrel Creek.

Flows in the Tongue River watershed upstream of the Tongue River Reservoir are highly regulated for irrigation purposes. Diversions deliver flow from Piney Creek in the Powder River watershed to Prairie Dog Creek and Little Goose Creek in the Tongue River watershed. High altitude reservoirs in the Bighorn Mountains store water for irrigation use, and water is then diverted among various streams and delivered to downstream users. Prairie diversions, stock ponds, irrigation withdrawals, irrigation return flows, surface water discharges, and domestic water withdrawals further alter stream flows. Each of these flow alterations is discussed in more detail in the Modeling Report.

Together, mountain streams, prairie streams, and flow alterations contribute to the flows measured in the Tongue River at Monarch, WY (USGS Gage 06299980) and Goose Creek near Acme, WY (USGS Gage 06305700). The Tongue River and Goose Creek then flow together, and the sum of most upstream flows is measured at the Tongue River Stateline gage (USGS Gage 06306300). Flows for all three gages are summarized in Table H-5, and Figure H-8 shows the average daily flow at the Stateline gage. Peaks flows at the Stateline are the highest in the entire watershed (average yearly peak flow of 3,185 cubic feet per second), and the highest recorded flow in the Tongue River watershed (15,400 cfs) was measured at the Stateline gage.

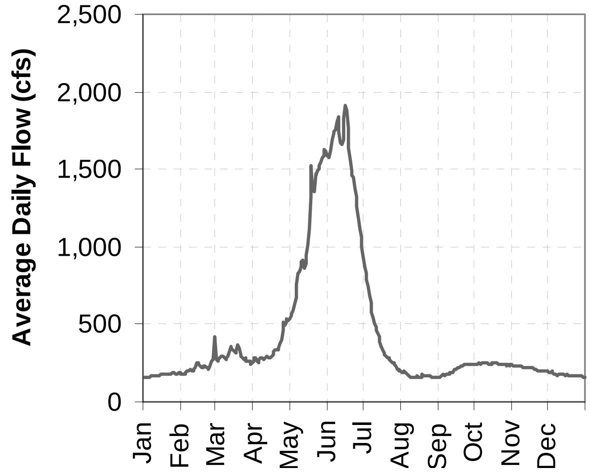

Figure H-7. Average daily flow, Tongue River Stateline gage

Table H-5. Summary of flows in the Tongue River and Goose Creek.

Station Name	Station ID	Count	Average (cfs)	Median (cfs)	Minimum (cfs)	Maximum (cfs)	5-Year Avg (cfs)[1]	Period of Record
Tongue River at Monarch, WY	06299980	758	166	81	16	2,660	166	2004-Present
Goose Creek near Acme, WY	06305700	8,079	152	85	3	3,040	110	1984-Present
Tongue River at State Line near Decker ,MT	06306300	16,902	429	226	5	15,400	271	1960-Present

[1]October 1, 2001-September 30, 2006.

After this gage, the Tongue River flows into the Tongue River Reservoir, which is regulated to provide flood control and irrigation water to downstream users. The Tongue River Reservoir is discussed in Section H.3.2, and flows downstream of the reservoir are discussed in Section H.3.3.

H.3.2 Tongue River Reservoir

The Tongue River Reservoir (TRR) was originally completed in 1940 by constructing an earthen dam on the Tongue River north of Decker, Montana (DNRC, 2004a). The reservoir was built for irrigation, recreational, and flood control purposes. A 1996–1999 rehabilitation project increased the reservoir's active storage capacity from approximately 68,000 acre-feet of water to 79,000 acre-feet of water. An additional spillway was also added during the rehabilitation project so that the maximum potential discharge from the reservoir is now approximately 4,000 cfs. The average depth of the reservoir is reported as 5.1 meters (16.6 feet) with a length of approximately 12.5 kilometers (7.8 miles) (DNRC, 2005). The average volume of water in the reservoir between 1999 and 2006 was 40,432 acre-feet and the median residence time during this period was approximately 88 days (with longer residence times during the fall, winter, and spring and shorter residence times during the summer) (DNRC, 2006).

Tongue River Reservoir Primary Spillway and Inlet Release Structure
(Photo by Tetra Tech, Inc.)

The primary spillway for the Tongue River Reservoir is a concrete labyrinth spillway (weirwall spillway) with a crest of 3,428.4 feet (79,071 acre-feet of water in the reservoir). The primary spillway was re-constructed in the late 1990's and the first full year of normal operation was 2000 (Personal Communication, Kevin Smith, Montana DNRC, June 14, 2004). Very little water has gone over the spillway since the re-construction. The reservoir also has an emergency spillway with a crest at 3,431.5 feet, or when the reservoir volume is at 91,107 acre-feet of water.

In addition to the primary and emergency spillways, the reservoir has two inlet structures. The first was built in 1940 and the second in 1999 (Personal Communication, Kevin Smith, Montana DNRC, June 14, 2004). Each structure has inverts at two elevations (3,375 feet and 3,390 feet) with grills on all sides and on top. Water flow through these grills is controlled through a central system located within the earthen dam. There is no way to close one grate versus another and water intake through the individual grills is therefore not regulated. At its fullest, the reservoir is drafting water through all grill inlets, the emergency spillway, and the primary spillway. However, normal operation is to draft water over the primary spillway and through the inlets. By the end of summer, water is typically only discharging through the two inlet towers. The reservoir is almost never drafted below an elevation of 3,404 feet (Personal Communication, Kevin Smith, Montana DNRC, June 14, 2004).

Information on the monthly volume of water in the Tongue River Reservoir is available from 1960 through the present (Figure H-9). The data indicate that reservoir volumes have fluctuated considerably over the past forty years with no apparent increasing or decreasing trend (DNRC, 2006). Figure H-10 shows that the reservoir typically fills during the winter and spring and then water is released during the summer to support downstream irrigation. The Montana Department of Fish, Wildlife, and Parks (MFWP) has requested that downstream flows are maintained at a minimum of 75 cfs at all times to provide suitable habitat for downstream fish. Flows out of the reservoir fell below this value 6 percent of the days between January 1, 2000 and September 30, 2006.

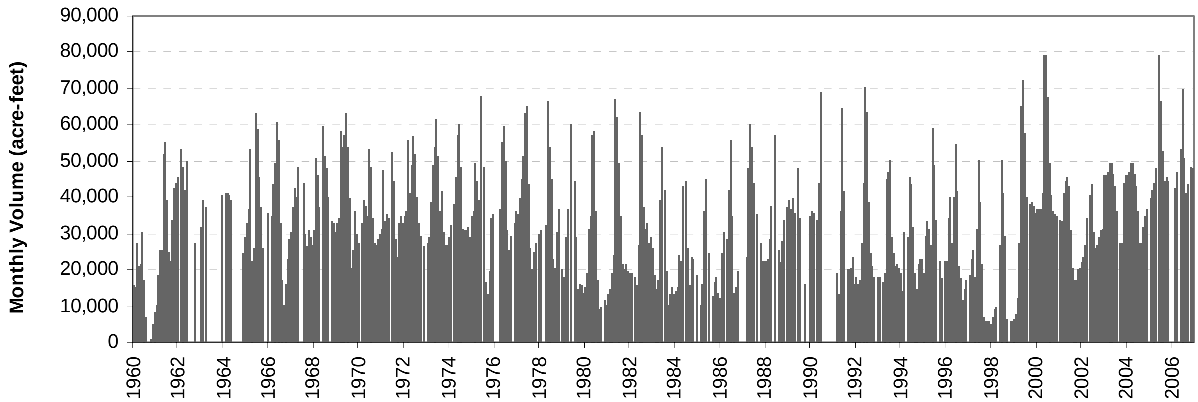

Figure H-9. Volume of water in the Tongue River Reservoir, 1960 to 2006.
**Data not available for certain months over the period of record. Reservoir levels during 1997 and 1998 were held below normal elevations due to rehabilitation and construction at dam.*

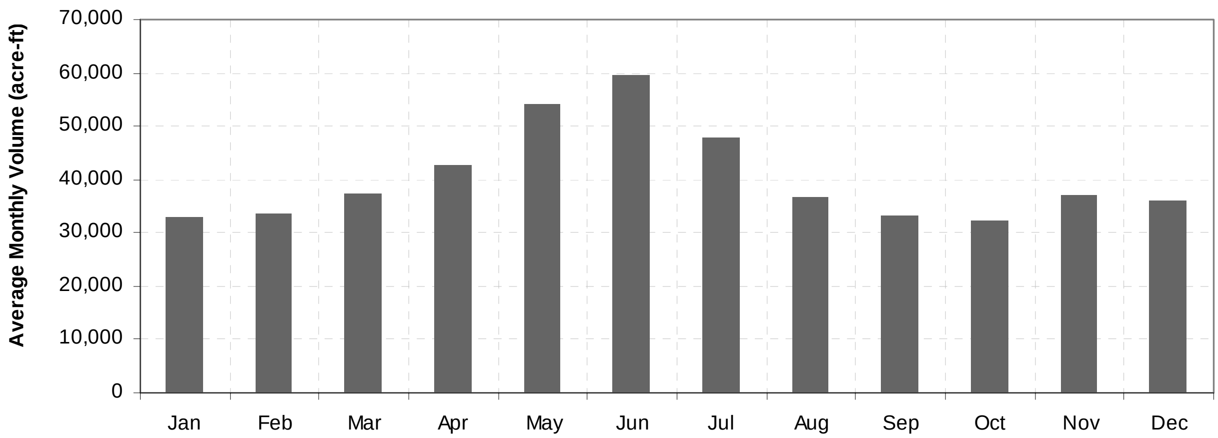

Figure H-10. Average monthly volume of water in the Tongue River Reservoir, 1999-2006.

The only measure of flow out of the reservoir is the USGS gage just downstream of the dam (station 06307500). Data from this gage show that on average, base flows are maintained from November to April (Figure H-11). In early April, additional water is released from the reservoir to provide flows for downstream irrigation. Upstream snowmelt generally causes the dam to overflow in May and June of each year, while additional water is held in the reservoir to provide late season irrigation flows. Flows taper off through the late summer and fall as the volume of water in the reservoir depletes, and irrigation demand goes down.

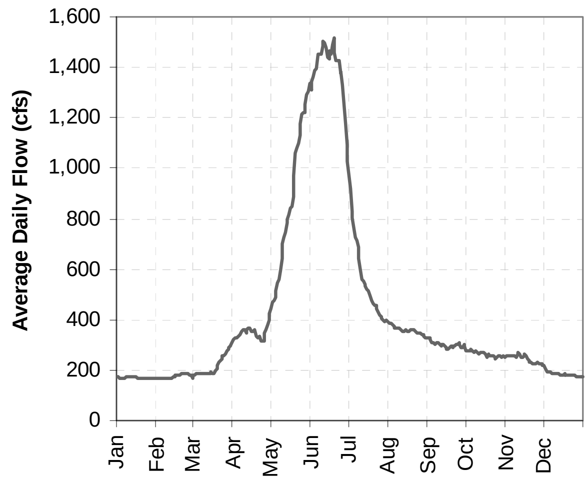

Figure H-11. Average daily flow in the Tongue River below the Tongue River Reservoir Dam (USGS Gage 06307500).

H.3.3 Tongue River Reservoir Dam to the Mouth

Downstream of the Tongue River Reservoir (i.e., lower Tongue River watershed), flows in the Tongue River are primarily controlled by releases from the Tongue River Reservoir Dam plus any uncontrolled overflow from the spillways. As shown in Table H-6, median flows in the lower Tongue River range from 220 to 250 cubic feet per second, depending on the location in the watershed and the period of record. On average, there is little increase in flow in a downstream direction. Base flows are governed primarily by releases from the reservoir, and high flows usually occur during spring snowmelt events in May and June.

At times, the prairie tributaries contribute a significant amount of flow to the Tongue River, potentially adding 100 percent or more water to the river. For example, Hanging Woman Creek, Otter Creek, and other prairie tributaries increased the flow in the Tongue River from an average of 156 cubic feet per second at the Tongue River Reservoir Dam to 1,700 cubic feet per second at the Brandenberg Bridge on March 6, 1975 (Figure H-12). In the Birney Day School, Brandenberg Bridge, and Miles City hydrographs, prairie storm events are exemplified by the higher variability in flows throughout the year (Figure H-13).

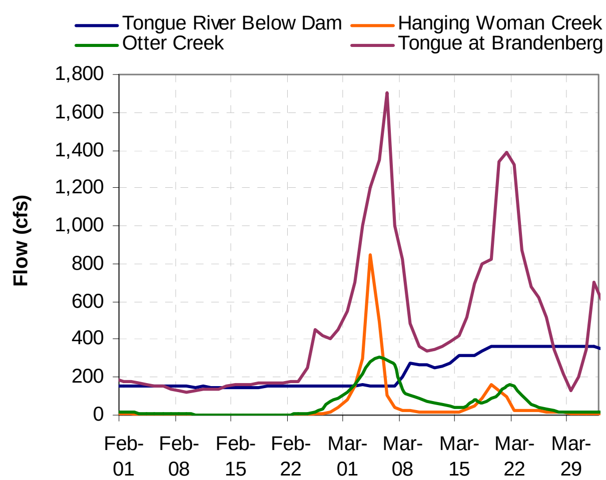

Figure H-12. Stream flows in the Tongue River, Otter Creek, and Hanging Woman Creek in February and March of 1975.

Near Miles City, an additional dam regulates flow in the Tongue River. The Tongue River Diversion Dam is located on the Tongue River near the confluence of Pumpkin Creek and approximately 12 miles upstream of Miles City. The dam diverts an average of 150 cubic feet per second of water into the Tongue and Yellowstone (T&Y) Irrigation Canal, which provides water to downstream irrigators (DNRC, 2004b). Water is diverted between April and October. As a result of this diversion structure, flows at Miles City are often lower than flows at the Brandenberg Bridge gage, particularly in July through September (see Figure H-13).

Flow from tributaries cause the Tongue River at Miles City to have the most variable hydrograph in the main stem. Tributary influence is particularly noticeable in March, when spring snowmelt and storms in the Great Plains, on average, double the flow in the Tongue River at Miles City.

Table H-6. Summary of flows in the Tongue River downstream of the Tongue River Reservoir.

Station Name	Station ID	Count	Average (cfs)	Median (cfs)	Min (cfs)	Max (cfs)	5-Year Avg (cfs)[1]	Period of Record
Tongue River at Tongue River Reservoir Dam near Decker, MT	06307500	24,687	425	246	1	9,580	254	1939-Present
Tongue River at Birney Day School Bridge near Birney, MT	06307616	9,819	362	235	28	3,740	254	1979-Present
Tongue River below Brandenberg Bridge near Ashland MT	06307830	6,257	404	250	40	7,600	254	1973-1984; 2000-Present
Tongue River at Miles City, MT	06308500	23,636	400	220	0	9,290	206	1938-Present

[1]October 1, 2002-September 30, 2006.

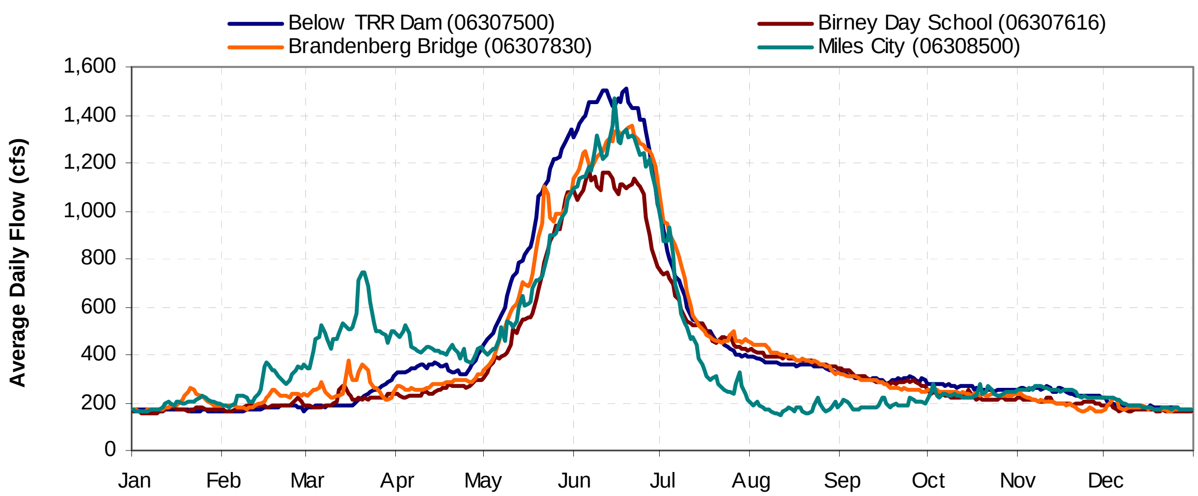

Figure H-13. Average daily flows at four USGS gages in the Tongue River downstream of the Tongue River Reservoir (entire period of record is shown).

Most of the tributaries in the lower Tongue River watershed are small (i.e., watershed area of less than 50 square miles) and have intermittent flows. Three larger tributaries – Hanging Woman Creek, Otter Creek, and Pumpkin Creek – have perennial flows, which at times can comprise more than 90 percent of the flow in the Tongue River at Miles City. However, most of the time, these three tributaries have low flows (median flows of 0.7, 1.8, and 0.07 cubic feet per second, respectively) (Table H-7). In contrast, the median flow in the Tongue River at the Miles City is 220 cubic feet per second. As shown in Figure H-14, early spring (i.e., February to April) snowmelt and rainfall produce the highest sustained tributary flows. Flows then decrease throughout the summer as water is evaporated, infiltrated, and used for irrigation. The streams are dynamic in that flows rapidly increase and decrease in response to storm events and snowmelt, resulting in steep "spikes" in the hydrograph. For example, the maximum-recorded day-to-day increase in flow at the Hanging Woman Creek Birney gage is 1,520 cubic feet per second. Flows in almost all of the smaller tributaries, as well as the mainstem Tongue River, are impacted by stock ponds, irrigation withdrawals, and surface water discharges, which are discussed in further detail in the Modeling Report.

Table H-7. Summary of flows in Hanging Woman Creek, Otter Creek, and Pumpkin Creek.

Station Name	Station ID	Count	Average (cfs)	Median (cfs)	Minimum (cfs)	Maximum (cfs)	5-Year Avg (cfs)[1]	Period of Record
Hanging Woman Creek near Birney, MT	06307600	8,615	3.15	0.70	0.00	1,730	0.07	1973-1995; 2004-Present
Otter Creek at Ashland, MT	06307740	8,858	4.29	1.80	0.00	350	1.30	1972-1995; 2004-Present
Pumpkin Creek near Miles City, MT	06308400	5,561	14.09	0.07	0.00	1,980	0.06	1972-1985; 2004-Present

[1]October 1, 2002-September 30, 2006.

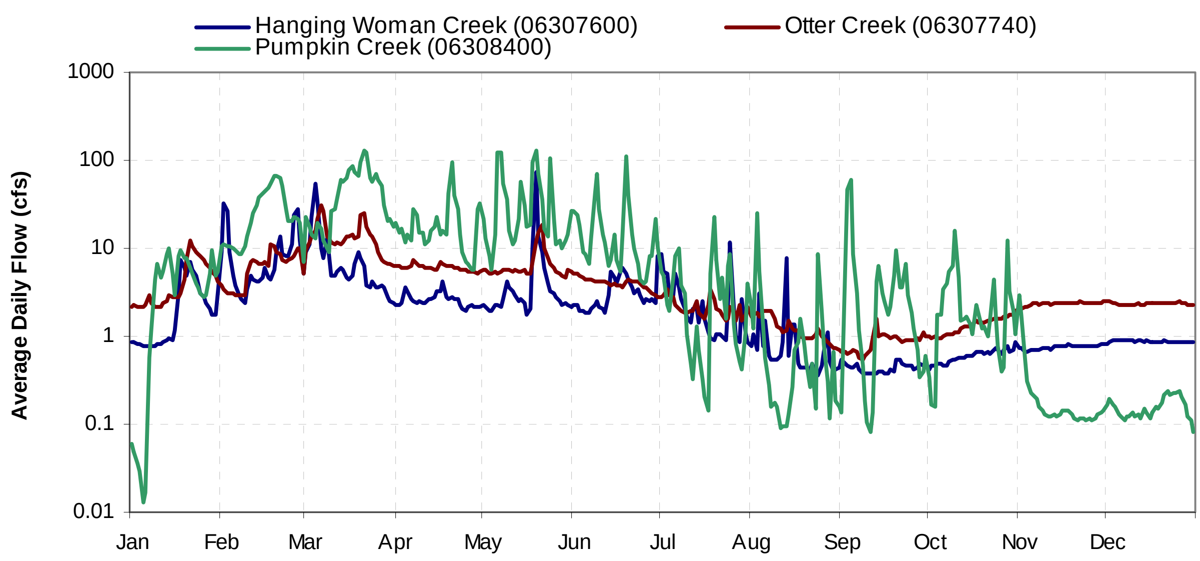

Figure H-14. Average daily flows for Hanging Woman Creek, Otter Creek, and Pumpkin Creek (entire period of record is shown).

H.3.4 Tongue River Flows – Summary

The Tongue River watershed is large and complex. Diversions, withdrawals, return flows, surface water discharges, operation of the Tongue River Reservoir Dam, and stock ponds contribute to the hydrologic complexity of the system. Hydrology in the Tongue River watershed is also complicated because of its shear size; the watershed encompasses 5,400 square miles, which is equal to the size of Connecticut. The main stem of the Tongue River is more than 250 river miles in length, with another 7,000 miles of tributaries (USGS, 2006).

Figure H-15 and Figure H-16 present a summary of the flows in the mainstem Tongue River. Figure H-15 shows that, on average, flows increase the most between Dayton and the Stateline, and are relatively constant downstream of the Tongue River Reservoir Dam. A schematic summarizing mainstem and tributary flows is presented in Figure H-16.

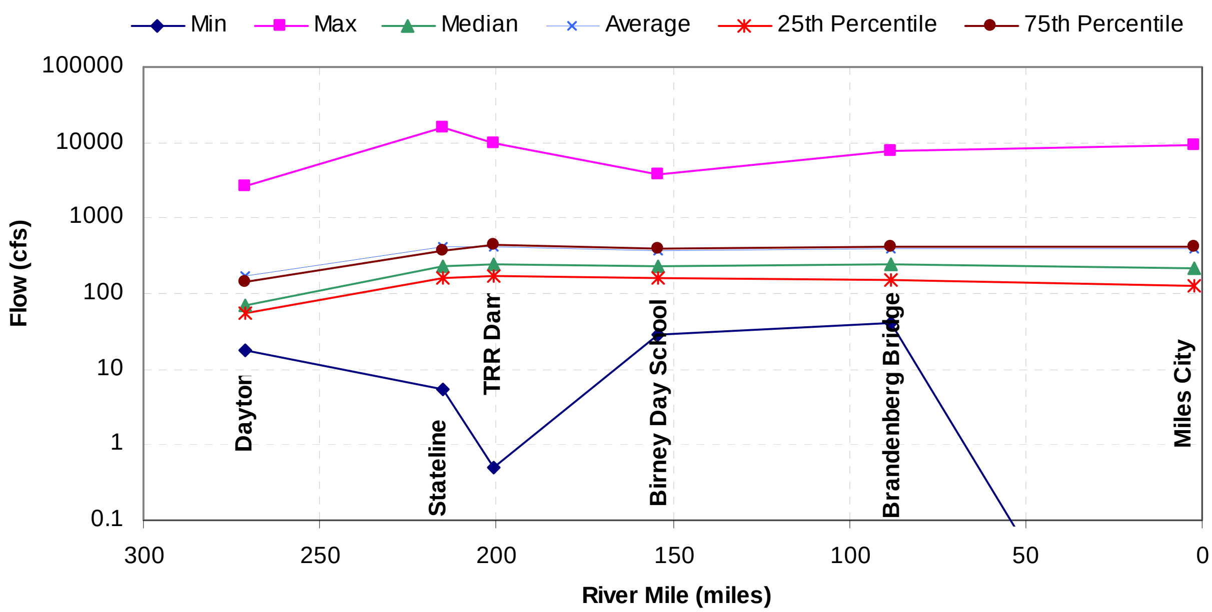

Figure H-15. Flow statistics for USGS stations with 10 or more years of flow data in the mainstem Tongue River. The entire period of record is shown for each station.

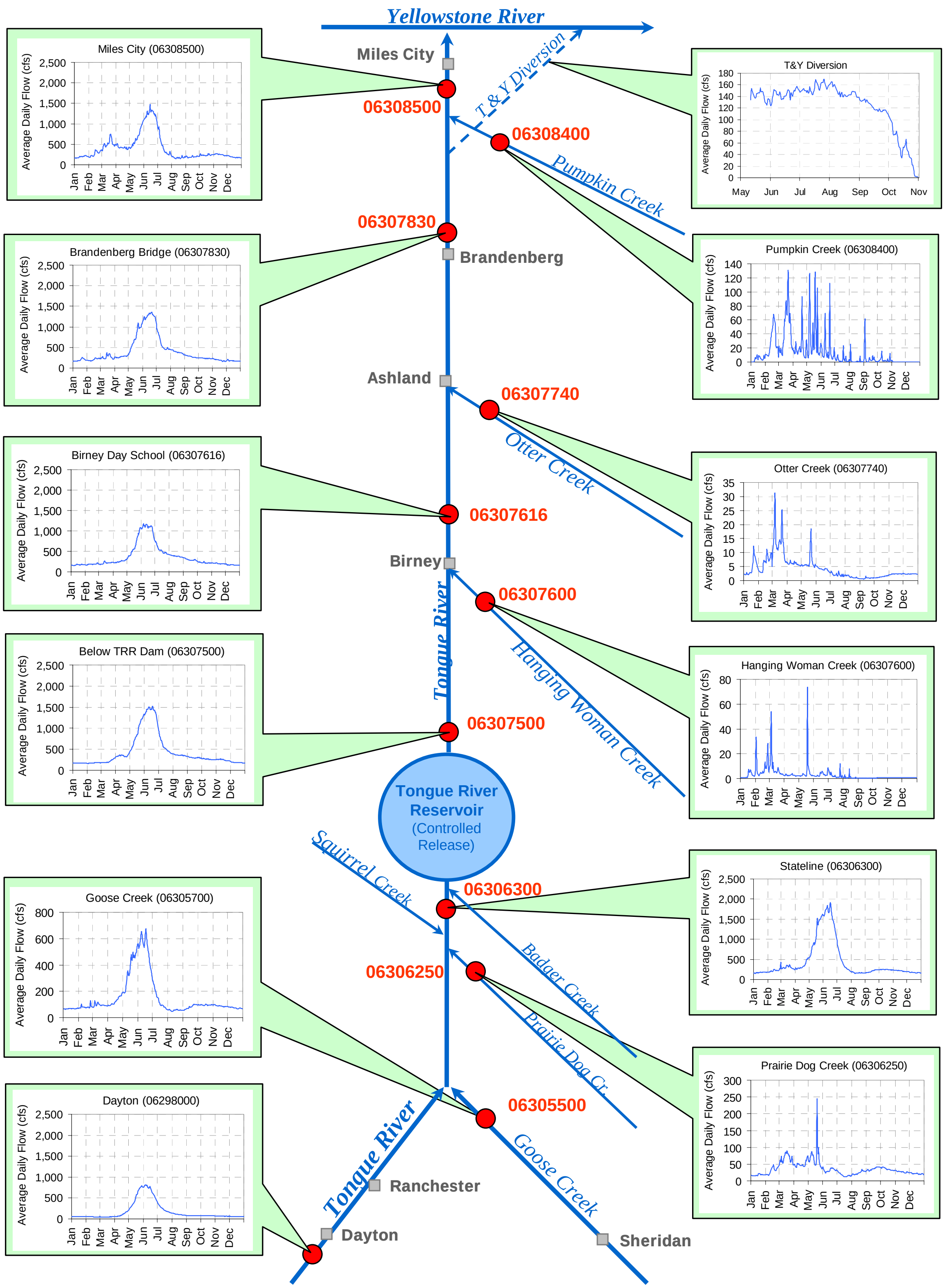

Figure H-16. Average daily flows at representative stations in the Tongue River and major tributaries. Entire period of record is shown. For illustration purposes only; not to scale.

H.4 Drought

The ongoing drought in southeastern Montana has been well documented by DNRC, NOAA, and USDA (NOAA, 2007; DNRC, 2007). The most severe effects have been documented in the Big Horn Mountains and streams originating in those mountains (i.e., Tongue River and tributaries). The Burgess Junction and Dome Lake precipitation gages in the Big Horn Mountains show that total precipitation averaged 28.5 inches per year between 1989 and 2000 (see Figure H-1). The average total precipitation in 2001 and 2002 was 22.6 and 23.4 inches, respectively, and 2001 and 2002 had the lowest recorded precipitation on record at the two gages. 2003 and 2005 had above average total precipitation, while 2004 and 2006 were below average. The effects of the drought have also been observed at the Sheridan and Miles City precipitation gages. Except for 2005, total yearly precipitation at Sheridan since 1999 has been less than the long term average (see Figure H-2). A similar pattern has been observed at Miles City, except that 2001 was also slightly above average.

Recent below average precipitation in both the Bighorn Mountains and prairie regions of the Tongue River watershed have had dramatic effects on almost all measured stream flows in the Tongue River watershed. The average flow at Miles City over the past five years (October 1, 2002 to September 30, 2006) was half the long-term average (206 versus 400 cfs). Similar impacts were also observed at every gage in the mainstem Tongue River (see Table H-5 and Table H-6) and tributaries (see Table H-4 and Table H-7). As described in Section H.2, the past 8 years are unique because of the consecutive drought years, which have had a cumulative impact on stream flow because water tables have been lowered, streams dewatered, and soil moisture depleted.

H.5 References

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APPENDIX I – BIOLOGICAL ASSEMBLAGES AND APPLICATION OF THE MULTIMETRIC INDEX (MMI), AND THE RIVER INVERTEBRATE PREDICTION AND CLASSIFICATION SYSTEM (RIVPACS) IN THE TONGUE RIVER WATERSHED

I.0 Biological Assemblages and Application of the Multimetric Index (MMI), and the River Invertebrate Prediction and Classification System (RIVPACS) in the Tongue River Watershed

I.1 Macroinvertebrates

Montana DEQ has two assessment tools for evaluating the health of macroinvertebrate aquatic life in streams: the Multimetric Indices (MMI), and the River Invertebrate Prediction and Classification System (RIVPACS).

The Multimetric Indices are based upon a series of macroinvertebrate metrics (e.g. clinger taxa, percent EPT) that were chosen because they can indicate a biological response from human-induced stressors. Scores are assigned to individual metrics, which are then summed to provide the MMI score for an individual sample. Additional details about the development of the MMI for Montana can be found in Jessup et al., 2006.

Montana DEQ used a reference based approach to develop a MMI threshold value for streams in the Plains region of Montana. Both reference and degraded streams were previously identified by Montana DEQ (Suplee et al., 2005). The average MMI score for reference sites in the Plains region was 41 (Feldman, 2006). To allow for natural variability, Montana DEQ chose a threshold value for the MMI that was 90 percent of the average reference value (i.e., a MMI score of 37). MMI values greater than or equal to 37 indicate that the sampling site is similar to reference conditions. Values less than 37 may indicate that the site differs from reference conditions (Feldman, 2006) (Table I-1).

The RIVPACS model is a tool for comparing the taxa that are expected at a site under a variety of environmental conditions with the actual observed taxa that were found when the site was sampled (sometimes referred to an “O/E” model – Observed/Expected). Jessup et al. (2006) describes the methodology for developing the RIVPACS model for Montana. As with the MMI, Montana DEQ established a RIVPACS threshold based on an analysis of reference sites. RIVPAC values greater than 0.80 indicate that the sampling site is similar to expected conditions. Values less than 0.80 indicate that the site was not similar to expected conditions (Feldman, 2006) (Table I-1).

Table I-1. Biological impairment thresholds for streams in the Plains region of Montana.

RIVPACS Score	MMI Score	Determination
>0.80	>37	Similar to Reference Condition
<0.80	<37	Not Similar to Reference Condition

It should be noted that sites sampled with the Surber sampling method were not included in the analysis because data were not comparable to samples obtained with a Kick Net or EMAP protocols (Personal Communication, Ben Jessup, Tetra Tech, Inc., 2007).

As with any model, there is error and uncertainty associated with data sampling and processing, model calibration, validation, and model use. For example, Jessup et. al. (2006) reported that the MMI for the Plains region had a discrimination efficiency of 77 percent, indicating that the MMI was unable to distinguish between reference and degraded sites in approximately 23 percent of the samples. The standard deviation for the O/E model was 0.24. Some sites, such as Otter Creek Site 200, were originally classified as “degraded” sites, but then had a MMI score indicating conditions that were similar to reference (see Section I.1.3). This situation is not surprising since the screening process used to identify "degraded" sites was less rigorous than the process used to identify reference sites; therefore, these streams may not represent truly "degraded" conditions. In addition, plains streams are highly variable and naturally flashy and support more tolerant organisms. Recent analyses have indicated areas for refining the classification approach used in the Plains MMI and expanding the reference site distribution in the plains ecoregions.

Despite these model limitations, there is greater confidence in the macroinvertebrate results when both independent models (i.e., MMI, O/E score) indicate that the site is similar to reference condition or different from reference. In cases where one model indicates the site is similar to reference and the other model indicates a degraded condition, each model result should be closely examined. Overall, the MMI and RIVPACS results provide insight into the biological condition of the stream, and should be used only as part of a weight of evidence approach for evaluating stream or beneficial use condition.

I.1.1 Macroinvertebrate Sampling Sites

Macroinvertebrate data were available for 32 sites in the Tongue River (Montana), Hanging Woman Creek, Otter Creek, and Pumpkin Creek (Figure I-1). Data were collected by multiple agencies including Montana DEQ, BLM, NRCS, USEPA, and USGS. The following sections summarize the data per stream segment.

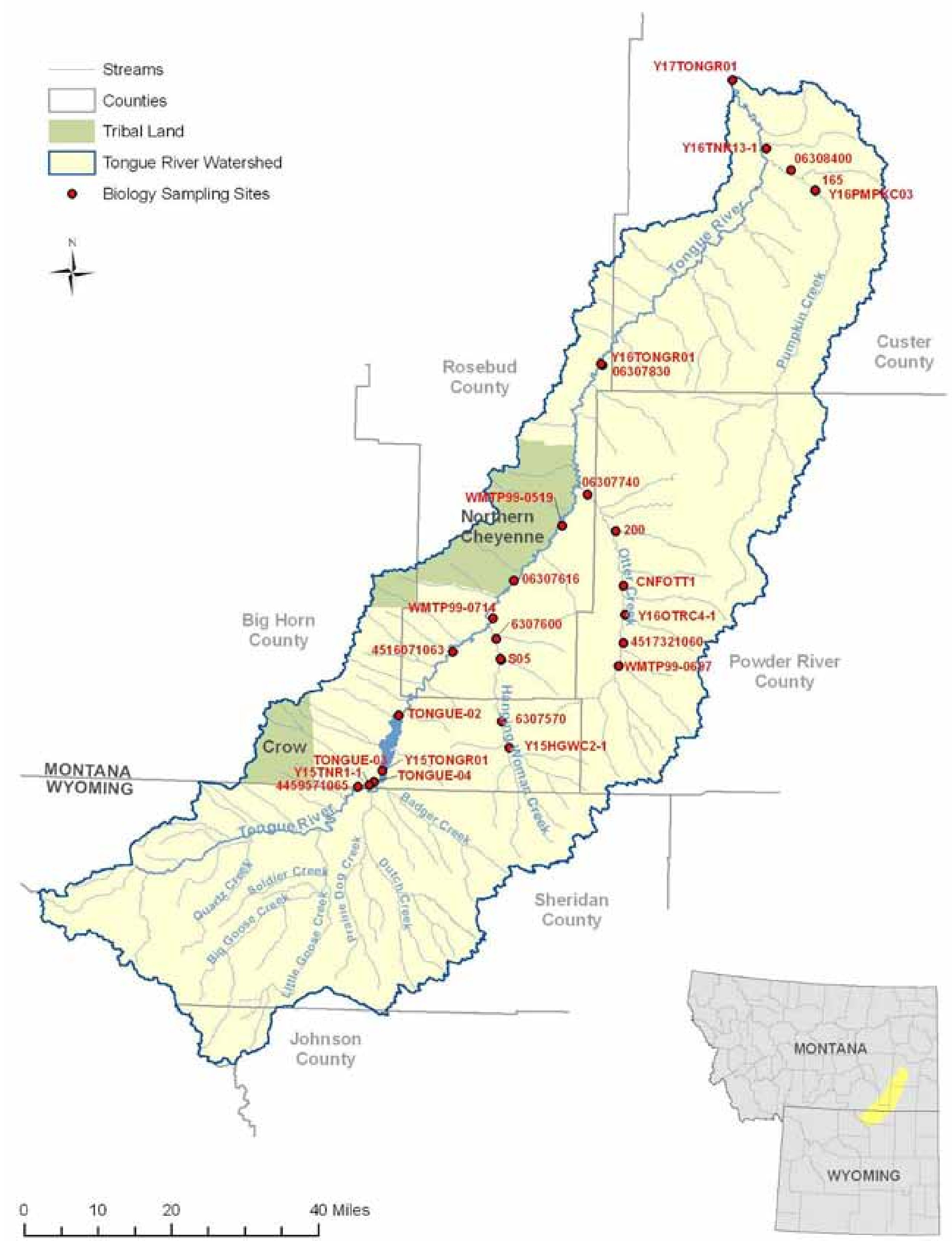

Figure I-1. Macroinvertebrate sampling sites in the Tongue River, Hanging Woman Creek, Otter Creek, and Pumpkin Creek, Montana.

I.1.2 Hanging Woman Creek

As shown in Table I-2 and Figure I-1, macroinvertebrates were sampled at five sites (five total samples) in Hanging Woman Creek between 2001 and 2005. Three sites sampled with the Surber method were excluded from the analysis (see Section I.1). MMI and RIVPACS scores were calculated for each sample and scores are shown in Table I-2. Highlighted scores in Table I-2 indicate values that are not similar to reference. Four out of the five samples had MMI and O/E scores that were in agreement – three sites classified as similar to reference conditions and one site classified as not similar. The one site where the two methods did not agree (Site SO5) had a low MMI score (i.e., not similar to reference conditions) and a high O/E score (similar to reference).

Table I-2. Plains MMI and RIVPACS scores for sites in the Hanging Woman Creek.

Station ID	Agency	Collection Method	Collection Date	Plains MMI Score	RIVPACS Score
Y15HGWC2-1	NRCS	Kick	15-Oct-02	**10.62**	**0.41**
HANGING-01	NRCS	Kick	22-Jun-04	45.19	0.95
6307600	USGS	Kick	23-Jun-05	66.44	1.04
SO5	REMAP	REMAP	29-Aug-01	**36.69**	1.05
6307570	USGS	Kick	22-Jun-05	45.09	1.08

Bold scores are not similar to reference conditions.

I.1.3 Otter Creek

As shown in Table I-3 and Figure I-1, macroinvertebrates were sampled at seven sites (eight total samples) in Otter Creek between 2002 and 2005. MMI and RIVPACS scores were calculated for each sample and scores are shown in Table I-3. Highlighted scores in Table I-3 indicate values that are not similar to reference. Five out of the eight samples had MMI and O/E scores that were in agreement, and all five sites were classified as similar to reference conditions. The three samples where the two methods did not agree (Sites CNFOTT1 and OTTERC-1) had low O/E scores (i.e., not similar to reference conditions) and MMI scores that were classified as similar to reference conditions.

Table I-3. Plains MMI and RIVPACS scores for sites in the Otter Creek.

Station ID	Agency	Collection Method	Collection Date	Plains MMI Score	RIVPACS Score
WMTP99-0697	EMAP	WEMAP-RW	09-Oct-02	53.84	1.04
4517321060	USGS	KICK	29-Jun-05	61.13	0.95
Y16OTRC4-1	DEQ	MAC-R-500	17-Oct-02	59.08	1.02
CNFOTT1	Heritage	REMAP	19-May-04	37.20	**0.76**
			20-May-05	46.10	**0.76**
200	REMAP	REMAP	18-Jul-00	59.67	1.00
OTTERC-1	NRCS	KICK	15-Jul-04	47.18	**0.63**
06307740	USGS	KICK	30-Jun-05	43.89	1.00

Bold scores are not similar to reference conditions.

I.1.4 Pumpkin Creek

As shown in Table I-4 and Figure I-1, macroinvertebrates were sampled at three sites (five total samples) in Pumpkin Creek between 1999 and 2005. MMI and RIVPACS scores were calculated for each sample and are scores shown in Table I-4. Four out of the five samples had MMI and O/E scores that were in agreement and all four sites were classified as similar to reference conditions. The one site where the two methods did not agree (Site 165, September 22, 1999) had a low MMI score (i.e., not similar to reference conditions) and a high O/E score (similar to reference).

Table I-4. Plains MMI and RIVPACS scores for sites in Pumpkin Creek.

Station ID	Collection Date	Sampling Method	Plains MMI Score	RIVPACS Score
165	22-Sep-99	REMAP	**34.68**	0.99
165	17-Jul-00	REMAP	51.15	0.99
165	19-Sep-00	REMAP	69.03	0.99
Y16PMPKC03	11-Aug-05	Riffle	70.17	0.87
06308400	23-Jun-05	Kick	43.19	1.12

Bold scores are not similar to reference conditions.

I.1.5 Tongue River

As shown in Table I-5 and Figure I-1, macroinvertebrates were sampled at thirteen sites (22 total samples) in the Tongue River between 2000 and 2005. Prior to calculating the MMI and RIVPACS scores for the Tongue River samples, samples were screened by the total number of organisms collected. Only samples with 300 or more organisms were retained, as a small sample size can over inflate the MMI scores and under inflate the O/E values. Nine sites were removed from the analysis because they had sample counts of less than 300 organisms (Table I-5). The reason for the low sample size is unclear.

Table I-5. Tongue River macroinvertebrate samples with less than 300 organisms.

Station ID	Collection Date	Sampling Method	Total Individuals
Y15TONGR01	01-Aug-02	Kick	293
Y16TNR13-1	18-Oct-02	Riffle	291
Y16TONGR01	14-Jul-03	Kick	85
Y16TONGR01	13-Jul-05	Unknown	110
Y17TONGR01	26-Jul-01	Unknown	17
Y17TONGR01	31-Jul-02	Kick	140
Y17TONGR01	14-Jul-03	Kick	50
Y17TONGR01	21-Jun-04	Hess	13
Y17TONGR01	13-Jul-05	Unknown	37

MMI and RIVPACS scores were calculated for each remaining sample and scores are shown in Table I-6. Highlighted scores in Table I-6 indicate values that are not similar to reference. Thirteen out of the twenty-two samples had MMI and O/E scores that were in agreement – nine were classified as similar to reference conditions and four were classified as not similar. All of the nine conflicting sites had low O/E scores (i.e., not similar to reference) and MMI scores that suggested conditions similar to reference conditions.

Table I-6. Plains MMI and RIVPACS scores for sites in the Tongue River.

Station ID	Collection Date	Sampling Method	Plains MMI Score	RIVPACS Score
4459571065	15-Aug-05	Kick	62.71	1.10
Y15TNR1-1	15-Oct-02	Riffle	45.00	0.82
Y15TNR1-1 (Rep)	15-Oct-02	Riffle	37.61	**0.68**
TONGUE-04	26-Jul-04	Kick	41.35	0.96
TONGUE-03	27-Jul-04	Kick	48.23	**0.79**
TONGUE-02	28-Jul-04	Kick	40.61	**0.77**
4516071063	16-Aug-05	Kick	53.43	1.01
WMTP99-0714	28-Jul-02	WEMAP	55.25	1.00
06307616	12-Sep-05	Kick	55.84	1.00
WMTP99-0519	23-Jul-00	WEMAP	64.82	**0.75**
Y16TONGR01	31-Jul-02	Hess	51.70	**0.12**
Y16TONGR01	14-Jul-03	Hess	39.17	**0.37**
Y16TONGR01	21-Jun-04	Hess	53.87	**0.25**
Y16TONGR01	13-Jul-05	Hess	37.35	**0.25**
06307830	13-Sep-05	Kick	58.20	0.99
Y16TNR13-1	18-Oct-02	Riffle	66.97	0.99
Y16TNR13-1 (Replicate)	18-Oct-02	Riffle	37.26	1.12
Y17TONGR01	26-Jul-01	Hess	**25.08**	**0.12**
Y17TONGR01	31-Jul-02	Hess	39.91	**0.74**
Y17TONGR01	14-Jul-03	Hess	**33.65**	**0.12**
Y17TONGR01	21-Jun-04	Hess	**25.87**	**0.37**
Y17TONGR01	13-Jul-05	Hess	**32.46**	**0.25**

Bold scores are not similar to reference conditions.

I.2 Fish

Bramblett et al. (2004) developed a fish multimetric index of biotic integrity (IBI) to help determine fishery beneficial use impairments for southeastern Montana streams. The IBI was created to identify impairment due to anthropogenic sources in wadable Northern Plains streams in Montana. It is not applicable to the main stem of the Tongue River or to streams primarily originating in the Big Horn Mountains (e.g., Goose Creek, Wolf Creek).

The fish IBI for the Montana Northern Plains includes ten metrics and addresses species richness, tolerance, feeding group, reproductive strategies, and fish abundance (Bramblett et al., 2004). The metrics found to be most useful for the fish IBI were:

Number of Native Species
Number of Native Families
Number of Catostomid and Ictalurid Species
Proportion of Tolerant Individuals
Proportion of Native Individuals
Proportion of Invertivorous Cyprinids
Number of Benthic Invertivorous Species
Proportion of Litho-Obligate Reproductive Guild Individuals
Proportion of Tolerant Reproductive Guild Individuals
Number of Species with Long-lived Individuals

Each metric score ranged from 0 to 100. All the metric scores were then summed so that the final IBI had values ranging from 0 to 1000. Actual fish IBI scores for the sites in this study ranged from 0 to 910 (Bramblett et al. 2003).

Based on fish IBIs for the reference sites, the following condition classes were defined:

- >60 indicates a *good* condition (i.e., similar to reference conditions)
- 41-59 indicates a *fair* condition (i.e., some deviation from reference conditions)
- <40 indicates a *poor* condition (i.e., extreme deviation from reference conditions)

It should be noted that a low IBI score does not necessarily mean that a stream is impaired. The harsh environment in the Tongue River watershed creates the possibility that natural factors will, on occasion, impact biota irrespective of human influence (Bramblett et al., 2003). Therefore, fish data and IBI scores should be used with caution and in conjunction with other sources of data.

Fish IBI scores are discussed in more detail in the following sections.

I.2.1 Hanging Woman Creek

In Hanging Woman Creek, fish data were collected between 2001 and 2004. As shown in Table I-7, five fish samples were collected in Hanging Woman Creek:

- One sample collected by USEPA on August 29, 2001, approximately 9 river miles upstream of the mouth and just upstream with the confluence with Lee Creek (Rosebud County, MT) –S05
- One sample collected by BLM on September 26, 2002, approximately 27 river miles upstream of the mouth and 3 miles downstream with the confluence of Corral Creek (Big Horn County, MT) – BLMHWC10.
- One sample collected by MFWP on May 12, 2004, near the confluence with Horse Creek (Big Horn County, MT) – FWPHWC2
- One sample collected by MFWP on July 7, 2004, approximately four miles upstream of the mouth (Rosebud County, MT) – FWPHWC1
- One sample collected by MFWP on August 5, 2004, approximately fifteen miles upstream of the mouth (Rosebud County, MT) – FWPHWC3.

Fish IBI scores in Hanging Woman Creek ranged from 33 (poor) to 55 (fair), with an average score of 42 (fair). The two best scoring sites (BLMHWC10 and FWPHWC2) were both located in the upstream reach of Hanging Woman Creek (upstream of the confluence with Horse Creek). These two sites had IBI scores of 55 and 48, respectively. Scores then decreased in a downstream direction, with scores of 33 and 36 near the mouth of Hanging Woman Creek. These results must be used with caution. Given the limited data, it is not possible to determine if these results are representative from a spatial and/or temporal perspective. Further, all five samples were collected during a drought period.

Table I-7. Plains IBI scores for sites in the Hanging Woman Creek watershed.

Station	Year Sampled	Score	Ranking
EMAPS05	2001	33	Poor
BLMHWC10	2002	55	Fair
FWPHWC1	2004	36	Poor
FWPHWC2	2004	48	Fair
FWPHWC3	2004	37	Poor

Thresholds: > 59 - Good; 41-59 – Fair; <41 – Poor

I.2.2 Otter Creek

As shown in Table I-8, four fish samples were collected in Otter Creek:

- One sample collected by USEPA on July 18, 2000, approximately eight miles upstream of the mouth and just upstream of the confluence with Threemile Creek (Powder River County, MT) – REMAP200
- One sample collected by MFWP on July 16, 2003, 4.7 miles upstream of the mouth (Rosebud County) – MWFP4.7
- One sample collected by MFWP on May 26, 2004 near the confluence with Elk Creek (Powder River County, MT) – FWPOTT1
- One sample collected by MFWP on May 26, 2004 near the confluence with Bear Creek (Powder River County, MT) – FWPOTT2

The IBI score for the 2000 fish sample was 35, indicating poor conditions. However, in 2003 and 2004, three segments in Otter Creek had good fish populations (MFWP4.7, FWPOTT1, and FWPOTT2). However, given the limited data, it is not possible to determine if the samples are representative from a spatial and/or temporal perspective, and the samples were collected during a drought period.

Table I-8. Plains Fish IBI scores for sites in the Otter Creek watershed.

Station	Year Sampled	Score	Rating
REMAP200	2000	30	Poor
MFWP4.7	2003	62	Good
FWPOTT1	2004	71	Good
FWPOTT2	2004	83	Good

Thresholds: > 59 - Good; 41-59 – Fair; <41 – Poor

I.2.3 Pumpkin Creek

In Pumpkin Creek, fish data were collected between 1999 and 2004. As shown in Table I-9, seven fish samples were recently collected in Pumpkin Creek:

- Three samples collected by USEPA at one site on September 22, 1999; July 17, 2000; and September 19, 2000. Site is located approximately 17 river miles upstream of the mouth (Custer County, Montana) – REMAP165
- Two samples collected by MFWP at one site on May 15, 2003 and May 10, 2004. Site is located approximately 36.2 river miles upstream of the mouth (Custer County, Montana) – MFWP36.2.
- One sample collected by MFWP at one site on May 16, 2003. Site is located approximately 87.2 river miles upstream of the mouth (Custer County, Montana) – MFWP87.2.
- One sample collected by MFWP at one site on May 26, 2004. Site is located approximately 146.0 river miles upstream of the mouth (Custer County, Montana) – MFWP146.0.

IBI scores from the USEPA sampling events at station REMAP165 in September 1999, July 2000, and September 2000 were 41, 38, and 28, respectively. These values equate to fair, poor, and poor conditions, respectively. At river mile 36.2, IBI scores were 48 in both 2003 and 2004, indicating fair conditions. Sampling at the most upstream site (river mile 146) found no water in 2004, and no IBI score could be calculated. All of the IBI results must be used with caution. Given the limited data, it is not possible to determine if these results are representative from a spatial perspective. Further, all samples were obtained during a drought period.

Table I-9. Plains fish IBI scores for sites in the Pumpkin Creek watershed.

Station	Year Sampled	Score	Ranking
REMAP165	September 1999	41	Fair
	July 2000	38	Poor
	September 2000	28	Poor
MFWP36.2	May 2003	48	Fair
MFWP87.2	May 2003	NA	*No Water
MFWP36.2	May 2004	48	Fair
MFWP146.0	May 2004	NA	*No Water

Thresholds: > 59 - Good; 41-59 – Fair; <41 – Poor

I.2.4 Tongue River

The Tongue River from the State Line downstream to Prairie Dog Creek (near Birney, Montana) is classified as a B-2 water, where growth and marginal propagation of salmonid fishes (i.e., cold water) and associated aquatic life are designated uses. Until recently, approximately 2000 trout were stocked in the tailrace section of the river below the Tongue River Reservoir annually and Montana Fish, Wildlife, and Parks (MFWP) managed this reach as a "put and take" recreational salmonid fishery. This fishery was supported by cool, relatively clear releases from the dam, but, since conditions were not suitable for spawning, it was not a self-sustaining fishery. Given land use changes that have limited public fishing access, MFWP is no longer stocking trout and has begun managing this reach of the river as a warm-water fishery focusing on smallmouth bass (personal communication with Brad Schmitz, July 15, 2005). Downstream from Birney, the Tongue River is classified as a B-3 water, where growth and marginal propagation of non-salmonid fishes (i.e., warm water) and associated aquatic life are designated uses.

Fish data were collected by several agencies in the Tongue River. However, without an appropriate reference stream, it is difficult to analyze the available data with respect to anthropogenic impacts. Furthermore, samples were obtained over two hundred river miles, and often at different times of year. This also limits the use of the data. As a result, the following data are provided for informational purposes only. Table I-10 shows the fish species identified during 21 sampling events (2000-2004) in the Tongue River. MFWP, USGS, and EPA collected the data in early spring (March/April) or mid-summer (July/August). Table I-11 shows the specific sampling events, site locations, and summary statistics for the data.

Montana Fish, Wildlife, and Parks considers the Tongue River from the T&Y Diversion Dam to the mouth to be at risk from periodic dewatering (i.e., dewatering is a significant problem only in drought or water-short years) (MFWP, 2005a). Also, while efforts are ongoing to remedy the issue, the T&Y Diversion Dam currently obstructs upstream fish migration. MFWP considers the warm-water fishery below the Tongue River Reservoir Dam to be limited by a number of factors including: flow alteration (reduced flood peaks during spring spawning migrations for some fish species), reduced turbidity/sediment levels, and possibly temperature (personal communications, Brad Schmitz, MFWP Fisheries Biologist, July 15, 2005).

Although site-specific data are not available for the Tongue River, it is known that blue suckers (a Montana Species of Concern known to inhabit the Tongue River) have been adversely affected in other river systems by habitat changes (particularly those caused by large dams that block passage to spawning grounds), altered streamflow, and elimination of peak flows that initiate spawning runs. Dams also discharge cold, clear water as opposed to the warm, turbid waters in which these species evolved (MFWP, 2005b). Additionally, low stream flows probably have eliminated some sturgeon chub populations (a Montana Species of Concern) in smaller streams such as the Tongue River (MFWP, 2005b). Saugar, another Montana Species of Concern inhabiting the Tongue River, are thought to have declined since the late 1970's in the Tongue River due to dam operations and associated affects (personal communication with Brad Schmitz, July 15, 2005).

Table I-10. Fish collected in the Tongue River, Montana between 1999 and 2004.

Common Name	Species Name	Origin	General Tolerance	# of Sampling Events where Collected	Montana Species of Concern
Black Bullhead	*Ameiurus melas*	Introduced	Tolerant	4	
Black Crappie	*Pomoxis nigromaculatus*	Introduced		2	
Blue Sucker	*Cycleptus elongatus*	Native		1	X
Brown Trout	*Salmo trutta*	Introduced	Moderate	1	
Channel Catfish	*Ictalurus punctatus*	Native	Moderate	17	
Common Carp	*Cyprinus carpio*	Introduced	Tolerant	20	
Emerald Shiner	*Notropis atherinoides*	Native	Moderate	6	
Fathead Minnow	*Pimephales promelas*	Native	Tolerant	2	
Flathead Chub	*Platygobio gracilis*	Native	Moderate	14	
Freshwater Drum	*Aplodinotus grunniens*	Native		1	
Goldeye	*Hiodon alosoides*	Native	Intolerant	11	
Green Sunfish	*Lepomis cyanellus*	Introduced	Tolerant	6	
Longnose Dace	*Rhinichthys cataractae*	Native	Intolerant	4	
Longnose Sucker	*Catostomus catostomus*	Native	Moderate	15	
Mountain Sucker	*Catostomus platyrhynchus*	Native	Moderate	4	
Pumpkinseed	*Lepomis gibbosus*	Introduced	Moderate	3	
Rainbow Trout	*Oncorhynchus mykiss*	Introduced		1	
River Carpsucker	*Carpoides carpio*	Native	Moderate	19	
Rock Bass	*Ambloplites ruprestris*	Introduced	Moderate	7	
Sand Shiner	*Notropis ludibundus*	Native	Moderate	3	
Sauger	*Sander canadensis*	Native	Moderate	10	X
Sauger X Walleye Hybrid				2	
Shorthead Redhorse	*Moxostoma macrolepidotum*	Native	Moderate	20	
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	Native		1	
Smallmouth Bass	*Micropterus dolomieui*	Introduced	Moderate	13	
Smallmouth Buffalo	*Ictiobus bubalus*	Native	Moderate	1	
Spottail Shiner	*Notropis hudsonius*	Introduced	Moderate	1	
Stonecat	*Noturus Flavus*	Native	Intolerant	17	
Sturgeon Chub	*Macrhybopsis gelida*	Native	Intolerant	2	X
Walleye	*Sander vitreum*	Introduced	Moderate	11	
Western Silvery Minnow	*Hybognathus argyritis*	Native	Moderate	9	
White Crappie	*Pomoxis annularis*	Introduced	Moderate	2	
White Sucker	*Catostomus commersoni*	Native	Tolerant	21	
Yellow Bullhead	*Ameiurus natalis*	Introduced	Moderate	6	

Fish collected by MFWP, USGS, and USEPA in 21 sampling events occurring between 2000 and 2004.

Table I-11. Fish sampling events in the Tongue River, Montana (1999-2004).

Stream	Site	Sample Date	% In-tolerant	% Tolerant	Total Number of Species	Total # of Native Species	Dominant Species
MT-WY Border to the Tongue River Reservoir	Tongue River at Stateline (06306300)	7/19/04	3%	27%	12	3	Rock Bass
Tongue River Reservoir Dam to the T&Y Diversion Dam	RM 195-202	8/5/03	0%	17%	15	6	Shorthead Redhorse
	Tongue River below reservoir (06307500)	7/19/04	0%	64%	8	3	Green Sunfish
	RM 167.0-173.0	7/31/03	0%	25%	12	6	Shorthead Redhorse
	RM 165.4-165.5	7/28/02	2%	25%	10	5	Shorthead Redhorse
	Tongue River near Birney, MT (06307616)	7/23/04	1%	78%	8	4	White Sucker
	RM 135.1-135.2	7/23/00	2%	11%	10	6	Shorthead Redhorse
	RM 88-95	7/30/03	0%	18%	14	9	Shorthead Redhorse
	Tongue River at Brandenberg Bridge, MT (06307830)	7/25/04	2%	84%	13	9	White Sucker
	RM 68-74	7/22/03	0%	20%	10	7	Shorthead Redhorse
T&Y Diversion Dam to the Mouth	RM 13.3-19.6	4/7/99	2%	6%	12	10	Flathead Chub
	RM 13.3-19.6	4/8/99	2%	5%	11	8	Longnose Sucker
	RM 13.3-19.6	4/20/00	4%	12%	15	12	Shorthead Redhorse
	RM 4.3-6.0	3/23/00	3%	11%	13	10	Shorthead Redhorse
	RM 4.3-6.0	3/24/00	4%	11%	13	10	Shorthead Redhorse
	RM 4.3-6.0	4/4/00	4%	7%	16	14	Shorthead Redhorse
	RM 4.3-6.0	4/19/00	6%	10%	16	13	Shorthead Redhorse
	RM 4.3-6.0	4/25/00	7%	8%	15	12	Shorthead Redhorse
	Tongue River at Miles City (06308500)	7/25/04	10%	5%	12	11	Flathead Chub
	RM 0.1-2.8	3/21/03	32%	3%	8	8	Shorthead Redhorse
	RM 0-5	7/10/03	13%	15%	15	9	Channel Catfish

Data collected by USEPA, MDEQ, and MFWP. RM – River Mile

I.2.5 Tongue River Reservoir

Montana Fish, Wildlife and Parks' (MFWP) personnel were contacted to obtain information on the aquatic life conditions in the Tongue River Reservoir. The reservoir is managed primarily as a crappie fishery and secondarily as a smallmouth bass and walleye fishery. Some sauger and walleye are believed to occasionally spawn up-river, but most of the crappies and other fish spawn in the reservoir. The reservoir is considered to be very productive and generally supports a healthy and highly diverse fish population. However, MFWP is concerned about the cumulative effects of multiple stressors on the reservoir (Vic Riggs, MFWP, personal communication March 18, 2005). Fish kills are believed to be occurring more frequently and a crappie fish kill during the winter of 2005 was considered to be more severe than previous fish kills. The specific causes of each kill are rarely known (Brad Schmitz, Montana Fish, Wildlife and Parks, personal communication June 24, 2005).

The MFWP MFISH database was evaluated to assess aquatic life conditions in the Tongue River Reservoir. More than 1,000,000 walleye were stocked in the reservoir each year from 1990 to 2006 and more than 400,000 sauger were stocked in the reservoir during both 2003 and 2004. According to the MFISH database, many fish species, such as black bullhead, black crappie, channel catfish, common carp, largemouth bass, longnose sucker, northern pike, pumpkinseed, sauger, shorthead redhorse, smallmouth bass, walleye, white crappie, white sucker, yellow bullhead, and yellow perch, are thought to be common year-round residents of the reservoir. According to MFISH, spottail shiners are the only species reported to be abundant.

Figure I-2 provides information on the number of yellow perch and walleye captured by MFWP in the Tongue River Reservoir from 1989 to 2003 (data for other species were not available for each year at the time this analysis was prepared). The data indicate that there is substantial year-to-year variability in the perch and walleye populations.

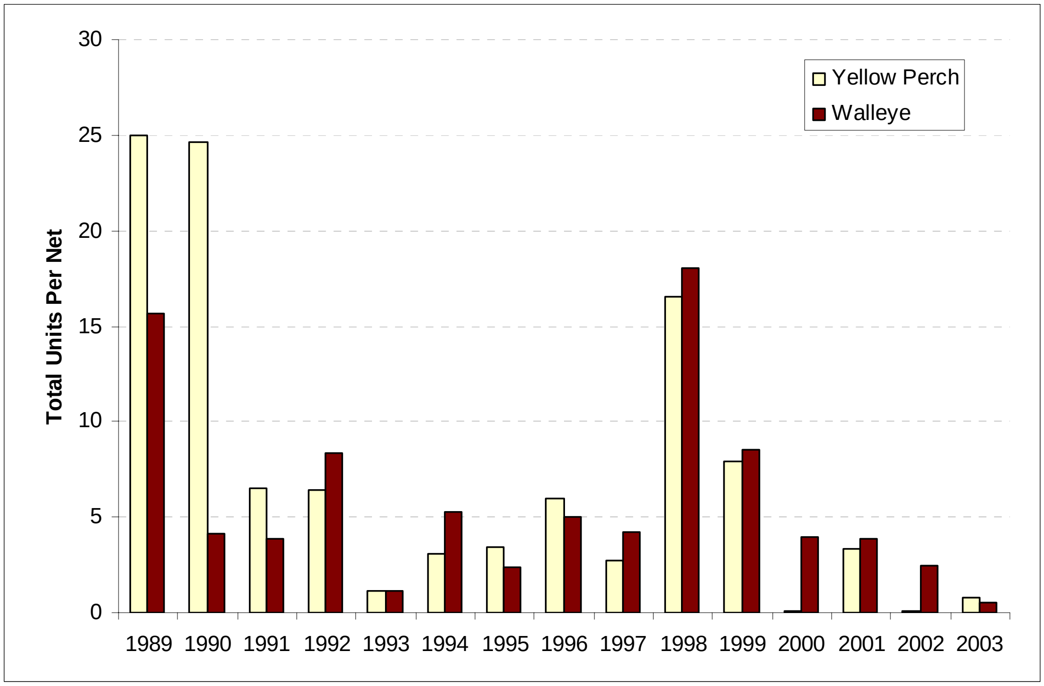

Figure I-2. Total number of yellow perch and walleye captured in Tongue River Reservoir, 1989 to 2003.

Two historic studies of aquatic life in the Tongue River Reservoir have been conducted. A 1977 study indicated that the reproductive success of largemouth and smallmouth bass in the reservoir was limited by suitable spawning substrate and turbidity. However, fingerling growth did not seem to be affected by differences in turbidity in parts of the lake (Penkal, 1977). A 1980 study of zooplankton populations in the reservoir found that the zooplankton population was similar to other non-alkaline lakes located at similar elevations and latitude (Leathe, 1980). The author of this study also determined that the zooplankton populations were likely to be more responsive to changes in the fish populations of the reservoir than to potential changes in water quality associated with proposed mining activities.

Few data are available documenting nuisance algal blooms in the Tongue River Reservoir. However, Montana Fish, Wildlife and Parks' personnel report that they are not uncommon. They typically occur later in the summer, especially during low water years, and can last for several days until they are dispersed by the wind. These blooms are believed to have a potentially significant impact on the juvenile fish populations, especially when they are already stressed due to other factors.

I.3 References

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APPENDIX J – MODEL SCENARIOS AND RESULTS

J.0 MODEL SCENARIOS

One of the primary purposes for developing the LSCP and CE-QUAL-W2 models for the Tongue River watershed was to determine if observed exceedances of water quality standards were a result of natural causes, anthropogenic causes, or a combination of both. It was envisioned that the models would also provide insight regarding the relative magnitude of influence associated with the various factors that influence water quality. This appendix first lists and briefly discusses the factors that influence salinity and SAR in the Tongue River watershed. The model scenarios that have been developed and run to date are then described. Model results for each of these scenarios are presented at the end of this appendix (Sections J.5 to J.10).

J.1 Factors Potentially Influencing SC and SAR in the Tongue River Watershed

Factors that potentially influence the levels of salinity and SAR in the Tongue River and its tributaries include:

- Irrigation
    - High altitude reservoirs
    - Diversions
    - Inter-basin transfers
    - Intra-basin transfers
    - Irrigation withdrawals
    - Irrigation returns
- Agriculture
    - Irrigated agriculture
    - Non-irrigated agriculture
- Stock ponds
- Tongue River Reservoir and operation of the dam
- CBM produced water discharge
    - Direct discharge to perennial surface waters
    - Discharge to ponds
    - Beneficial reuse
- Coal mining
    - Permitted discharges
    - Stormwater
    - Strip mines
- Wastewater treatment
    - City of Sheridan WWTP
    - Ranchester and Dayton lagoons
    - Other small permitted discharges
- Natural sources
- Soils and geology

Each of these sources is summarized in Table J-3 at the end of this appendix, and each source has been simulated with the LSPC model for the Tongue River watershed or the CE-QUAL-W2 model for the Tongue River Reservoir.

J.2 Scenarios

To date, all of the following model scenarios have been developed and run with the exception of Scenario 3:

1. Existing Condition
2. Natural Condition
3. All Reasonable Land, Soil, and Water Conservation Practices
4. CBM Influence
5. Stock Pond Influence
6. Irrigation Influence
7. Influence of Interbasin Transfers
8. Municipal Wastewater Treatment Plant Influence
9. Hypothetical CBM Discharges in Hanging Woman and Badger Creeks

Each of these is described below and model results are provided at the end of this appendix. It is anticipated that additional scenarios will be developed and evaluated in the future under a separate scope of work.

Scenario 1 - Existing Condition - *What is the current condition?*

The existing condition scenario is the baseline from which all other scenarios are compared. Model simulations of the existing condition attempt to replicate the actual hydrologic influences and pollutant generation, fate, and transport from each of the above factors. For the purposes of these analyses and in the absence of monitoring data to facilitate calibration of each of the individual processes simulated by the models, it is assumed that these are reasonably well simulated by the models since reasonable calibrations have been obtained in the Tongue River and its tributaries (see Section 4.0 and Appendix B the Modeling Report).

The existing condition scenario has been run for a period of 10 years between October 1, 1993 and September 30, 2003. This time period includes 2 wet years (1995 and 1997), 3 dry years (2000, 2001, and 2002), and 5 average years (1994, 1996, 1998, 1999, and 2003) (see Figure J-1). All of the following scenarios have been modeled for the same set of wet, dry, and average years.

All diversions and irrigation have been modeled based on the available data for these 10 years. Discharge and water quality from the Sheridan WWTP, Ranchester Lagoons, Bighorn Mountain KOA, Dayton Lagoons, and Decker East/West coal mines have also been modeled based on the available data for the 10 year period. The Powder Horn Ranch has been input as of September 2006 because this facility only began discharging in 2001.

CBM ponds and CBM discharges were input as the average flow and concentration occurring between *October 1, 2005 and September 30, 2006*, as reported in the provided Wyoming DEQ database and Montana DEQ DMR Data. An outfall was included in the analysis if it had at least one flow reported during this period – 140 CBM outfalls were identified. Figure J-2 shows the CBM facilities included in Scenario 1 (and all other scenarios discussed in this memo where CBM discharge has been modeled).

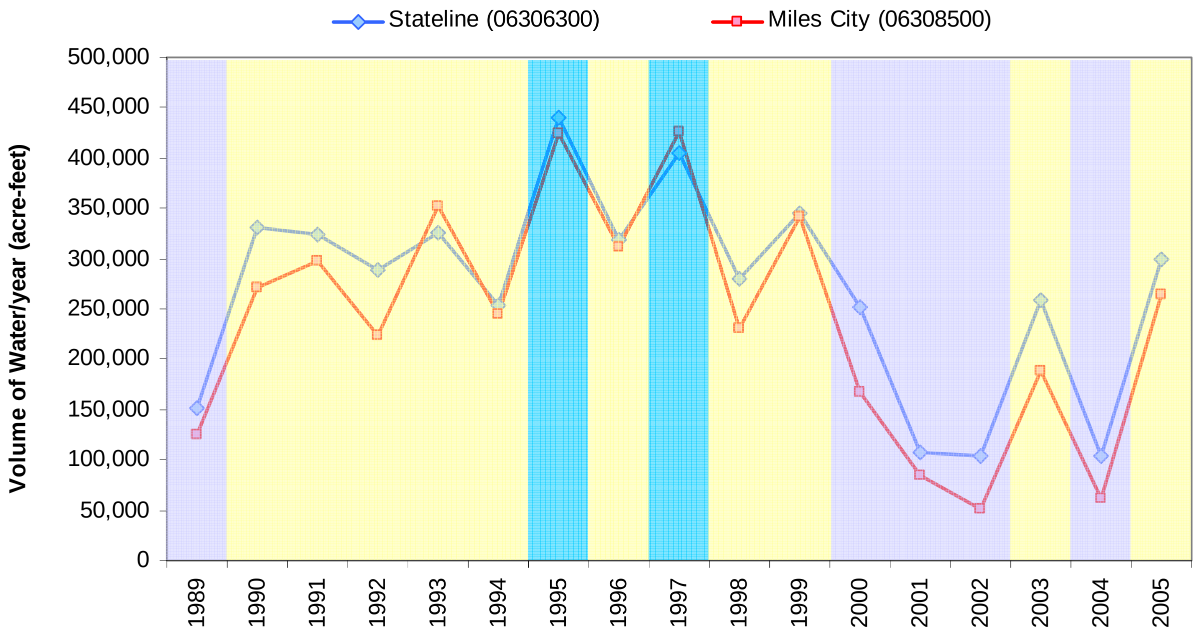


Figure J-1. Total yearly flow in the Tongue River at Miles City (06308500) and State Line (06306300).

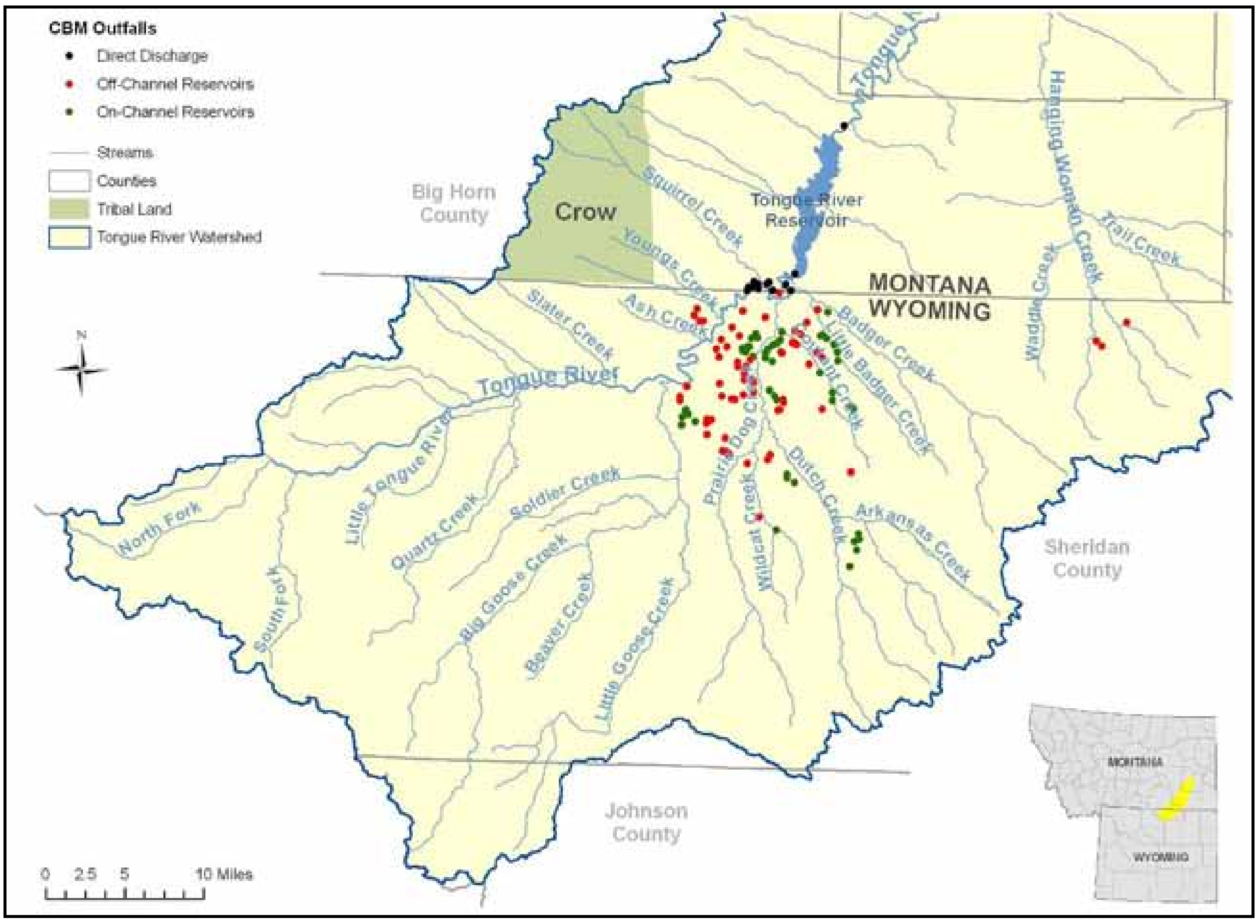


Figure J-2. CBM outfalls modeled in the scenarios.

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

Table J-1. Evaluation points for Scenarios 1, 2, 4, 5, 6, and 7.

Evaluation Point	Subbasin	Purpose	Parameters
Tongue River at Stateline (06306300)	3006	Determine the magnitude of Wyoming's contribution	SC, SAR, TN, TP, Flow
Tongue River at Miles City (06308500)	1002	Examine watershed-scale effects at the mouth of the river and evaluate effects of the T&Y Ditch	SC, SAR, Flow
Tongue River Reservoir	3000	Examine potential changes within the reservoir	SC, SAR, TN, TP
Hanging Woman Creek near Birney (06307600)	1095	Examine watershed-scale effects at the mouth of the creek.	SC, SAR, Flow
Otter Creek at Ashland (06307740)	1059	Examine watershed-scale effects at the mouth of the creek.	SC, SAR, Flow
Pumpkin Creek near mouth (06308400)	1007	Examine watershed-scale effects at the mouth of the creek.	SC, SAR, Flow
Tongue River before Tongue River Reservoir	3001	Determine the nutrient loads to the Tongue River Reservoir	TN, TP

The results from the existing condition scenario do not attempt to replicate past conditions and, therefore, cannot be directly compared to the observed data.

The frequency of exceedances of the Montana water quality standards reported at the end of this appendix may be different than those reported, based on observed data, in the Assessment Report. This is because:

1. The existing condition scenario is a hypothetical scenario where the conditions that exist "today" are used to "force" hydrologic and chemical processes over a 10-year period of wet, dry and average years. Thus, the variability in factors such as CBM discharge that have occurred over time in the past has been eliminated. The intent of the existing condition scenario is to fix "today's" condition in time to provide a baseline for comparison to other scenarios.

2. The observed data for the various parameters that have been evaluated (e.g., SC, SAR, nutrients, etc.) is sporadic. For example, in the Tongue River at Miles City (since 1990), monthly SC data were collected between 1990 and 2003, and daily data were collected between 2004 and present. In contrast, the LSPC model produces output at an hourly time step. Thus, model estimated frequency of exceedance is based on a more complete data set (e.g., 30 daily average values per month with the model versus 0-30 daily average observed values) which may result in discrepancies between observed and predicted data.

<u>Scenario 2 - Natural Condition</u> - *What would water quality conditions be like in the absence of human influence?*

The potential extreme magnitude of anthropogenic influence on water quality has been estimated by removing the majority of human-caused influences from the model. This scenario has removed the following from the model:

- High altitude diversions, inter-basin transfers, irrigation withdrawals, irrigation returns, stock ponds, CBM produced water discharge, coal mining, and wastewater treatment discharge. Irrigated agriculture would be modeled as 100% grassland. Non-irrigated agricultural and urban lands would be modeled as grassland.
- The high altitude reservoirs and Tongue River Reservoir would <u>remain</u> in the model but would be assumed to operate in "run of the river" mode (i.e., outflow naturally over the spillway).

Although it is acknowledged that this condition is unattainable and may not meet everyone's definition of "natural", model results from this scenario place upper bounds on the potential range of affect. It is intended to be the first step in a step wise modeling approach. If the model results from the "natural" scenario do not differ significantly from the "existing condition" scenario then the question of whether or not current water quality conditions are a result of natural or anthropogenic causes has already been answered and no further modeling is necessary. On the other hand, if there is a significant difference between the modeled "natural condition" and "existing condition" then additional modeling may be necessary to estimate the relative importance of each of the anthropogenic causes.

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

<u>Scenario 3 - All Reasonable Land, Soil and Water Conservation Practices</u> - *What would water quality conditions be like if all reasonable land, soil, and water conservation practices were applied to all of the human-caused factors influencing water quality?*

Without specific guidance from Montana DEQ, it is not possible to interpret what the phrase "all reasonable land, soil and water conservation practices" means. It is assumed to mean full application of all best management practices (BMPs) for all of the factors that have anthropogenic influence on water quality. To effectively develop such a scenario, it would be necessary to individually evaluate each of the factors listed above, determine the extent to which BMPs have already been employed, develop a conceptual suite of BMPs for cases where they have not already been employed, conceptualize how the BMPs might reduce pollutant loads and/or affect hydrology, and then modify model inputs accordingly.

While it is possible to develop and run this model scenario, it is beyond the current scope of work and, therefore, has not been evaluated.

<u>Scenario 4 - CBM Influence</u> – *What influence is the discharge of CBM produced water having on water quality?*

To evaluate the potential magnitude of influence associated with the discharge of CBM produced water, direct discharge and CBM ponds has been removed from the model (Scenario 4a). Then to individually evaluate the effects of direct discharge (Scenario 4b) and ponds (Scenario 4c), they have been removed from the model one at a time.

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

Scenario 5 – Stock Pond Influence – *What influence are stock ponds having on water quality?*

To evaluate the potential magnitude of influence associated with stock ponds, they have been removed from the model.

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

Scenario 6 – Irrigation Influence – *What influence is irrigation having on water quality?*

Factors associated with irrigation that may have influence on SC and SAR include high altitude reservoirs, high altitude diversions, inter-basin transfers, irrigation withdrawals, irrigation returns, irrigated agriculture, and operation of the Tongue River Reservoir Dam.

Scenario 6 removes irrigation withdrawals and irrigation returns from the model. The high altitude reservoirs and the Tongue River Reservoir remain, but are assumed to operate in "run of the river" mode (i.e., outflow naturally over the spillway). The T&Y Diversion and high altitude reservoirs have been removed from the model. It is acknowledged that this is an unrealistic scenario. However, the purpose of evaluating this scenario is to determine the potential maximum magnitude of influence resulting from irrigation.

If the model results from Scenario 6 differ significantly from the "existing condition" scenario then more refined scenarios can be developed to determine the significance of the individual factors at play (e.g., remove irrigation withdrawals and returns separately).

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

Scenario 7 – Interbasin Transfers - *What influence are the interbasin transfers having on water quality?*

Scenario 7 removes the interbasin transfers from the Powder River from the LSPC model. The high altitude reservoirs and Tongue River Reservoir remain, but are assumed to operate in "run of the river" mode (i.e., outflow naturally over the spillway). The high altitude diversions were also removed. It is acknowledged that this is an unrealistic scenario. However, the purpose of evaluating this scenario is to determine the potential maximum magnitude of influence resulting from interbasin transfers.

If the model results from Scenario 7 differ significantly from the "existing condition" scenario then more refined scenarios can be developed to determine the significance of the individual factors at play (increase of decrease the amount of water, change the location of the diversions).

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

Scenario 8 – Wastewater Treatment - *What influence is the discharge of municipal wastewater having on water quality?*

Scenario 8 removes the municipal wastewater treatment facilities from the LSPC model. The following facilities were removed: Sheridan WWTP, Ranchester Lagoons, Dayton Lagoons, Bighorn Mountain KOA, and Powder Horn Ranch. The City of Sheridan drinking water withdrawal was also removed. All other model inputs remained the same.

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

<u>Scenario 9 – Hypothetical CBM Discharge Scenarios in Hanging Woman and Badger Creek</u> - *How might future CBM discharges affect water quality in both the tributaries and downstream in the Tongue River?*

In March 2007, Montana DEQ and Wyoming DEQ jointly requested that the LSPC model be used to answer the following question:

What end-of-pipe effluent limits, what volumes, and during what months can discharge to Hanging Woman Creek and Badger Creek occur, and meet Montana's expectations?

The following three scenarios were developed and evaluated to provide insight relative to this question:

<u>Scenario 9a – Draft Wyoming Permit Limits</u>

Wyoming DEQ released a draft general permit for the Badger/Hanging Woman Creek Watershed for committee review on July 26, 2006 (WDEQ, 2006). Scenario 9a is based on the effluent limits for "Category 1 Discharges" (i.e., direct discharge) as specified in the draft permit. The draft permit states that 5 cfs of direct discharge will be allowed at the Montana-Wyoming Stateline. It was assumed that 5 cfs of CBM effluent was directly discharged into both Hanging Woman and Badger Creeks. The draft permit allows for an SC of 2,440 µS/cm, a sodium concentration of 420 mg/L, and an SAR of 5.2. Cations required for the LSPC model (i.e., Ca, Mg, Na) were based on the relationship between the cations and SC in Hanging Woman Creek [SC = 78.801 (Ca + Na + Mg) + 172.9, in milliequivalents]. Final modeled cations are shown in Table J-2. It should be noted that a permit limit of 2440 µS/cm and a sodium concentration of 420 cannot result in a SAR of 5.2 (the calculation is provided at the end of this section). The resulting SAR would be approximately 8. Thus, this scenario was based on an SAR of 8.0 as opposed to that which was specified in the draft permit.

<u>Scenario 9b – Untreated CBM Discharge</u>

Scenario 9b was developed to evaluate the affect of potential future CBM discharges at 5 cfs at concentrations equal to the average measured concentrations of current CBM outfalls in the Hanging Woman Creek and Badger Creek watersheds. Average measured concentrations were based on the entire period of record for all CBM outfalls in those two watersheds (Table J-2).

<u>Scenario 9c – Montana Average Growing Season Standards</u>

Scenario 9c was developed to evaluate the affect of potential future CBM discharges at 5 cfs at concentrations equal to the Montana average monthly growing season standards for SC and SAR in the tributaries to the Tongue River (i.e., 500 and 3.0, respectively) (ARM 17.30.670). Table J-2 shows the individual cation concentrations.

Table J-2. Concentrations implemented in the Scenario 9 model runs.

Parameter	Option A (Wyoming Draft Permit Limits)	Option B (Avg Observed)	Option C (MT Permit Limits)
Calcium (mg/L)	79	9	11.5
Magnesium (mg/L)	79	5	11.5
Sodium (mg/L)	420	493	60
EC (µS/cm)	2,440	1,924	500
SAR	8	33.8	3

The geographic points where model results have been extracted for evaluation are shown in Table J-1. The results are provided at the end of this appendix.

J.3 References

WDEQ. 2006. Badger / Hanging Woman Creek Watershed General Permit for Surface Discharges Related to Coal Bed Methane Production – Draft Permit Dated July 26, 2006. Wyoming Department of Environmental Quality, Water Quality Division, WYPDES Program. Cheyenne, Wyoming. Available online at http://deq.state.wy.us/wqd/WYPDES_Permitting/WYPDES_cbm/Pages/CBM_Watershed_Permitting/Tongue_PrairieDog_HangingWoman_Badger_Creek%5D/Tongue%20PHB%20Downloads/wypdes_cbm_wsperm_LowerTongue.asp

Table J-3. Potential sources of salinity and/or nutrients in the Tongue River watershed.

Category	Name	Type	What is It?	Potential Influence on Salinity/SAR
Stock Ponds	Stock Ponds	Anthropogenic	Stock ponds are generally located in small, ephemeral tributaries, and are created with the purpose of providing water to livestock. The estimated total stock pond capacity in the Tongue River watershed is 13,725 acre-feet, with an estimated drainage area to the ponds of 1,164 square miles (23% of the total watershed area).	Stock ponds modify stream hydrology by capturing and storing storm event runoff. This potentially results in increased infiltration, and higher water tables. Evaporation in the ponds and mixing with high salinity soils and groundwater can result in increased salt concentrations in the infiltrated water.
Irrigation	High Altitude Reservoirs	Anthropogenic	Reservoirs constructed in the Bighorn Mountains to capture mountain snowmelt and release water for later irrigation use. The 6 major reservoirs in the Tongue River watershed include Twin, Park, Bighorn, Cross Creek, Dome, and Sawmill Reservoirs. The total full capacity of the reservoirs is 26,956 acre-feet.	High altitude reservoirs modify stream hydrology by capturing, storing, and releasing mountain snowmelt.
	High Altitude Diversions	Anthropogenic	High altitude diversions are used to adjust the location and timing of water delivered to downstream irrigators. This includes diversions from the Big Goose Creek watershed to the Little Goose Creek watershed (average of 49 cfs from the Park and Mountain Supply Diversions).	Modifies volume and timing of water. Moves low salinity water among various streams/ subbasins.
	Transbasin Diversions	Anthropogenic	Three canals (Meade-Coffen, Piney-Cruse, and Prairie Dog) divert water from Piney Creek in the Powder River watershed to Little Goose Creek and Prairie Dog Creek in the Tongue River watershed. An average of 67 cfs (max of 100 cfs) is diverted between April and October of each year.	Modifies timing and volume of water. The quality of this water (and its potential salinity impact) is dependant on the supply from Piney Creek, but the water is essentially mountain snowmelt that is minimally affected by anthropogenic sources.
	Irrigation Withdrawals	Anthropogenic	Water withdrawn or applied (i.e., flood irrigation) at the point of use to meet crop consumptive use requirements.	Reduces the total volume of water in the stream, thereby resulting in less dilution for any downstream high salinity inputs.
	Irrigation Return Flows	Anthropogenic	Water returned to the stream from irrigation.	Return flow water equilibrates with groundwater and generally returns to the stream at a higher salinity concentration than when withdrawn.
	Irrigated Agriculture (Full Supply)	Anthropogenic	Land that is irrigated with stream water to meet the full water demand of the crop. Calculated at 80,980 acres in the Tongue River watershed.	Irrigated land has more dense plants, resulting in more rainfall interception, more water uptake in the root zone, and concentration of salts by plant uptake. Generally reduces the available water in the system and concentrates salts.

Table J-3. Potential sources of salinity and/or nutrients in the Tongue River watershed.

Category	Name	Type	What is It?	Potential Influence on Salinity/SAR
	Irrigated Agriculture (Partial Supply)	Anthropogenic	Land that is irrigated with stream water to meet a partial water demand of the crop (assumed to be ½ the water demand). Calculated at 32,442 acres in the Tongue River watershed.	Irrigated land has more dense plants, resulting in more rainfall interception, more water uptake in the root zone, and concentration of salts by plant uptake. Generally reduces the available water in the system and concentrates salts.
	Nonirrigated Agriculture	Anthropogenic	Dry-land farming that does not use irrigation, but does have some land management.	Increased canopy cover plus water used can reduce the volume of available water and concentrate salts in the root zone.
	T&Y Dam and Diversion	Anthropogenic	Diversion Dam located approximately 12 miles upstream of Miles City diverts an average of 133 cfs from the Tongue River to the T&Y Ditch during the growing season, which irrigates land in both the Tongue River and Yellowstone River watersheds.	Decrease in flow results in less dilution potential. Return flows increase salinity loading.
CBM	CBM Pond Discharges	Anthropogenic	CBM wells that discharge water to on or off channel ponds for containment/ infiltration. CBM effluent in the Tongue watershed generally has higher salinity and sodium concentrations that ambient stream concentrations. 427 known discharges to CBM ponds (as of September 30, 2006).	CBM effluent in the Tongue watershed generally has higher salinity and sodium concentrations that ambient stream concentrations. Ponds are generally unlined, and infiltrate the high salinity water into the water table. On channel ponds also act like stock ponds (see above), reducing stream flows and increasing infiltration.
	CBM Direct Discharges	Anthropogenic	CBM wells that discharge water directly to a perennial stream. 18 direct discharges to the Tongue River watershed (as of September 30, 2006).	CBM effluent in the Tongue watershed generally has higher salinity and sodium concentrations that ambient stream concentrations. Therefore, untreated discharges increase salinity, SAR, and flow in streams.
Coal Mines	Coal Mine Discharges	Anthropogenic	Three coal mines (Decker East, Decker West, Spring Creek) currently discharge water into the Tongue River watershed. Average total flow of 3.6 cfs.	Coal mine effluent in the Tongue watershed generally has higher salinity and sodium concentrations that ambient stream concentrations. Therefore, the discharges increase salinity, SAR, and flow in streams.
	Strip Mining	Anthropogenic	Strip mines.	Strip mines alter infiltration, no plant interception.
Wastewater Treatment	Sheridan WWTP	Anthropogenic	The Sheridan WWTP is an activated sludge treatment plant for the City of Sheridan, Wyoming. It discharges an average of 4.6 cfs to Goose Creek.	No salinity data were available for the Sheridan WWTP. It is assumed that salinity increases between the intake (near the Big Goose Creek Canyon) to the outfall downstream of Sheridan. This results in an increase in salinity, and a net decrease in flow through consumption.

Table J-3. Potential sources of salinity and/or nutrients in the Tongue River watershed.

Category	Name	Type	What is It?	Potential Influence on Salinity/SAR
	Ranchester and Dayton Lagoons	Anthropogenic	The Ranchester and Dayton lagoons are the two other large wastewater treatment systems in the Tongue River watershed. Discharge an average of 0.21 and 0.16 cfs to the Tongue River, respectively.	It is assumed that salinity increases between the intake to the outfall. This results in an increase in salinity, and a net decrease in flow through consumption.
	Other Wastewater Treatment	Anthropogenic	Powder Horn Ranch, Bighorn KOA, and Burgess Junction Waste Dump all have lagoons discharging to the Tongue River watershed. Discharge an average of 0.030, 0.003, and 0.000 cfs, respectively.	It is assumed that salinity increases between the intake to the outfall. This results in an increase in salinity, and a net decrease in flow through consumption.
Tongue River Reservoir	Tongue River Reservoir Dam Operations	Anthropogenic	Located downstream of the MT-WY Stateline, the Tongue River Reservoir has a capacity of 79,000 acre-feet of water.	The reservoir is managed to store and release water to serve downstream irrigators. This results in downstream hydromodification. The reservoir, due to its long residence time (90 day average), also serves to mix high and low salinity water.
Natural Sources	Soils/Geology	Natural	Areas of naturally high soils, geology, and groundwater exist throughout the Tongue River watershed.	High salinity geology and soils contribute naturally high loads to the Tongue River watershed.

Calculation of SAR Permit Limits at a Specific Conductance of 2,440 µS/cm and a sodium concentration of 420 mg/L

Eq. 1: $SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$,where Ca, Mg, and Na are in milliequivalents.

EC = sum of the cations <u>or</u> anions (in milliequivalents). Assume that the cations are Ca, Mg, and Na + miscellaneous other cations. Use measured data in Hanging Woman Creek near Birney Montana (USGS Gage 06307600) to determine the relationship between sum of cations (Ca + Mg + Na) and EC. Relationship equals:

Eq. 2: EC (µS/cm) = 78.801 (Ca + Mg + Na) + 172.9

Knowns: (a) Wyoming Permit Limit for EC = 2440 µS/cm
(b) Wyoming permit limit for sodium = 420 mg/L = 18.26 meq/L

Eq. 3: 2440 = 78.801 (Ca + Mg + 18.26) + 172.9
Eq. 4: 28.77 = (Ca + Mg + 18.26)
Eq. 5: 10.51 = Ca + Mg

Eq. 6: $SAR = \frac{18.26}{\sqrt{(10.51)/2}} = 8.0$

J.4 Scenario Results

The following sections present scenario results for the Tongue River at Miles City, Tongue River at the Montana-Wyoming State Line, Hanging Woman Creek near the mouth, Otter Creek near the mouth, Pumpkin Creek near the mouth, and the Tongue River Reservoir near the Tongue River Reservoir Dam. Results are presented for flow, specific conductance, and sodium adsorption ratio at all of the sites. Total nitrogen and total phosphorus results are also presented for the Tongue River Reservoir. Data and results for additional sites throughout the Tongue River watershed are available upon request.

Throughout this document, 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.

J.5 Tongue River at Miles City, Montana

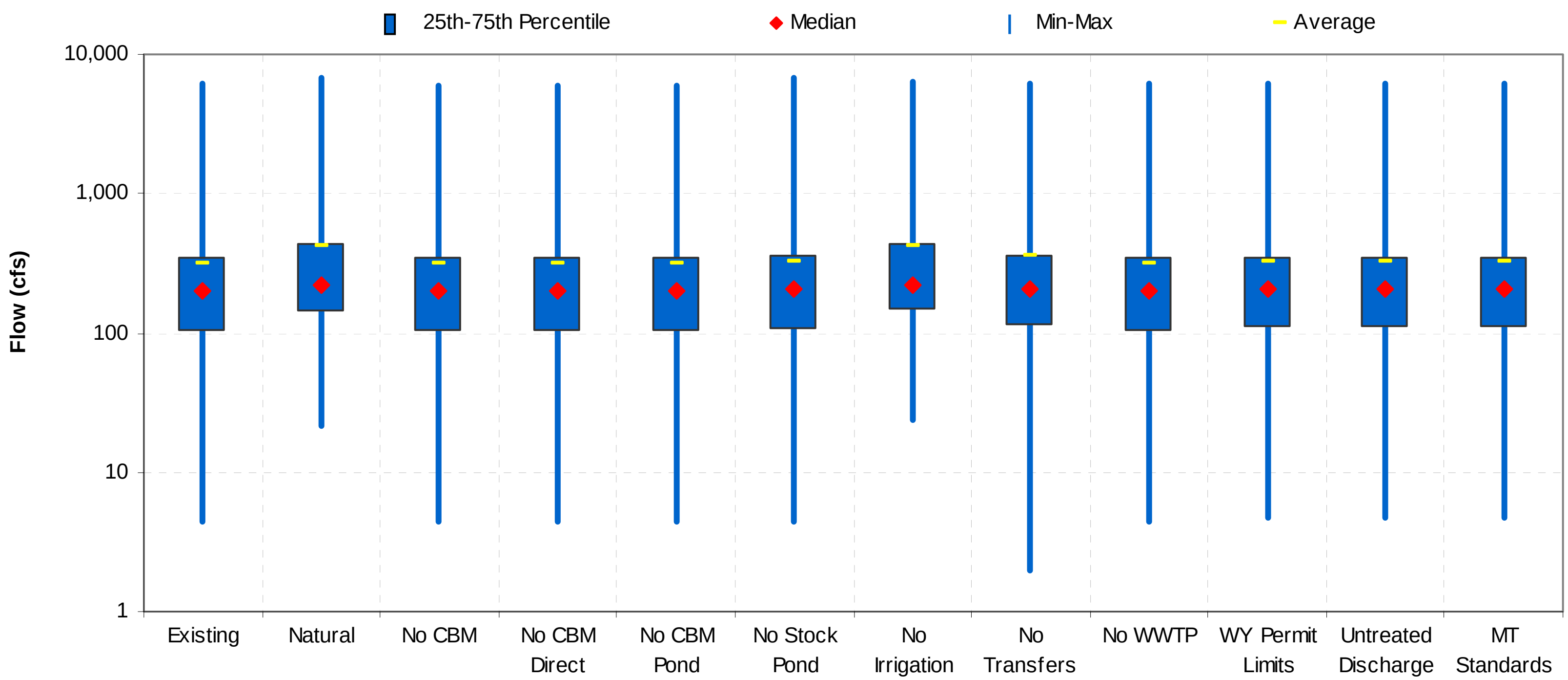


Figure J-3. Scenario results for flow in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Table J-4. Flow statistics for various scenarios in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	346	441	343	345	346	354	437	353	348	353	353	353
25th Percentile	103	140	102	102	103	104	146	113	103	108	108	108
Median	201	219	201	201	201	205	223	210	201	207	207	207
Average	316	426	310	312	314	323	427	364	317	324	324	324
Max	6,089	6,817	5,891	5,965	6,037	6,681	6,264	6,254	6,101	6,163	6,163	6,163
Min	4	21	4	4	4	4	24	2	4	5	5	5

Table J-5. Comparison of mean flow (cfs) values from various scenarios to the existing condition scenario, Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean Flow (cfs)	316	426	310	312	314	323	427	364	317	324	324	324
Mean Flow Differs From Existing Condition Mean Flow?[1]	NA	Yes	No	No	No	No	Yes	Yes	No	No	No	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

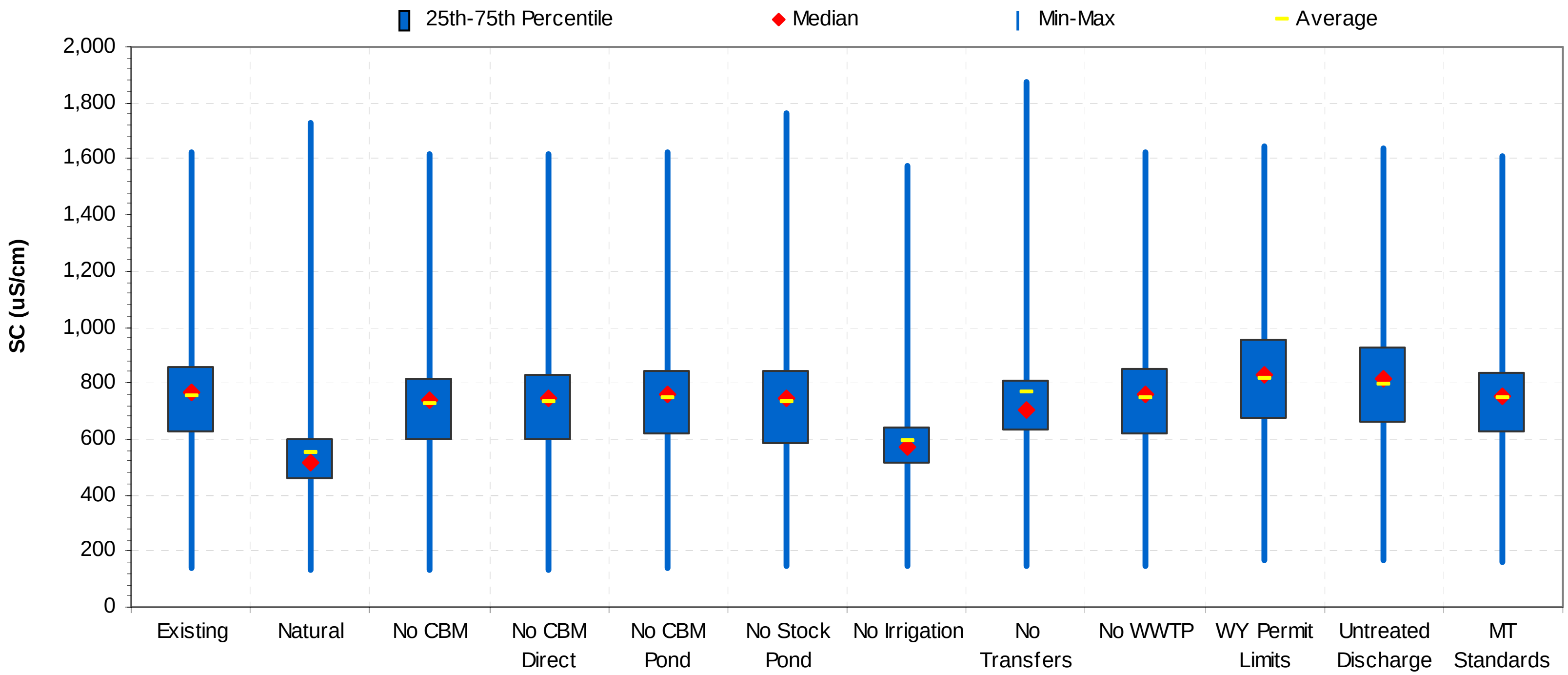


Figure J-4. Scenario results for salinity (specific conductance) in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Table J-6. SC (µS/cm) statistics for various scenarios in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	857	596	815	828	846	842	640	806	848	955	926	833
25th Percentile	618	456	589	595	612	578	509	629	611	667	654	619
Median	767	517	736	742	760	749	572	703	760	832	814	750
Average	754	553	725	732	747	732	595	764	747	817	798	743
Max	1,626	1,728	1,618	1,620	1,624	1,761	1,577	1,874	1,622	1,646	1,637	1,612
Min	142	136	135	136	136	144	144	148	146	168	166	159

Table J-7. Percentage of SC exceedances per scenario in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Evaluation Period	Season	Standard (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Instantaneous Maximum	Growing Season	1500	2450	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%	5.4%	0.2%	0.2%	0.2%	0.2%
	Nongrowing Season	2500	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	1000	80	7.5%	2.5%	6.3%	6.3%	6.3%	6.3%	2.5%	16.3%	6.3%	16.3%	12.5%	6.3%
	Nongrowing Season	1500	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0	0

Table J-8. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	754	553	725	732	747	732	595	764	747	817	798	743
Mean SC Differs From Existing Condition Mean SC?[1]	NA	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes

[1]Means were compared using a Student's T-Test at an α of 0.05.

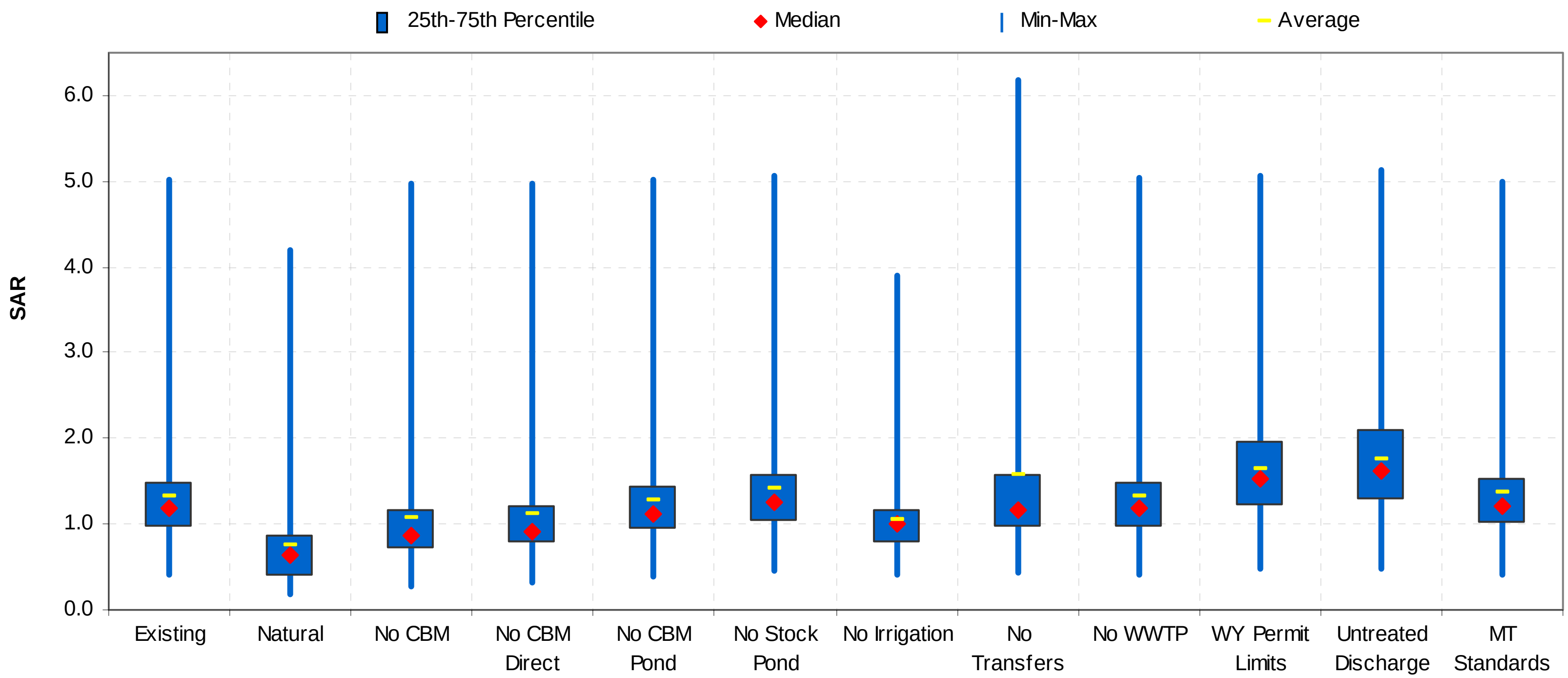


Figure J-5. Scenario results for SAR in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Table J-9. SAR statistics for various scenarios in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	1.48	0.88	1.17	1.22	1.43	1.57	1.15	1.57	1.48	1.96	2.09	1.52
25th Percentile	0.96	0.40	0.72	0.77	0.93	1.03	0.77	0.95	0.96	1.21	1.28	1.00
Median	1.18	0.65	0.88	0.92	1.12	1.25	1.01	1.15	1.18	1.52	1.63	1.22
Average	1.33	0.76	1.08	1.12	1.29	1.41	1.06	1.57	1.32	1.64	1.75	1.36
Max	5.03	4.19	4.97	4.97	5.02	5.07	3.89	6.19	5.03	5.06	5.14	4.99
Min	0.40	0.18	0.28	0.31	0.39	0.46	0.42	0.42	0.40	0.47	0.49	0.41

Table J-10. Percentage of SAR exceedances per scenario in the Tongue River at Miles City, Montana (Modeling subbasin 1002).

Evaluation Period	Season	Standard	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Instantaneous Maximum	Growing Season	4.5	2450	0.3%	0.0%	0.2%	0.2%	0.3%	0.3%	0.0%	8.0%	0.3%	0.3%	0.4%	0.3%
	Nongrowing Season	7.5	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	3	80	3.8%	0.0%	2.5%	2.5%	3.8%	5.0%	0.0%	15.0%	3.8%	5.0%	6.3%	3.8%
	Nongrowing Season	5	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table J-11. Comparison of mean SAR values from various scenarios to the existing condition scenario, Tongue River at Miles City, Montana (Modeling subbasin 1002).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SAR	1.33	0.76	1.08	1.12	1.29	1.41	1.06	1.57	1.32	1.64	1.75	1.36
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

[1]Means were compared using a Student's T-Test at an α of 0.05.

J.6 Tongue River at the Montana-Wyoming State Line

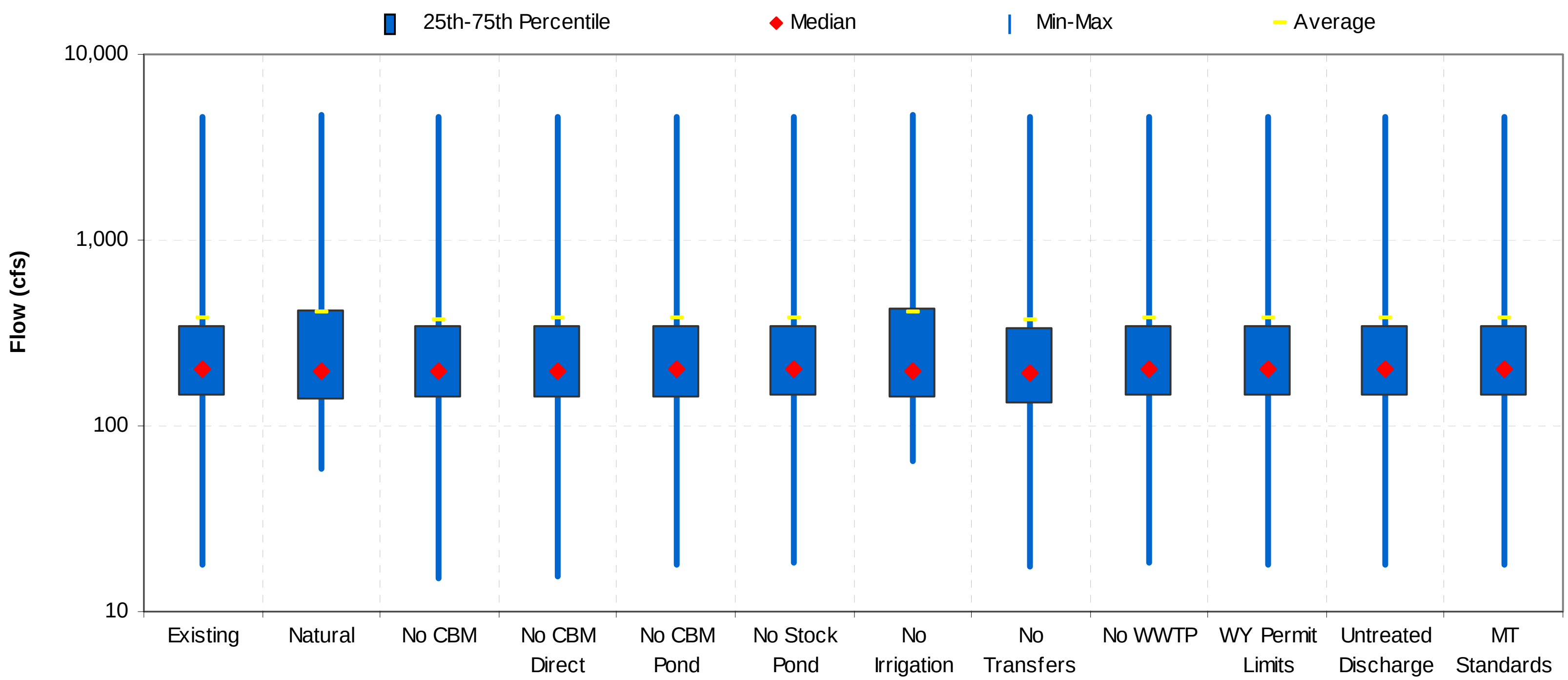


Figure J-6. Scenario results for flow in the Tongue River at the State Line (Modeling subbasin 3006).

Table J-12. Flow statistics for various scenarios in the Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Inter-basin Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Stnd. 9c
75th Percentile	345	423	341	342	344	347	424	337	348	345	345	345
25th Percentile	143	139	139	140	142	143	141	132	143	143	143	143
Median	202	198	197	199	200	202	199	191	202	202	202	202
Average	379	405	375	376	377	380	408	371	380	379	379	379
Max	4,568	4,711	4,559	4,564	4,562	4,571	4,760	4,605	4,570	4,568	4,568	4,568
Min	18	59	15	15	18	18	65	17	18	18	18	18

Table J-13. Comparison of mean flow (cfs) values from various scenarios to the existing condition scenario, Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Stnd. 9c
Mean Flow (cfs)	379	405	375	376	377	380	408	371	383	379	379	379
Mean Flow Differs From Existing Condition Mean Flow?[1]	NA	Yes	No	No	No	No	Yes	Yes	No	No	No	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

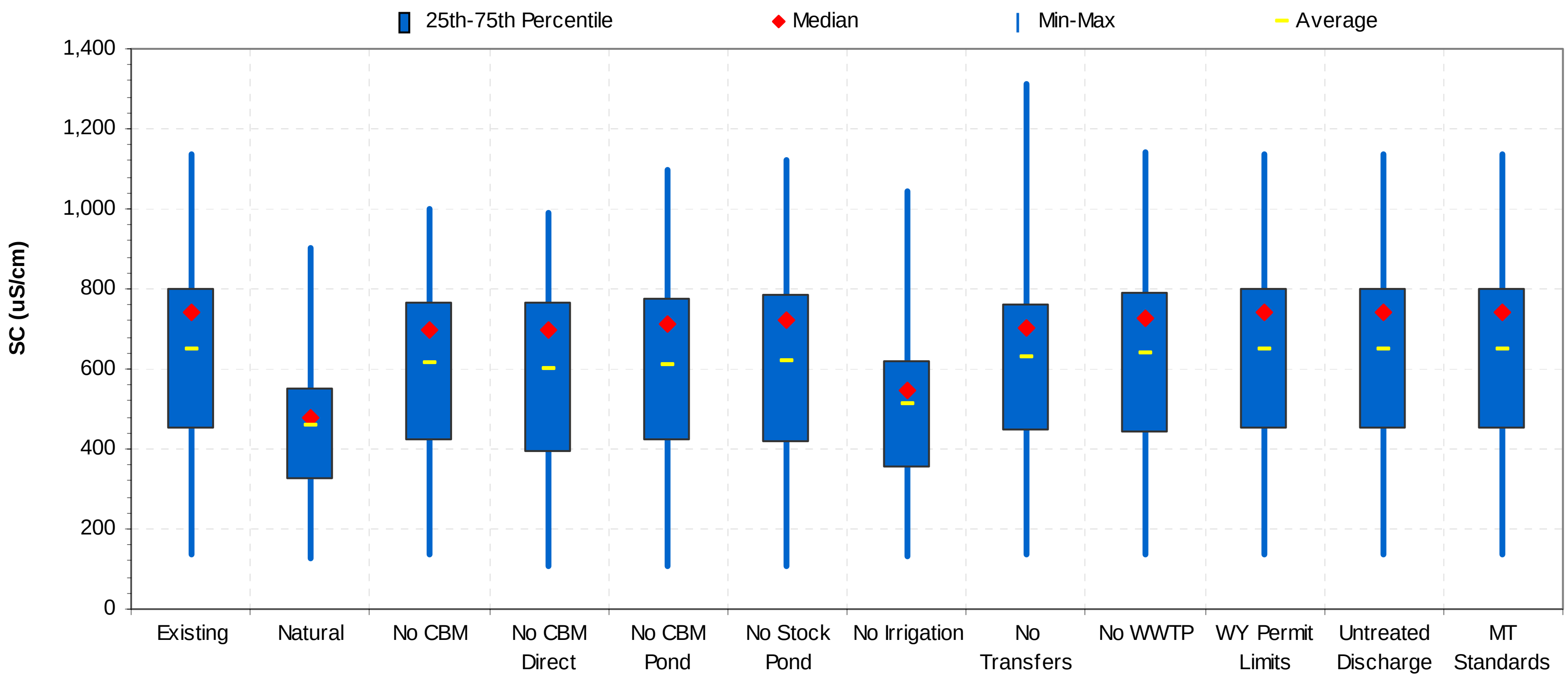


Figure J-7. Scenario results for salinity (specific conductance) in the Tongue River at the State Line (Modeling subbasin 3006).

Table J-14. SC (µS/cm) statistics for various scenarios in the Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	801	551	764	764	774	784	617	762	790	801	801	801
25th Percentile	448	323	420	393	417	417	349	444	438	448	448	448
Median	741	480	698	699	712	721	549	703	728	741	741	741
Average	647	459	613	599	610	618	510	631	638	647	647	647
Max	1,134	901	998	993	1,099	1,120	1,046	1,312	1,140	1,134	1,134	1,134
Min	138	127	135	109	109	109	130	137	137	138	138	138

Table J-15. Percentage of SC exceedances per scenario in the Tongue River at the State Line (Modeling subbasin 3006).

Evaluation Period	Season	Standard (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Instantaneous Maximum	Growing Season	1500	2450	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	2500	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	1000	80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	1500	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table J-16. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	647	459	613	599	610	618	510	631	638	647	647	647
Mean SC Differs From Existing Condition Mean SC?[1]	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

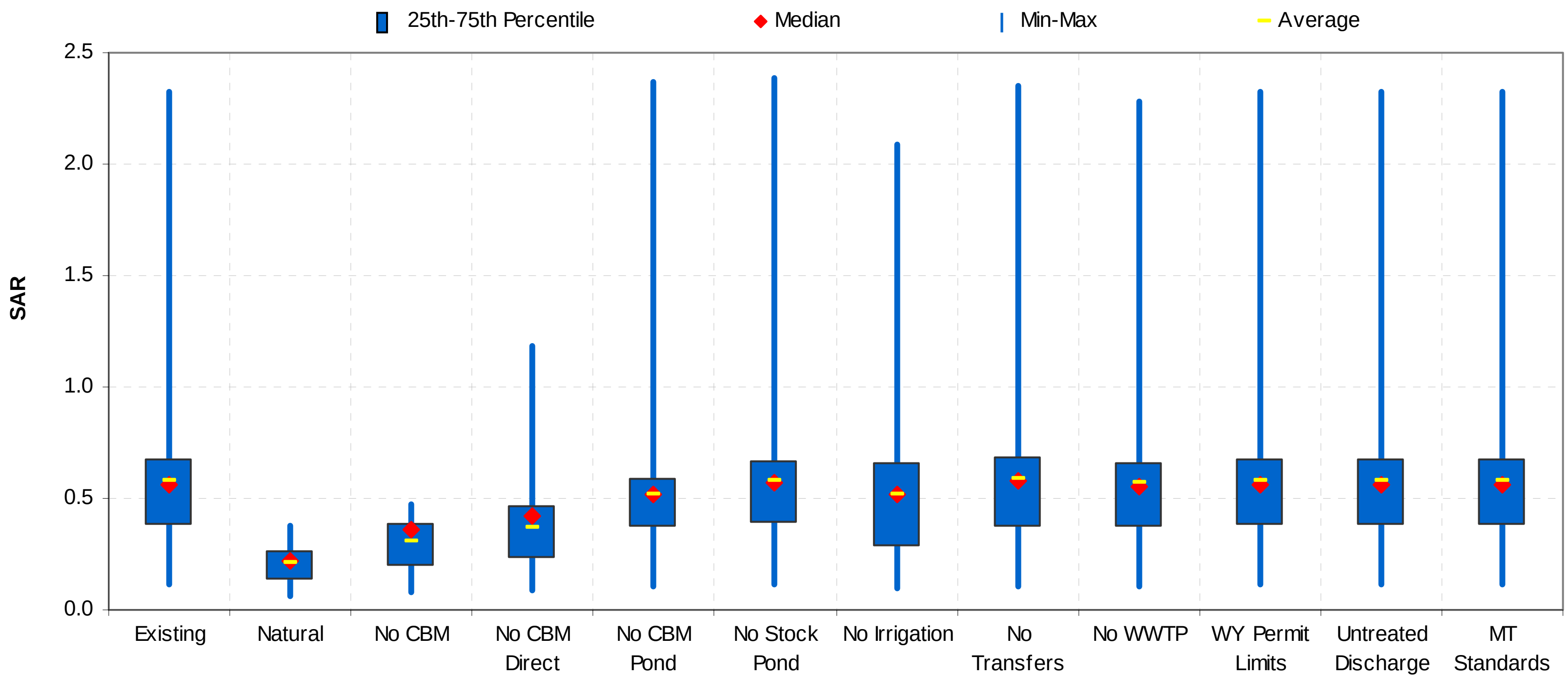


Figure J-8. Scenario results for SAR in the Tongue River at the State Line (Modeling subbasin 3006).

Table J-17. SAR statistics for various scenarios in the Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Inter-basin Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Stnd. 9c
75th Percentile	0.67	0.26	0.38	0.47	0.59	0.67	0.66	0.69	0.66	0.67	0.67	0.67
25th Percentile	0.38	0.13	0.20	0.23	0.36	0.39	0.28	0.37	0.37	0.38	0.38	0.38
Median	0.57	0.22	0.36	0.42	0.52	0.57	0.52	0.58	0.55	0.57	0.57	0.57
Average	0.58	0.21	0.30	0.37	0.52	0.58	0.51	0.58	0.57	0.58	0.58	0.58
Max	2.33	0.38	0.47	1.19	2.37	2.39	2.09	2.35	2.28	2.33	2.33	2.33
Min	0.11	0.06	0.08	0.09	0.10	0.12	0.10	0.11	0.11	0.11	0.11	0.11

Table J-18. Percentage of SAR exceedances per scenario in the Tongue River at the State Line (Modeling subbasin 3006).

Evaluation Period	Season	Standard	Count of Values	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Stnd. 9c
Instantaneous Maximum	Growing Season	4.5	2450	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	7.5	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	3	80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	5	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table J-19. Comparison of mean SAR values from various scenarios to the existing condition scenario, Tongue River at the State Line (Modeling subbasin 3006).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Stnd. 9c
Mean SAR	0.58	0.21	0.30	0.37	0.52	0.58	0.51	0.58	0.57	0.58	0.58	0.58
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

J.7 Hanging Woman Creek near the Mouth

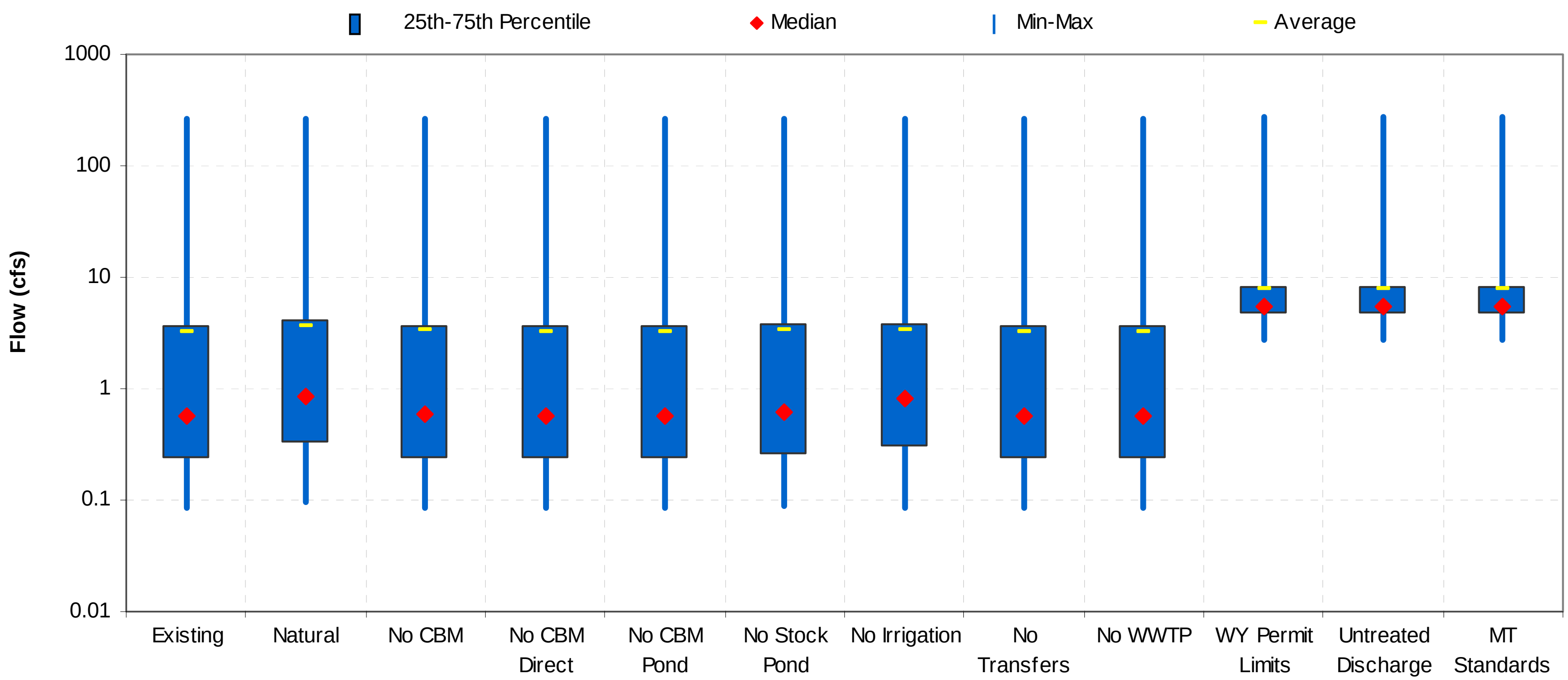


Figure J-9. Scenario results for flow in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Table J-20. Flow statistics for various scenarios in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	3.6	4.0	3.7	3.6	3.6	3.8	3.9	3.6	3.6	8.2	8.2	8.2
25th Percentile	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2	4.6	4.6	4.6
Median	0.6	0.9	0.6	0.6	0.6	0.6	0.8	0.6	0.6	5.4	5.4	5.4
Average	3.3	3.6	3.3	3.3	3.3	3.4	3.4	3.3	3.3	7.8	7.8	7.8
Max	260.8	266.6	262.0	260.8	260.8	267.4	258.8	260.8	260.8	270.7	270.7	270.7
Min	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.8	2.8	2.8

Table J-21. Comparison of mean flow (cfs) values from various scenarios to the existing condition scenario, Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean Flow (cfs)	3.3	3.6	3.3	3.3	3.3	3.4	3.4	3.3	3.3	7.8	7.8	7.8
Mean Flow Differs From Existing Condition Mean Flow?[1]	NA	No	No	No	No	No	No	No	No	Yes	Yes	Yes

[1]Means were compared using a Student's T-Test at an α of 0.05.

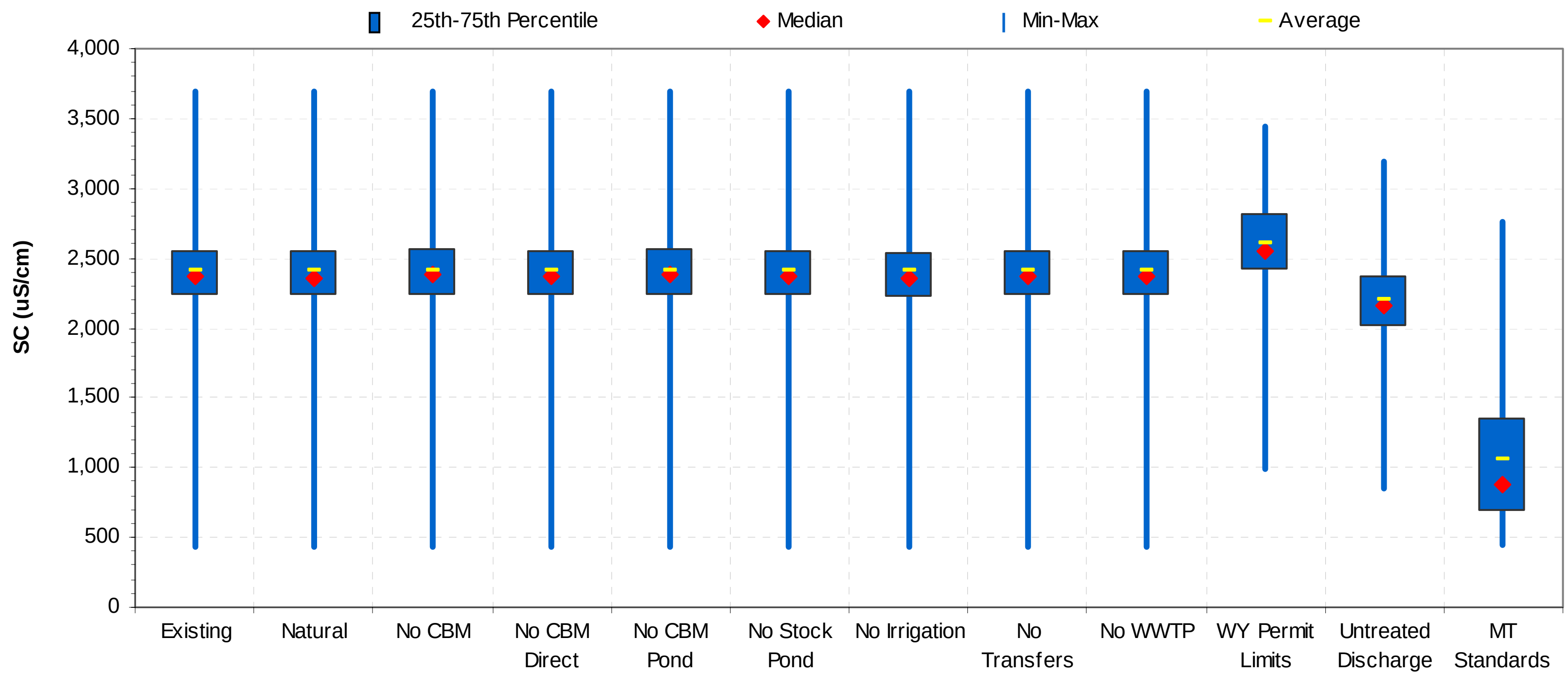


Figure J-10. Scenario results for salinity (specific conductance) in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Table J-22. SC (µS/cm) statistics for various scenarios in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	2,555	2,548	2,560	2,555	2,560	2,552	2,533	2,555	2,555	2,821	2,369	1,353
25th Percentile	2,229	2,226	2,233	2,229	2,233	2,230	2,217	2,229	2,229	2,407	2,005	689
Median	2,371	2,360	2,377	2,371	2,377	2,370	2,349	2,371	2,371	2,548	2,154	876
Average	2,413	2,417	2,416	2,413	2,416	2,412	2,407	2,413	2,413	2,606	2,197	1,054
Max	3,694	3,688	3,699	3,694	3,699	3,688	3,688	3,694	3,694	3,446	3,190	2,764
Min	433	429	435	433	435	431	429	433	433	992	850	452

Table J-23. Percentage of SC exceedances per scenario in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Evaluation Period	Season	Standard (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrig	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Inst. Maximum	Growing Season	500	2450	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Nongrowing Season	500	1202	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	100.0%	100.0%	99.9%
Monthly Average	Growing Season	500	80	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Nongrowing Season	500	40	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table J-24. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	2,413	2,417	2,416	2,413	2,416	2,412	2,407	2,413	2,413	2,606	2,197	1,054
Mean SC Differs From Existing Condition Mean SC?[1]	NA	No	No	No	No	No	No	No	No	Yes	Yes	Yes

[1]Means were compared using a Student's T-Test at an α of 0.05.

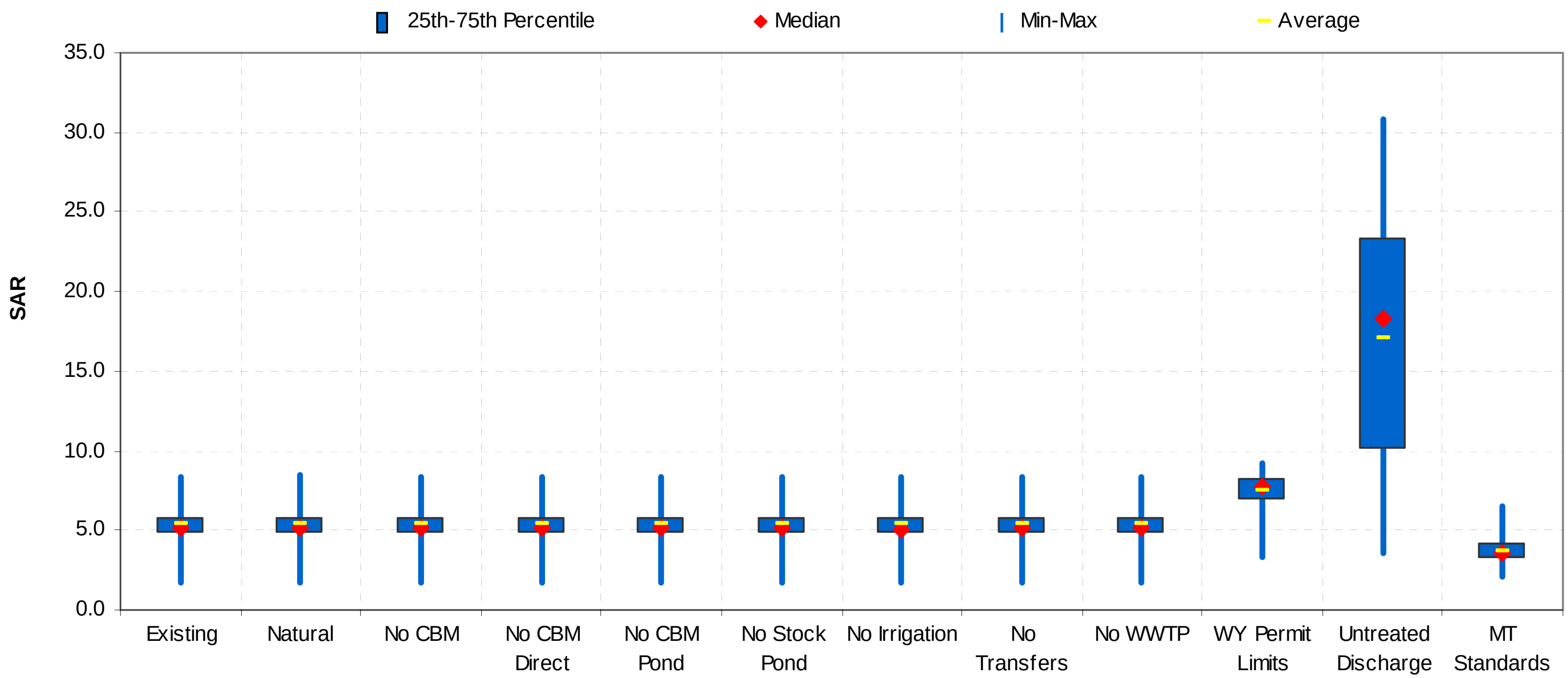


Figure J-11. Scenario results for SAR in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Table J-25. SAR statistics for various scenarios in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Inter-basin Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Standards 9c
75th Percentile	5.75	5.78	5.75	5.75	5.75	5.75	5.73	5.75	5.75	8.20	23.31	4.13
25th Percentile	4.79	4.78	4.81	4.79	4.81	4.79	4.74	4.79	4.79	6.84	10.13	3.20
Median	5.12	5.11	5.14	5.12	5.14	5.11	5.08	5.12	5.12	7.73	18.35	3.62
Average	5.38	5.39	5.39	5.38	5.39	5.38	5.35	5.38	5.38	7.48	17.06	3.74
Max	8.39	8.44	8.40	8.39	8.40	8.38	8.39	8.39	8.39	9.26	30.78	6.56
Min	1.71	1.69	1.72	1.71	1.72	1.70	1.69	1.71	1.71	3.32	3.51	2.05

Table J-26. Percentage of SAR exceedances per scenario in Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Evaluation Period	Season	Standard	Count of Values	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrig 6	No Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Standards 9c
Inst. Maximum	Growing Season	4.5	2450	94%	94%	94%	94%	94%	94%	94%	94%	94%	100%	100%	17%
	Nongrowing Season	7.5	1202	0%	0%	0%	0%	0%	0%	0%	0%	0%	47%	90%	0%
Monthly Average	Growing Season	3	80	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Nongrowing Season	5	40	25%	25%	25%	25%	25%	25%	23%	25%	25%	98%	100%	0%

Table J-27. Comparison of mean SAR values from various scenarios to the existing condition scenario, Hanging Woman Creek near the mouth (Modeling subbasin 1095).

Statistic	Existing 1	Natural 2	No CBM 4a	No CBM Direct 4b	No CBM Pond 4c	No Stock Pond 5	No Irrigation 6	No Transfers 7	No WWTP 8	WY Permit Limits 9a	Untreated Discharge 9b	MT Standards 9c
Mean SAR	5.38	5.39	5.39	5.38	5.39	5.38	5.35	5.38	5.38	7.48	17.06	3.74
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	No	No	No	No	No	No	No	No	Yes	Yes	Yes

[1]Means were compared using a Student's T-Test at an α of 0.05.

J.8 Tongue River Reservoir

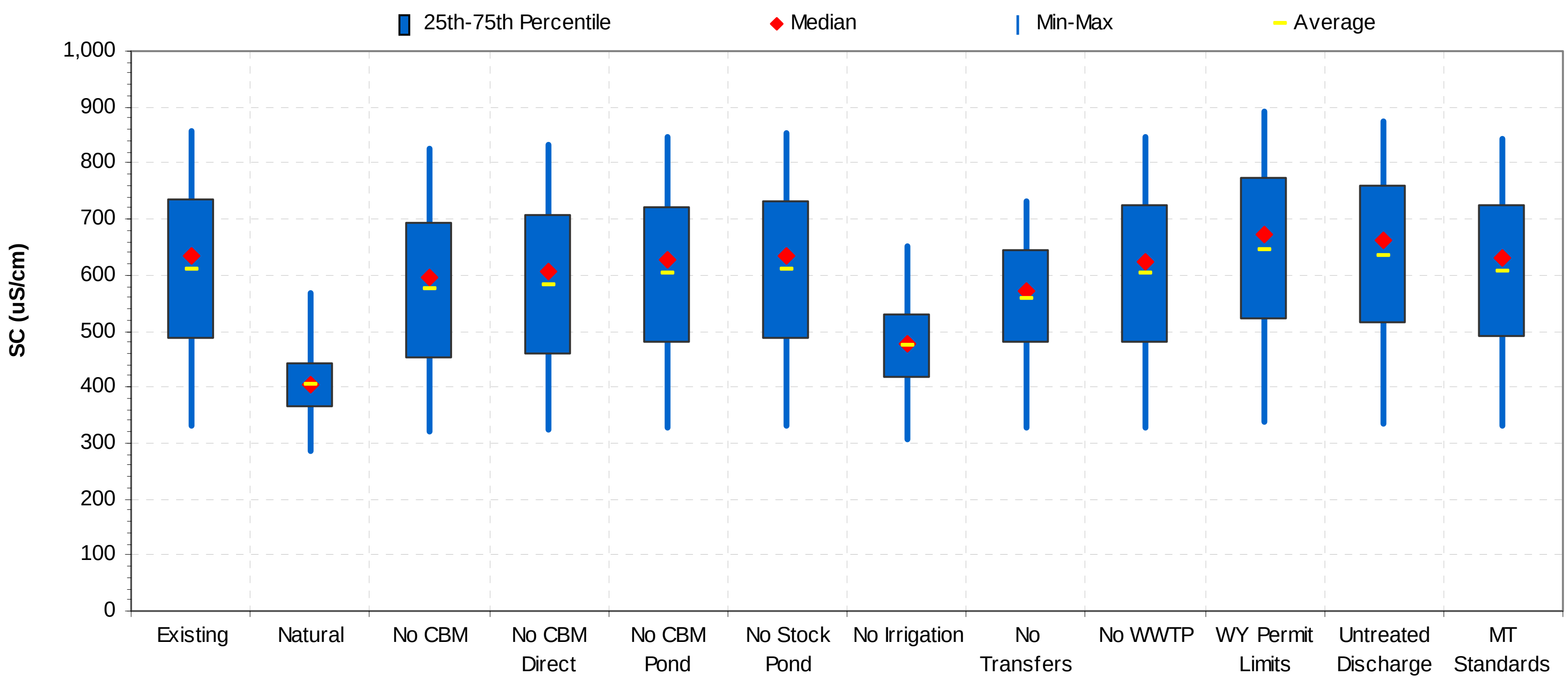


Figure J-12. Scenario results for salinity (specific conductance) in the Tongue River Reservoir (Modeling subbasin 3000).

Table J-28. SC (µS/cm) statistics for various scenarios in the Tongue River Reservoir (Modeling Subbasin 3000).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	734	443	694	706	721	732	531	643	724	774	761	725
25th Percentile	484	363	450	457	478	483	414	477	478	519	512	489
Median	634	404	597	605	626	633	478	571	625	672	661	631
Average	610	405	574	583	601	609	472	557	602	646	636	606
Max	855	567	825	833	847	853	651	732	846	893	876	844
Min	330	285	322	325	328	330	306	328	328	336	335	330

Table J-29. Percentage of SC exceedances per scenario in the Tongue River Reservoir (Modeling Subbasin 3000).

Evaluation Period	Season	Standard (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Instantaneous Maximum	Growing Season	1000	2450	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	1500	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	1000	80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	1500	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table J-30. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Tongue River Reservoir (Modeling Subbasin 3000).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	610	405	574	583	601	609	472	557	602	646	636	606
Mean SC Differs From Existing Condition Mean SC?[1]	NA	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

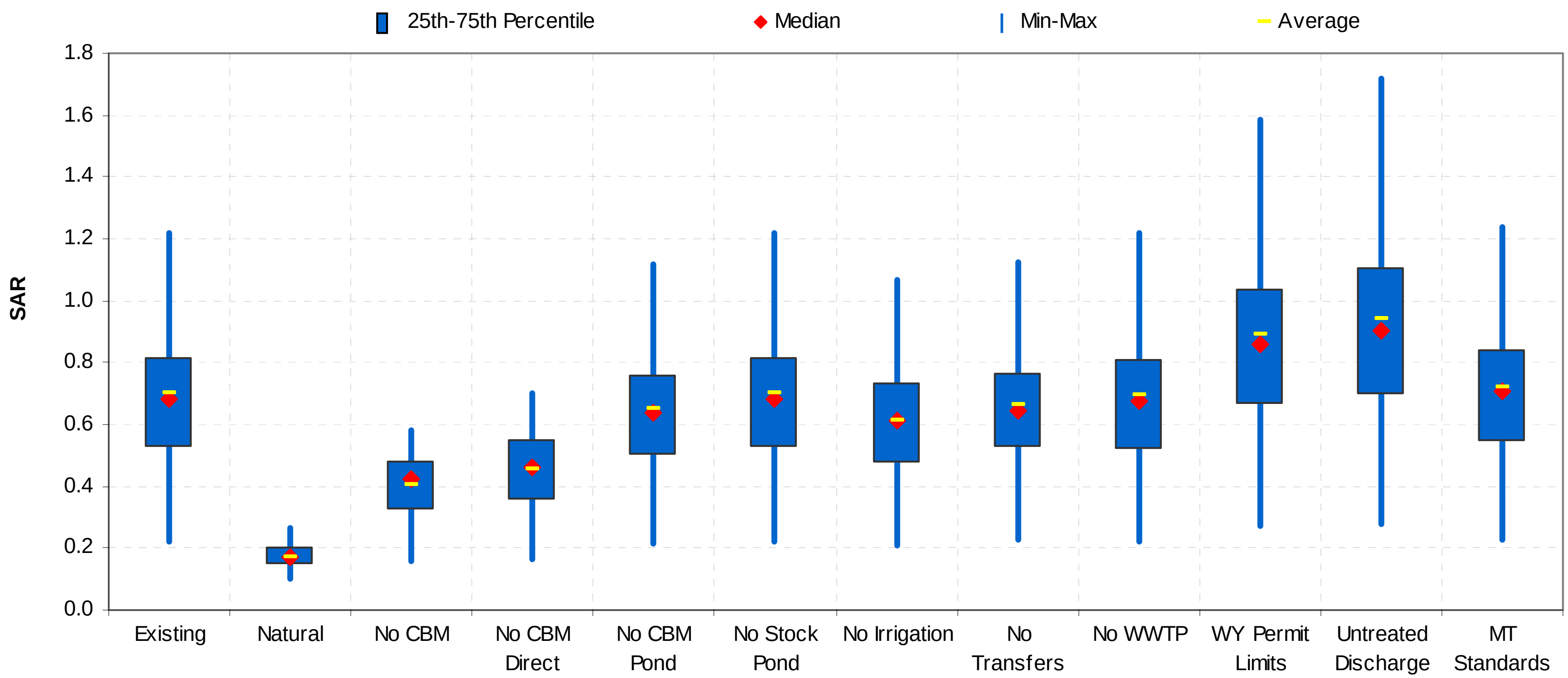


Figure J-13. Scenario results for SAR in the Tongue River Reservoir (Modeling subbasin 3000).

Table J-31. SAR statistics for various scenarios in the Tongue River Reservoir (Modeling Subbasin 3000).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	0.82	0.20	0.48	0.55	0.76	0.81	0.74	0.76	0.81	1.03	1.10	0.84
25th Percentile	0.52	0.15	0.32	0.36	0.50	0.52	0.47	0.52	0.52	0.66	0.69	0.54
Median	0.68	0.17	0.42	0.46	0.64	0.68	0.61	0.65	0.67	0.86	0.90	0.71
Average	0.70	0.17	0.40	0.45	0.65	0.70	0.61	0.66	0.69	0.89	0.94	0.72
Max	1.22	0.27	0.58	0.70	1.12	1.22	1.07	1.12	1.22	1.58	1.72	1.24
Min	0.22	0.10	0.16	0.17	0.21	0.22	0.21	0.23	0.22	0.27	0.28	0.23

Table J-32. Percentage of SAR exceedances per scenario in the Tongue River Reservoir (Modeling Subbasin 3000).

Evaluation Period	Season	Standard (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Instantaneous Maximum	Growing Season	4.5	2450	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	7.5	1202	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Monthly Average	Growing Season	3	80	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Nongrowing Season	5	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table J-33. Comparison of mean SAR values from various scenarios to the existing condition scenario, Tongue River Reservoir (Modeling Subbasin 3000).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SAR	0.70	0.17	0.40	0.45	0.65	0.70	0.61	0.66	0.69	0.89	0.94	0.72
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No

[1]Means were compared using a Student's T-Test at an α of 0.05.

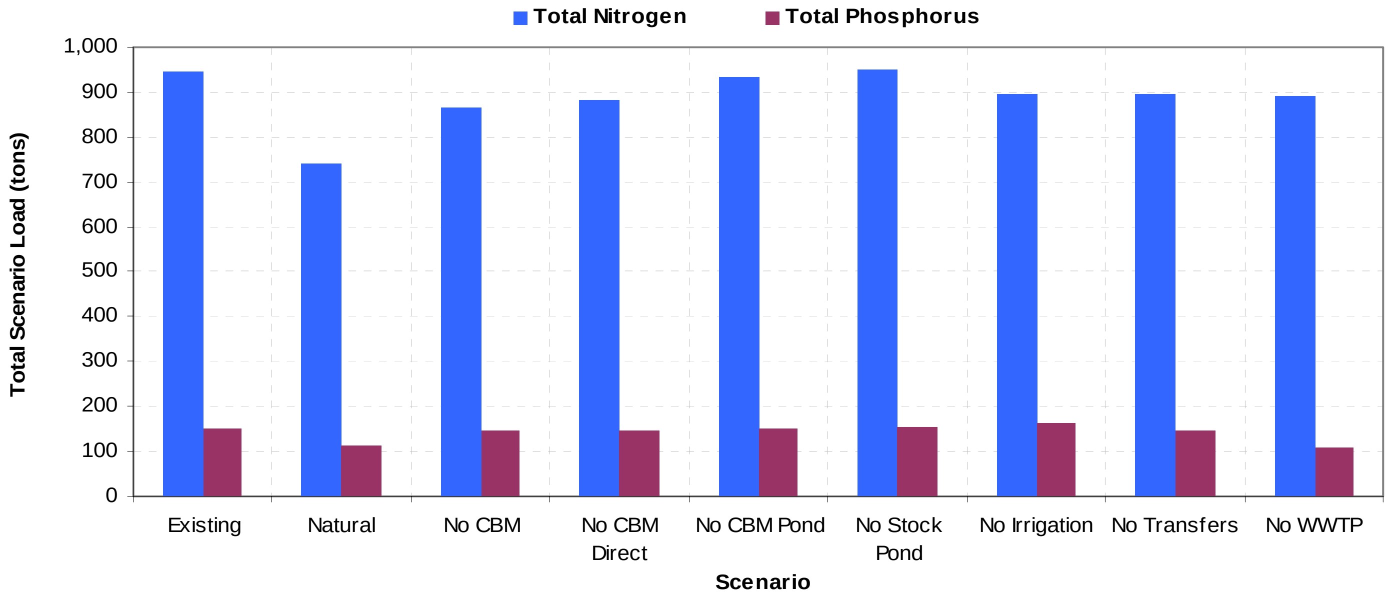


Figure J-14. Scenario results for total nitrogen and total phosphorus loads to the Tongue River Reservoir from upstream sources (Modeling subbasin 3001).

Table J-34. Upstream total nitrogen and total phosphorus daily loading statistics for various scenarios in the Tongue River Reservoir (Modeling Subbasin 3001) (pounds per day).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP
	1	2	4a	4b	4c	5	6	7	8
75th Percentile	464	331	422	428	458	466	423	433	427
25th Percentile	208	104	165	172	200	208	179	188	188
Median	303	161	259	267	295	304	247	284	270
Average	518	405	475	482	511	520	490	490	488
Max	10,170	10,259	10,114	10,132	10,152	10,356	10,355	10,165	10,153
Min	47	31	15	15	46	47	81	46	46

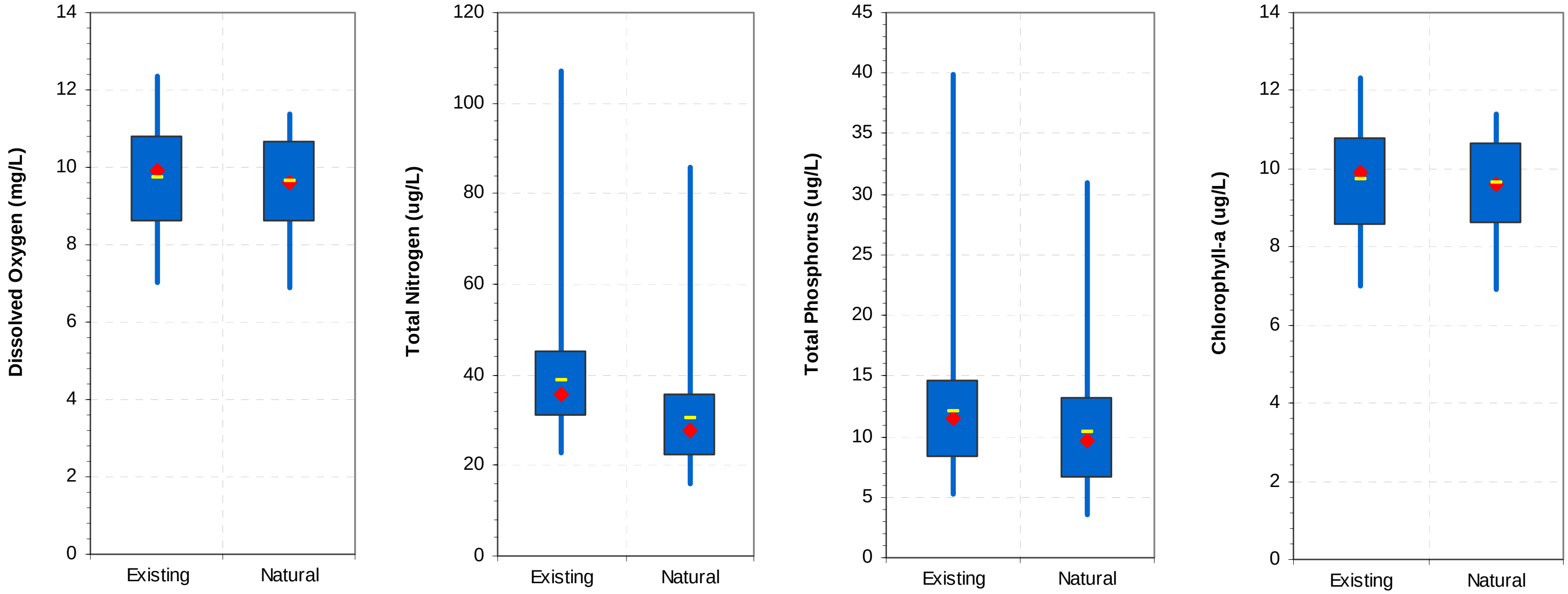


Table J-35. Modeling existing versus natural dissolved oxygen, total nitrogen, total phosphorus, and chlorophyll-*a* concentrations in the Tongue River Reservoir near the dam (surface layer).

J.9 Otter Creek near the Mouth

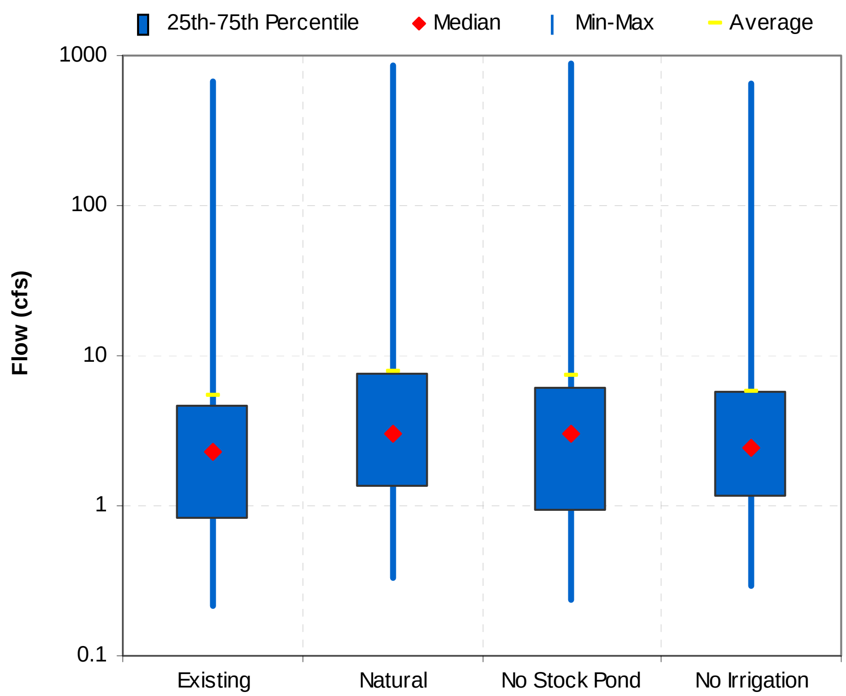


Figure J-15. Scenario results for flow in Otter Creek near the mouth (Modeling subbasin 1059).

Table J-36. Flow statistics for various scenarios in Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	4.7	7.6	NA	NA	NA	6.1	5.8	NA	NA	NA	NA	NA
25th Percentile	0.8	1.3	NA	NA	NA	0.9	1.1	NA	NA	NA	NA	NA
Median	2.3	3.0	NA	NA	NA	3.0	2.4	NA	NA	NA	NA	NA
Average	5.4	7.7	NA	NA	NA	7.3	5.8	NA	NA	NA	NA	NA
Max	668.1	857.5	NA	NA	NA	873.8	654.4	NA	NA	NA	NA	NA
Min	0.2	0.3	NA	NA	NA	0.2	0.3	NA	NA	NA	NA	NA

Table J-37. Comparison of mean flow (cfs) values from various scenarios to the existing condition scenario, Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean Flow (cfs)	5.4	7.7	NA	NA	NA	7.3	5.8	NA	NA	NA	NA	NA
Mean Flow Differs From Existing Condition Mean Flow?[1]	NA	Yes	NA	NA	NA	Yes	No	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

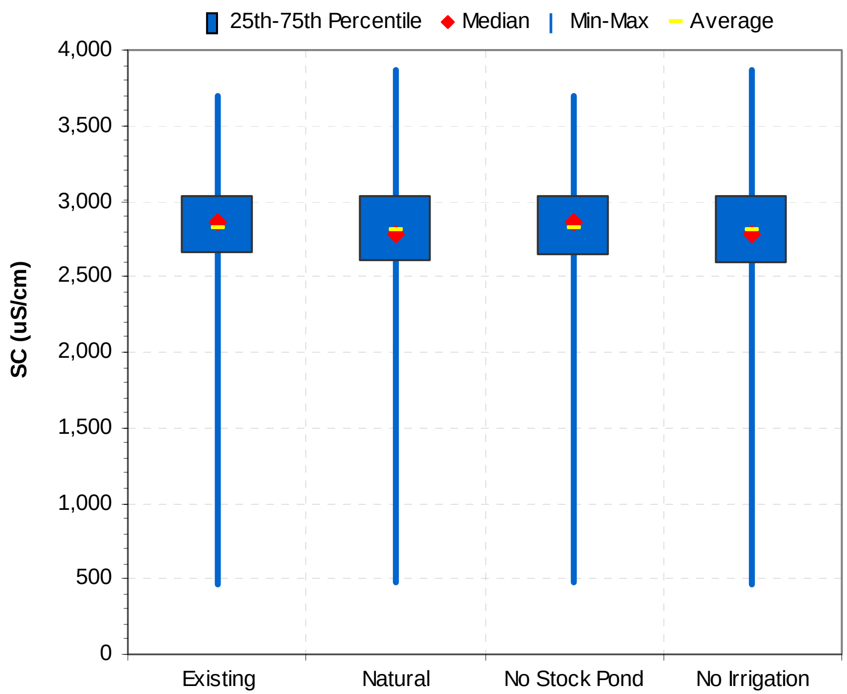


Figure J-16. Scenario results for salinity (specific conductance) in Otter Creek near the mouth (Modeling subbasin 1059).

Table J-38. SC (µS/cm) statistics for various scenarios in Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	3,033	3,035	NA	NA	NA	3,032	3,034	NA	NA	NA	NA	NA
25th Percentile	2,643	2,591	NA	NA	NA	2,640	2,589	NA	NA	NA	NA	NA
Median	2,864	2,780	NA	NA	NA	2,860	2,781	NA	NA	NA	NA	NA
Average	2,825	2,806	NA	NA	NA	2,824	2,805	NA	NA	NA	NA	NA
Max	3,697	3,862	NA	NA	NA	3,689	3,866	NA	NA	NA	NA	NA
Min	468	479	NA	NA	NA	479	467	NA	NA	NA	NA	NA

Table J-39. Percentage of SC exceedances per scenario in Otter Creek near the mouth (Modeling subbasin 1059).

Evaluation Period	Season	Std (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrig	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Inst. Maximum	Growing Season	500	2450	99.7%	99.8%	NA	NA	NA	99.7%	99.7%	NA	NA	NA	NA	NA
	Nongrowing Season	500	1202	81.9%	77.4%	NA	NA	NA	81.9%	81.9%	NA	NA	NA	NA	NA
Monthly Average	Growing Season	500	80	100.0%	100.0%	NA	NA	NA	100.0%	100.0%	NA	NA	NA	NA	NA
	Nongrowing Season	500	40	100.0%	100.0%	NA	NA	NA	100.0%	100.0%	NA	NA	NA	NA	NA

Table J-40. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	2,825	2,806	NA	NA	NA	2,824	2,805	NA	NA	NA	NA	NA
Mean SC Differs From Existing Condition Mean SC?[1]	NA	Yes	NA	NA	NA	No	Yes	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

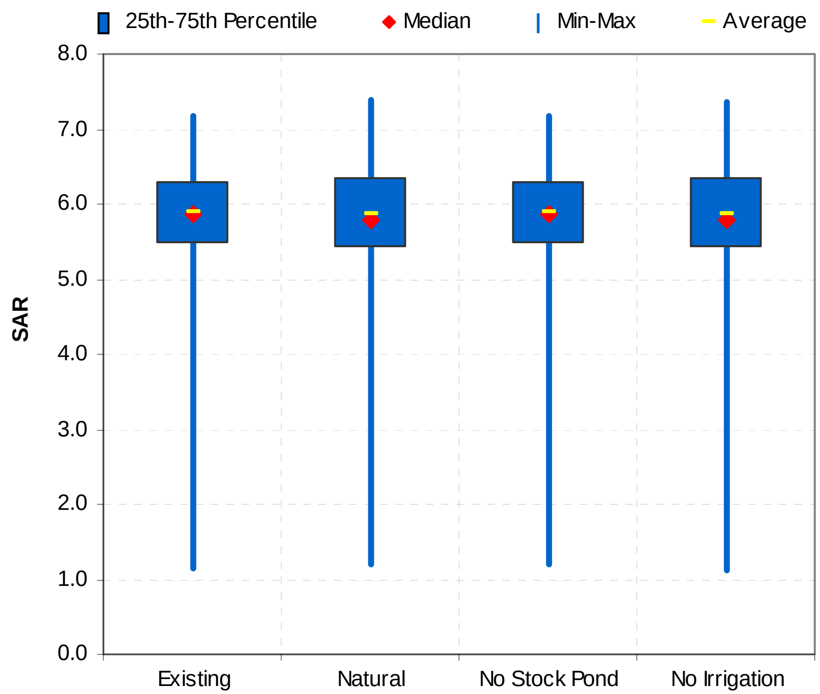


Figure J-17. Scenario results for SAR in Otter Creek near the mouth (Modeling subbasin 1059).

Table J-41. SAR statistics for various scenarios in Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	6.30	6.34	NA	NA	NA	6.30	6.34	NA	NA	NA	NA	NA
25th Percentile	5.48	5.41	NA	NA	NA	5.47	5.41	NA	NA	NA	NA	NA
Median	5.87	5.78	NA	NA	NA	5.86	5.78	NA	NA	NA	NA	NA
Average	5.89	5.86	NA	NA	NA	5.89	5.86	NA	NA	NA	NA	NA
Max	7.16	7.38	NA	NA	NA	7.18	7.37	NA	NA	NA	NA	NA
Min	1.14	1.20	NA	NA	NA	1.21	1.13	NA	NA	NA	NA	NA

Table J-42. Percentage of SAR exceedances per scenario in Otter Creek near the mouth (Modeling subbasin 1059).

Evaluation Period	Season	Standard	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrig	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Inst. Maximum	Growing Season	4.5	2450	99%	99%	NA	NA	NA	99%	99%	NA	NA	NA	NA	NA
	Nongrowing Season	7.5	1202	0%	0%	NA	NA	NA	0%	0%	NA	NA	NA	NA	NA
Monthly Average	Growing Season	3	80	100%	100%	NA	NA	NA	100%	100%	NA	NA	NA	NA	NA
	Nongrowing Season	5	40	98%	98%	NA	NA	NA	98%	98%	NA	NA	NA	NA	NA

Table J-43. Comparison of mean SAR values from various scenarios to the existing condition scenario, Otter Creek near the mouth (Modeling subbasin 1059).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SAR	5.89	5.86	NA	NA	NA	5.89	5.86	NA	NA	NA	NA	NA
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	Yes	NA	NA	NA	No	Yes	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

J.10 Pumpkin Creek

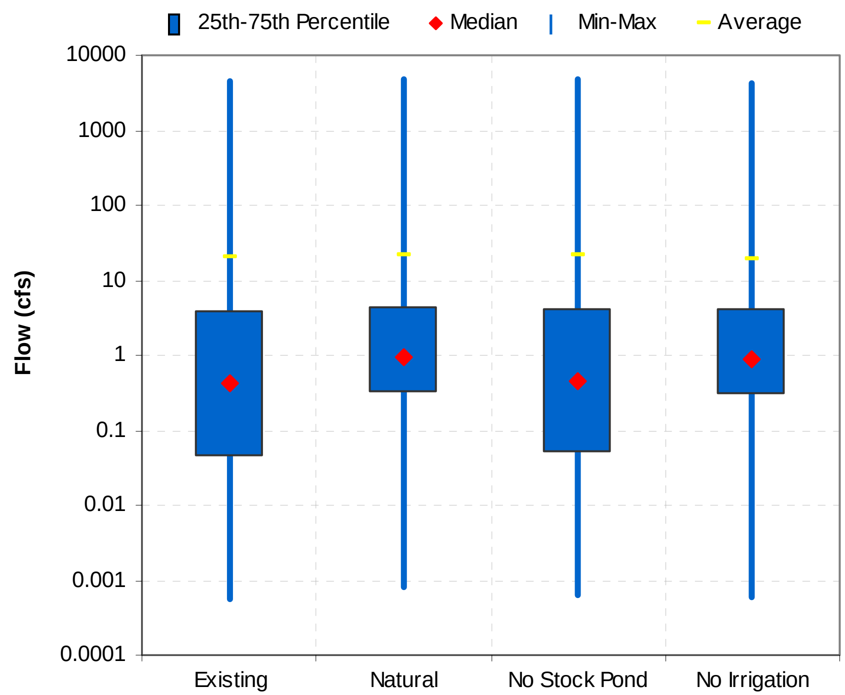


Figure J-18. Scenario results for flow in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Table J-44. Flow statistics for various scenarios in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	3.8	4.4	NA	NA	NA	4.1	4.0	NA	NA	NA	NA	NA
25th Percentile	0.0	0.3	NA	NA	NA	0.0	0.3	NA	NA	NA	NA	NA
Median	0.4	0.9	NA	NA	NA	0.4	0.9	NA	NA	NA	NA	NA
Average	20.1	21.4	NA	NA	NA	22.0	19.4	NA	NA	NA	NA	NA
Max	4,397.1	4,886.3	NA	NA	NA	4,933.5	4,350.3	NA	NA	NA	NA	NA
Min	0.0	0.0	NA	NA	NA	0.0	0.0	NA	NA	NA	NA	NA

Table J-45. Comparison of mean flow (cfs) values from various scenarios to the existing condition scenario, Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean Flow (cfs)	20.1	21.4	NA	NA	NA	22.0	19.4	NA	NA	NA	NA	NA
Mean Flow Differs From Existing Condition Mean Flow?[1]	NA	No	NA	NA	NA	No	No	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

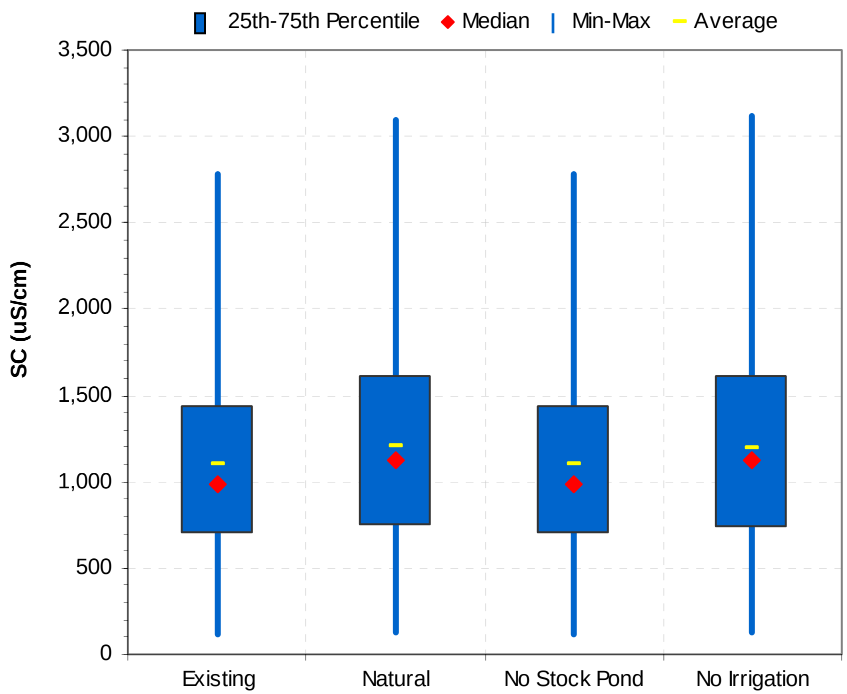


Figure J-19. Scenario results for salinity (specific conductance) in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Table J-46. SC (µS/cm) statistics for various scenarios in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	1,435	1,607	NA	NA	NA	1,433	1,611	NA	NA	NA	NA	NA
25th Percentile	693	739	NA	NA	NA	695	736	NA	NA	NA	NA	NA
Median	985	1,126	NA	NA	NA	987	1,121	NA	NA	NA	NA	NA
Average	1,103	1,200	NA	NA	NA	1,102	1,197	NA	NA	NA	NA	NA
Max	2,786	3,099	NA	NA	NA	2,778	3,122	NA	NA	NA	NA	NA
Min	121	122	NA	NA	NA	121	122	NA	NA	NA	NA	NA

Table J-47. Percentage of SC exceedances per scenario in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Evaluation Period	Season	Std (µS/cm)	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrig	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Stnd.
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Inst. Maximum	Growing Season	500	2450	86.8%	88.5%	NA	NA	NA	86.9%	88.3%	NA	NA	NA	NA	NA
	Nongrowing Season	500	1202	86.6%	84.9%	NA	NA	NA	86.4%	84.9%	NA	NA	NA	NA	NA
Monthly Average	Growing Season	500	80	96.3%	95.0%	NA	NA	NA	96.3%	95.0%	NA	NA	NA	NA	NA
	Nongrowing Season	500	40	90.0%	87.5%	NA	NA	NA	90.0%	87.5%	NA	NA	NA	NA	NA

Table J-48. Comparison of mean SC (µS/cm) values from various scenarios to the existing condition scenario, Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SC (µS/cm)	1,103	1,200	NA	NA	NA	1,102	1,197	NA	NA	NA	NA	NA
Mean SC Differs From Existing Condition Mean SC?[1]	NA	Yes	NA	NA	NA	No	Yes	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

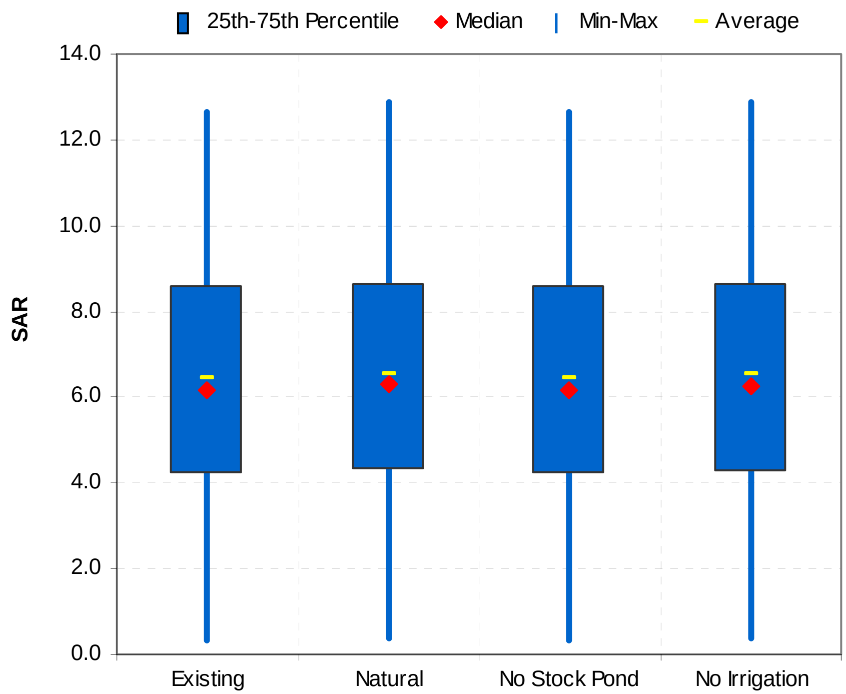


Figure J-20. Scenario results for SAR in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Table J-49. SAR statistics for various scenarios in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Inter-basin Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
75th Percentile	8.61	8.65	NA	NA	NA	8.59	8.65	NA	8.61	NA	NA	NA
25th Percentile	4.21	4.27	NA	NA	NA	4.22	4.26	NA	4.21	NA	NA	NA
Median	6.18	6.28	NA	NA	NA	6.16	6.26	NA	6.18	NA	NA	NA
Average	6.44	6.55	NA	NA	NA	6.43	6.54	NA	6.44	NA	NA	NA
Max	12.67	12.86	NA	NA	NA	12.64	12.86	NA	12.67	NA	NA	NA
Min	0.31	0.39	NA	NA	NA	0.32	0.39	NA	0.31	NA	NA	NA

Table J-50. Percentage of SAR exceedances per scenario in Pumpkin Creek near the mouth (Modeling subbasin 1007).

Evaluation Period	Season	Standard	Count of Values	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrig	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
				1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Inst. Maximum	Growing Season	4.5	2450	71%	73%	NA	NA	NA	71%	73%	NA	NA	NA	NA	NA
	Nongrowing Season	7.5	1202	53%	51%	NA	NA	NA	53%	51%	NA	NA	NA	NA	NA
Monthly Average	Growing Season	3	80	100%	100%	NA	NA	NA	100%	100%	NA	NA	NA	NA	NA
	Nongrowing Season	5	40	73%	73%	NA	NA	NA	73%	73%	NA	NA	NA	NA	NA

Table J-51. Comparison of mean SAR values from various scenarios to the existing condition scenario, Pumpkin Creek near the mouth (Modeling subbasin 1007).

Statistic	Existing	Natural	No CBM	No CBM Direct	No CBM Pond	No Stock Pond	No Irrigation	No Transfers	No WWTP	WY Permit Limits	Untreated Discharge	MT Standards
	1	2	4a	4b	4c	5	6	7	8	9a	9b	9c
Mean SAR	6.44	6.55	NA	NA	NA	6.43	6.54	NA	NA	NA	NA	NA
Mean SAR Differs From Existing Condition Mean SAR?[1]	NA	Yes	NA	NA	NA	No	No	NA	NA	NA	NA	NA

[1]Means were compared using a Student's T-Test at an α of 0.05.

APPENDIX K – COMPARISON OF GREAT PLAINS STREAMS WATER CHEMISTRY DATA

K.0 COMPARISON OF GREAT PLAINS STREAMS WATER CHEMISTRY DATA

This appendix presents the results of a comparison of selected water quality data in prairie streams in the Northwestern Great Plains ecoregion in Montana, Wyoming, North Dakota, and South Dakota. The purpose of this analysis was to compare water quality concentrations in Hanging Woman Creek, Otter Creek, Pumpkin Creek, and the Tongue River to concentrations sampled at similar streams in neighboring watersheds. 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.

K.1 Tributaries to the Tongue River

The primary factor considered while selecting the streams was the ecoregional setting and type of watershed. An ecoregion map (USEPA, 2007) for the states of Montana, Wyoming, North Dakota, and South Dakota was used to differentiate prairie streams from mountainous streams (Figure K-1). The ecoregion coverage was also used to compare climate and elevation for each stream. Streams in the Tongue River watershed presented in the analysis include Pumpkin Creek, Otter Creek, Hanging Woman Creek, and Squirrel Creek (Figure K-2). Streams selected from adjacent watersheds include Sarpy Creek, Armells Creek, Cherry Creek, Beaver Creek, O'Fallon Creek, Donkey Creek, Belle Fourche River, Black Thunder Creek, Mizpah Creek, Little Powder River, Rosebud Creek, and Antelope Creek (Figure K-2). These streams were selected on the premise that they receive similar amounts of precipitation, their watersheds are entirely located in the Northwestern Great Plains ecoregion (including their headwaters), and they are prairie type streams with a similar drainage area to Hanging Woman Creek, Otter Creek, and/or Pumpkin Creek.

Water quality data for the analysis was acquired from the United States Geological Survey (USGS) National Water Information System (NWIS). Stations with the greatest numbers of samples and sampling period were selected for each stream listed above. Table K-1 lists stations used in this analysis, sampling period of record, station location information, drainage area, and elevation. Additionally, Table K-2 provides a list of parameters evaluated. Data for multiple parameters with the same group name were assumed to approximate the same parameter and were combined. Table K-3 through Table K-12 and Figure K-3 through Figure K-13 present a summary of statistics and box plots of data for all stations and parameter groups.

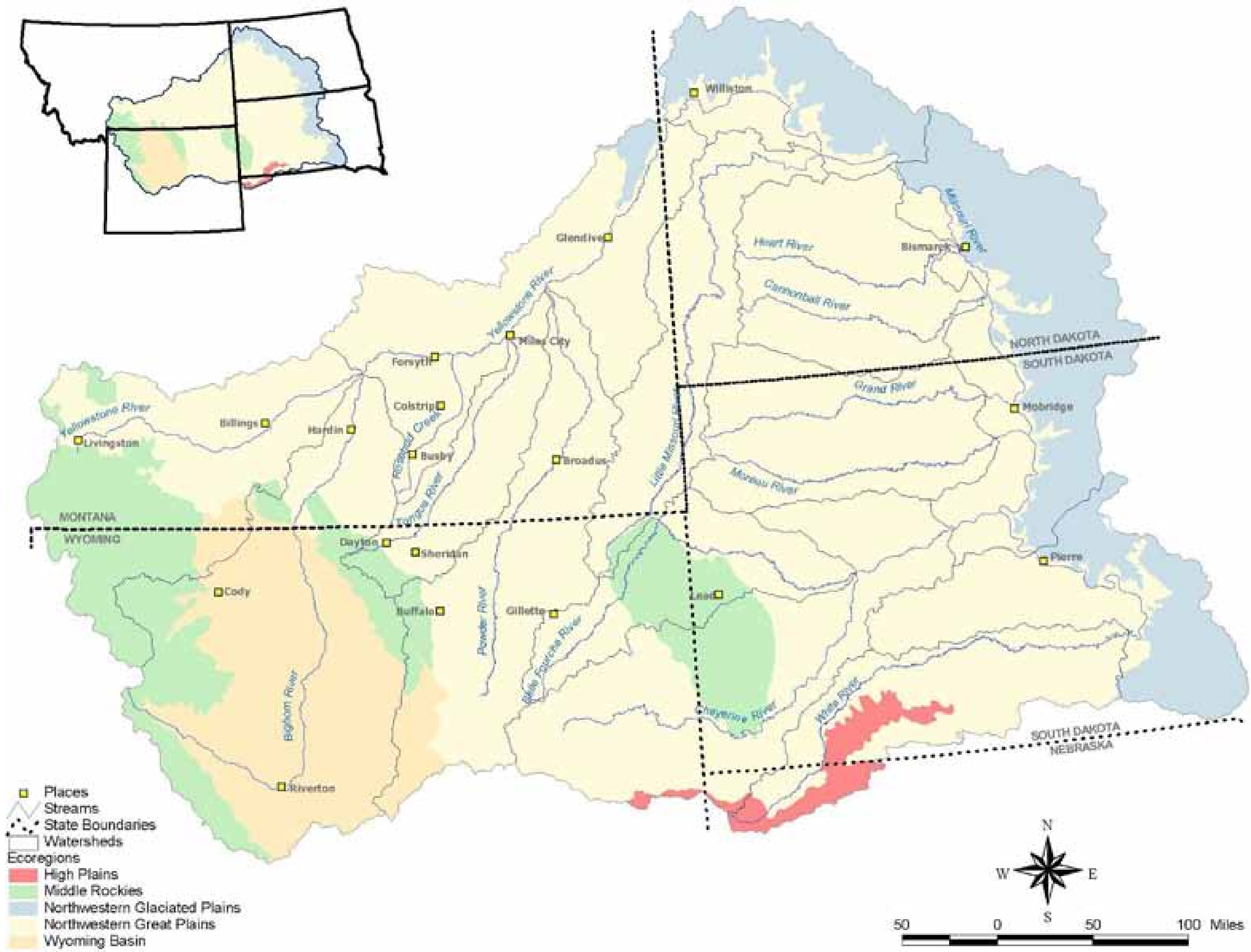


Figure K-1. Montana, Wyoming, North Dakota, and South Dakota ecoregions.

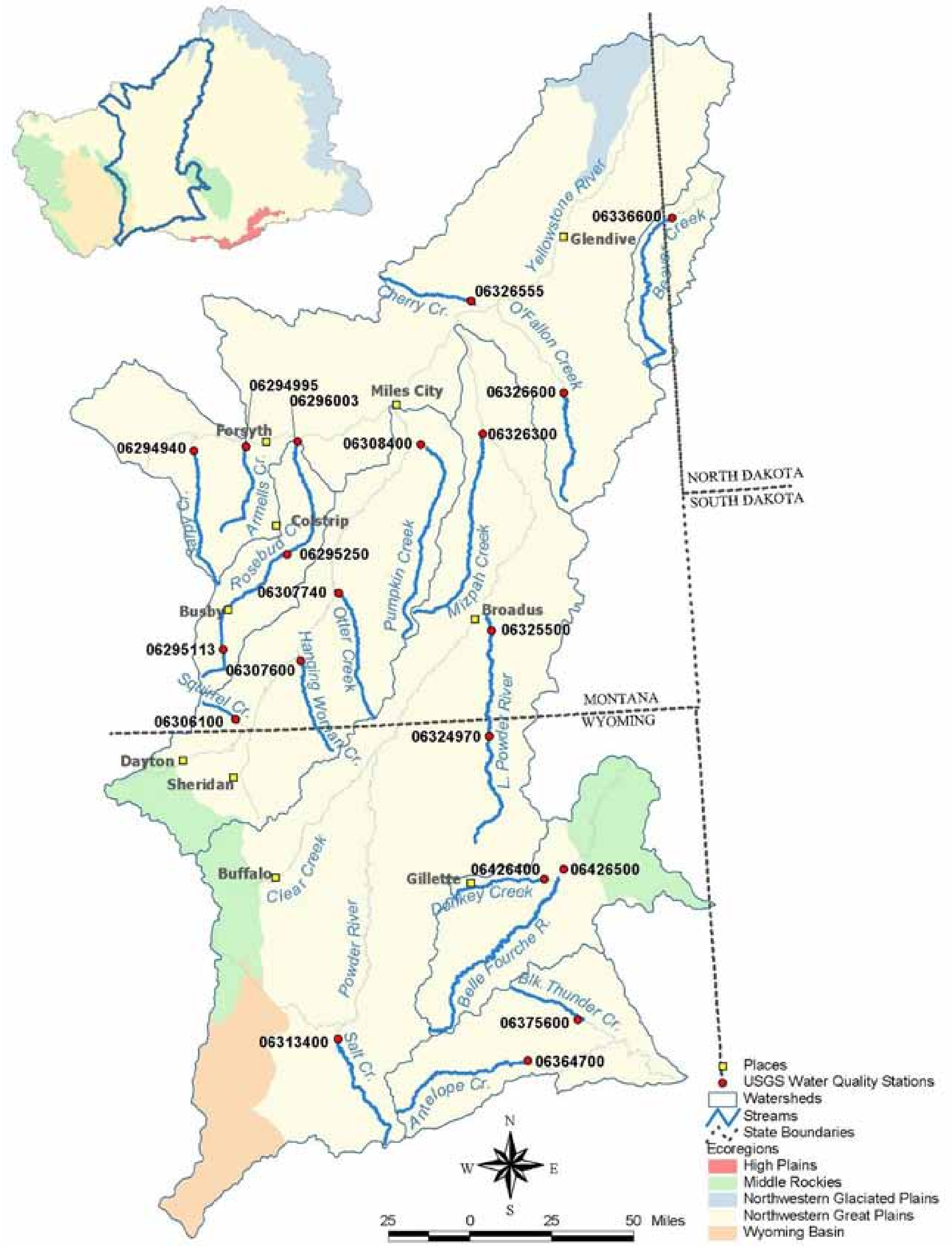


Figure K-2. Location of selected Prairie streams and USGS water quality gages.

Table K-1. USGS sampling stations, location information, and period of sampling.

Station ID	Location	Begin Date	End Date	State	HUC	Latitude	Longitude	Drainage Area	Altitude (meters)
06294940	Sarpy Creek near Hysham, MT	12/3/1974	6/28/1984	MT	10100001	46.2386	-107.1373	453	2,680
06294995	Armells Creek near Forsyth, MT	10/8/1974	8/22/1995	MT	10100001	46.2497	-106.8067	370	2,560
06295113	Rosebud Creek at Reservation Boundary near Kirby, MT	10/1/1979	7/13/2004	MT	10100003	45.3611	-106.9903	123	3,780
06295250	Rosebud Creek near Colstrip, MT	10/9/1974	10/1/2003	MT	10100003	45.7675	-106.5700	799	3,000
06296003	Rosebud Creek at mouth near Rosebud, MT	10/10/1974	10/1/2003	MT	10100003	46.2647	-106.4756	1,302	2,480
06307600	Hanging Woman Cr. nr Birney, MT	10/2/1974	6/22/2004	MT	10090101	45.2992	-106.5084	470	3,150
06307740	Otter Creek at Ashland, MT	10/2/1974	8/18/2004	MT	10090102	45.5883	-106.2553	707	2,916
06308400	Pumpkin Creek near Miles City, MT	10/15/1975	8/2/1985	MT	10090102	46.2283	-105.6906	697	2,490
06313400	Salt Creek near Sussex, WY	10/9/1967	9/22/2003	WY	10090204	43.6219	-106.3684	769	4,480
06324970	Little Powder River above Dry Creek near Weston, WY	1/8/1975	9/16/2003	WY	10090208	44.9269	-105.3533	1,237	3,410
06325500	Little Powder River near Broadus, MT	8/30/1978	9/3/2003	MT	10090208	45.3903	-105.3047	1974	3,020
06326300	Mizpah Creek near Mizpah, MT	10/17/1975	9/30/2003	MT	10090210	46.2608	-105.2933	797	2,490
06326555	Cherry Creek near Terry, MT	10/9/1977	6/9/1994	MT	10100004	46.8500	-105.3247	357	2,301
06326600	O'Fallon Creek near Ismay, MT	10/24/1977	4/21/1992	MT	10100005	46.4214	-104.7616	669	2,590
06336600	Beaver Creek near Trotters, ND	2/29/1948	8/20/2003	ND	10110204	47.1631	-103.9927	616	2,370
06364700	Antelope Creek near Teckla, WY	10/3/1977	9/8/2003	WY	10120101	43.4853	-105.2253	959	NA
06375600	Little Thunder Creek near Hampshire, WY	9/30/1977	5/28/1997	WY	10120103	43.6550	-104.9092	234	4,400
06426400	Donkey Creek near Moorcroft, WY	9/29/1977	9/9/2003	WY	10120201	44.2828	-105.0639	236	NA
06426500	Belle Fourche River near Moorcroft, WY	9/22/1972	9/8/2003	Wy	10120201	44.3219	-104.9405	1690	4110

Table K-2. USGS Parameters and Parameter Groupings.

Group	USGS Parameter Code	Parameter Name
Calcium	915	Calcium, Dissolved (mg/L as Ca)
Chloride	940	Chloride, Dissolved (mg/L as Cl)
Chlorophyll a	70953	Chlorophyll A, Phytoplankton, Chromotographic- Fluorometric (mg/L)
Chlorophyll a	70954	Chlorophyll B, Phytoplankton, Chromotographic- Fluorometric (μg/L)
Dissolved Oxygen	300	Oxygen, Dissolved (mg/L)
Dissolved Phosphorus	666	Phosphorus, Dissolved (mg/L as P)
Hardness	900	Hardness, Total (mg/L as Ca03)
Magnesium	925	Magnesium, Dissolved (mg/L as Mg)
Nitrate	618	Nitrogen, Nitrate, Dissolved (Mg/L As N)
Nitrate	620	Nitrogen, Nitrate, Total (mg/L as N)
Nitrate	71851	Nitrogen, Nitrate, Dissolved (mg/L As No3)
Nitrate + Nitrite	630	Nitrogen, Nitrite Plus Nitrate, Total (mg/L as N)
Nitrate + Nitrite	631	Nitrogen, Nitrite Plus Nitrate, Dissolved (Mg/L As N)
Nitrite	613	Nitrogen, Nitrite, Dissolved, mg/L As N
Nitrite	615	Nitrogen, Nitrite, Total (mg/L as N)
Nitrite	71856	Nitrogen, Nitrite, Dissolved (mg/L as No2)
SAR	931	Sodium Adsorption Ratio
Sodium	930	Sodium, Dissolved (mg/L as Na)
Specific Conductance	94	Specific Conductance, Field (μS/cm at 25 Degrees Celsius)
Specific Conductance	95	Specific Conductance, Field (μS/cm at 25 Degrees Celsius)
Specific Conductance	90094	Specific Conductance, Area Weighted Average (μS/cm at 25 Degrees Celsius)
Specific Conductance	90095	Specific Conductance, Lab (μS/cm at 25 Degrees Celsius)
SRP	660	Phosphate, Ortho, Dissolved (mg/L as Po4)
SRP	671	Phosphorus, Orthophosphate, Dissolved (mg/L as P)
SRP	70507	Phosphorus, Orthophosphate, Total (mg/L as P)
Sulfate	945	Sulfate, Dissolved (mg/L as So4)
Temperature	10	Temperature, Water, (Degrees Celsius)
TKN	605	Nitrogen, Organic, Total (mg/L as N)
TKN	625	Nitrogen, Ammonia Plus Organic, Total (mg/L as N)
TN	600	Nitrogen, Total (mg/L as N)
TN	71887	Nitrogen, Total (mg/L as NO3)
TP	665	Phosphorus, Total (mg/L as P)
TP	669	Phosphorus, Hydrolyzable, Total (mg/L as P)
TP	678	Phosphorus, Hydrolizable Plus Ortho, Total (mg/L as P)
TP	71886	Phosphorus, Total (mg/L as PO4)
TSS	500	Solids, Residue on Total Evaporation at 105 Degrees Celsius (mg/L)
TSS	530	Residue, Total Non Filterable (mg/L)
TSS	70299	Solids, Residue at 110 Deg. C, Suspended, Total (mg/L)
TSS	80154	Suspended Sediment Concentration (mg/L)
Turbidity	70	Turbidity (Jackson Candle Units)
Turbidity	76	Turbidity (NTU)

Table K-3. TSS and SSC sampling period of record and summary statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	12/10/1979	5/12/2004	49	24	84	463	66
Powder	L. Powder R. near Weston, WY	06324890	182	6/3/1975	8/12/1983	58	1	71	1,120	151
Cheyenne	L. Thunder Cr.	06375600	234	9/30/1977	5/28/1997	63	17	985	9,350	1,925
Belle Fourche	Donkey Cr.	06426400	236	9/29/1977	6/9/1981	58	11	382	6,040	938
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	6/9/1994	64	6	643	16,900	2,428
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	133	13	145	1,860	216
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	75	4	83	416	82
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**10/2/1974**	**6/22/2004**	**159**	**4**	**86**	**650**	**91**
Little Missouri	Beaver Cr.	06336600	616	10/14/1977	7/8/1981	56	14	175	2,560	388
Lower Yellowstone	O'fallon Cr.	06326600	669	10/24/1977	6/27/1984	66	26	223	4,390	537
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**7/31/1985**	**57**	**9**	**2,195**	**27,100**	**5,458**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**7/13/2004**	**161**	**2**	**93**	**536**	**74**
Powder	Salt Cr.	06313400	769	12/10/1975	10/15/1987	114	61	5,300	88,200	13,428
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	73	14	2,100	25,900	4,706
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	100	5	158	1,040	204
Cheyenne	Antelope Cr.	06364700	959	10/3/1977	8/11/1981	51	5	110	1,130	176
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	1/8/1975	9/16/2003	190	8	993	19,400	2,734
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	10/1/2003	148	4	686	21,600	2,303
Belle Fourche	Belle Fourche R.	06426500	1,690	2/10/1976	10/19/1999	103	9	684	10,500	1,655
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	7/26/1988	9/3/2003	24	48	141	388	75

303(d) listed streams in the Tongue River watershed are in bold.

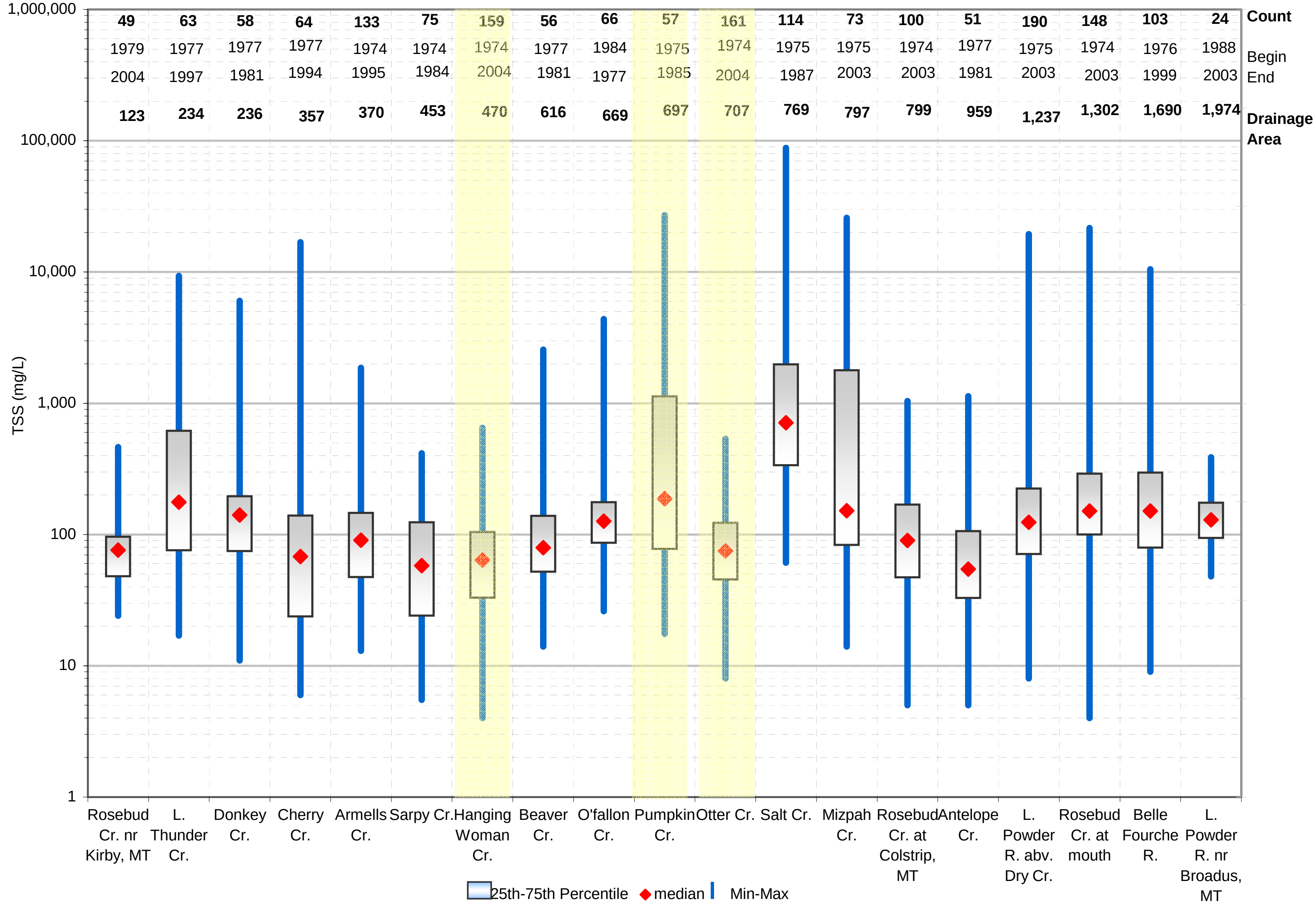


Figure K-3. TSS and SSC box plot.

Turbidity sampling period of record and summary statistics (NTU).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	9/25/2003	9/25/2003	1	5	5	5	
Cheyenne	L. Thunder Cr.	06375600	234	9/27/1980	6/3/1991	3	15	1,555	4,500	2,551
Belle Fourche	Donkey Cr.	06426400	236	6/8/1978	9/19/1983	17	1	37	180	41
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/8/1978	11	1	61	450	132
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	9/5/1978	42	1	72	780	146
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/8/1978	31	2	30	280	52
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**11/7/1974**	**10/2/2003**	**52**	**2**	**49**	**400**	**87**
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**9/13/1978**	**22**	**7**	**1,046**	**11,000**	**2,589**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**10/2/2003**	**51**	**1**	**49**	**999**	**143**
Powder	Salt Cr.	06313400	769	12/10/1975	3/11/1981	10	20	543	2,600	871
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/30/2003	29	5	1,015	9,500	2,119
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	49	3	77	600	130
Cheyenne	Antelope Cr.	06364700	959	4/10/1980	4/10/1980	1	5	5	5	
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	5/7/2002	133	1	268	5,500	919
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	10/1/2003	50	3	240	2,500	522
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	8/18/1993	92	2	183	4,600	556

303(d) listed streams in the Tongue River watershed are in bold.

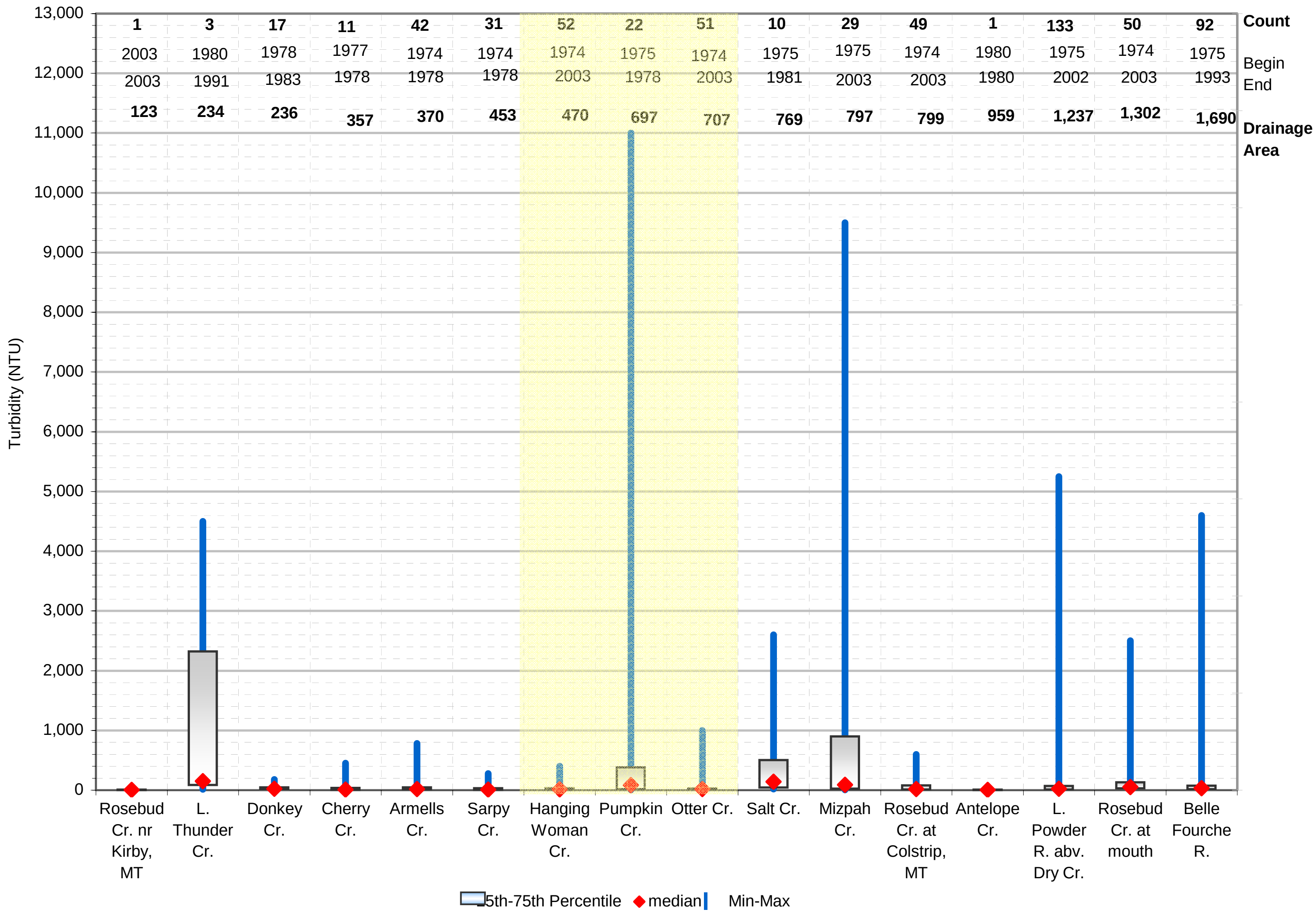
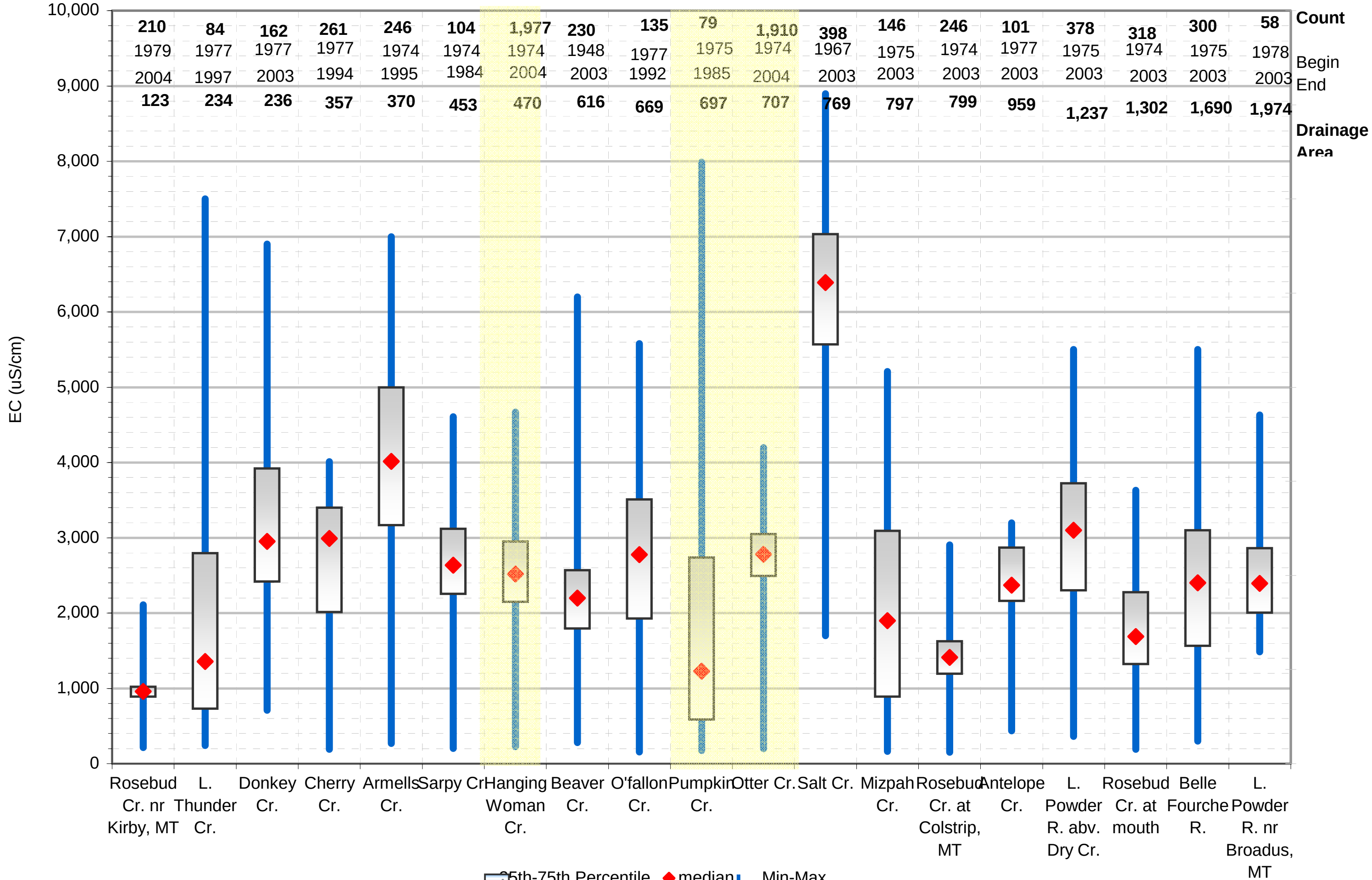


Figure K-4. Turbidity Box Plot.

Table K-4. SC Sampling Period of Record and Summary Statistics (µS/cm).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	7/13/2004	210	215	957	2,110	158
Cheyenne	L. Thunder Cr.	06375600	234	9/30/1977	5/28/1997	84	150	1,718	7,500	1,276
Belle Fourche	Donkey Cr.	06426400	236	9/29/1977	9/9/2003	162	710	3,103	6,900	1,096
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	6/9/1994	261	162	2,474	4,010	1,105
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	246	250	3,891	7,000	1,459
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	104	204	2,539	4,720	975
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**10/2/1974**	**6/22/2004**	**1,977**	**226**	**2,494**	**4,670**	**603**
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	230	232	2,051	6,200	798
Lower Yellowstone	O'fallon Cr.	06326600	669	10/24/1977	4/21/1992	135	155	2,652	5,580	1,216
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**8/2/1985**	**79**	**168**	**1,753**	**7,990**	**1,709**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**8/18/2004**	**1,910**	**200**	**2,730**	**4,200**	**470**
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	398	1,700	6,076	8,920	1,375
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/30/2003	146	162	2,032	5,210	1,277
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	246	152	1,434	2,903	401
Cheyenne	Antelope Cr.	06364700	959	10/3/1977	7/15/2003	101	435	2,466	3,300	552
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	378	358	2,896	5,500	1,112
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	10/1/2003	318	190	1,798	3,770	736
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	300	299	2,356	5,500	1,007
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	58	1,440	2,392	4,630	653

303(d) listed streams in the Tongue River watershed are in bold.



	Rosebud Cr. nr Kirby, MT	L. Thunder Cr.	Donkey Cr.	Cherry Cr.	Armells Cr.	Sarpy Cr	Hanging Woman Cr.	Beaver Cr.	O'fallon Cr.	Pumpkin Cr.	Otter Cr.	Salt Cr.	Mizpah Cr.	Rosebud Cr. at Colstrip, MT	Antelope Cr.	L. Powder R. abv. Dry Cr.	Rosebud Cr. at mouth	Belle Fourche R.	L. Powder R. nr Broadus, MT
Count	210	84	162	261	246	104	1,977	230	135	79	1,910	398	146	246	101	378	318	300	58
Begin	1979	1977	1977	1977	1974	1974	1974	1948	1977	1975	1974	1967	1975	1974	1977	1975	1974	1975	1978
End	2004	1997	2003	1994	1995	1984	2004	2003	1992	1985	2004	2003	2003	2003	2003	2003	2003	2003	2003
Drainage Area	123	234	236	357	370	453	470	616	669	697	707	769	797	799	959	1,237	1,302	1,690	1,974

Figure K-5. Specific Conductance Box Plot.

Table K-5. SAR Sampling Period of Record and Summary Statistics.

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	52	0.4	0.7	1.0	0.1
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	5/28/1997	49	0.7	4.1	10.0	2.7
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	9/9/2003	76	1.0	6.5	22.0	3.7
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	0.8	7.1	9.0	2.0
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	132	1.0	10.5	20.0	3.9
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	76	0.6	6.1	12.0	2.1
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**10/2/1974**	**6/22/2004**	**162**	**0.7**	**4.9**	**8.0**	**1.2**
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	85	0.7	5.4	11.0	2.1
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	6/27/1984	57	1.3	11.9	23.0	4.8
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**4/2/1985**	**54**	**1.9**	**8.5**	**25.0**	**4.8**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**6/23/2004**	**159**	**1.0**	**5.4**	**7.3**	**0.9**
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	306	4.7	25.6	50.0	11.5
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	79	2.0	12.8	34.7	6.4
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	101	0.5	1.4	3.6	0.7
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	7/15/2003	67	1.0	2.6	4.0	0.5
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	251	1.2	5.7	12.0	1.8
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	5/22/2003	136	0.9	3.1	10.3	1.8
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	142	0.9	5.4	14.0	2.4
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	36	5.1	8.0	13.4	2.3

303(d) listed streams in the Tongue River watershed are in bold.

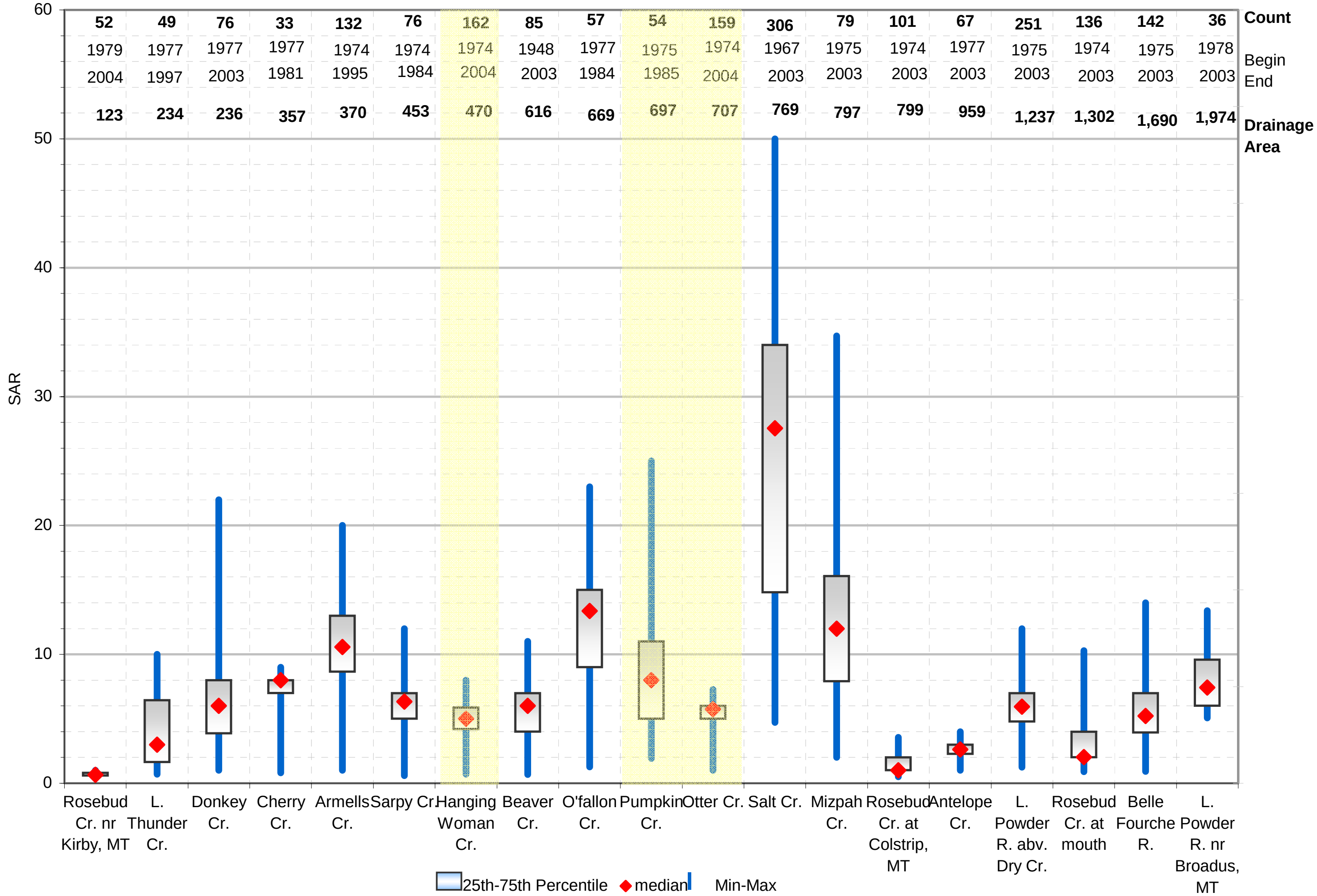


Figure K-6. SAR Box Plot.

Table K-6. Calcium Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	52	56.0	74.4	91.0	7.9
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	5/28/1997	50	19.0	84.1	180.0	43.7
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	9/9/2003	76	45.0	141.4	250.0	44.4
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	22.0	97.9	140.0	28.0
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	132	17.0	104.4	220.0	50.8
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	76	8.6	91.1	190.0	33.9
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**10/2/1974**	**6/22/2004**	**162**	**14.0**	**98.0**	**230.0**	**30.6**
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	85	16.0	86.0	160.0	34.5
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	6/27/1984	57	11.0	54.6	180.0	28.3
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**4/2/1985**	**54**	**5.8**	**48.0**	**150.0**	**36.9**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**6/23/2004**	**159**	**23.0**	**79.1**	**140.0**	**20.9**
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	306	22.0	103.8	290.0	62.1
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	79	4.0	39.5	110.0	23.4
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	101	29.0	77.6	120.0	15.1
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	7/15/2003	67	33.0	248.2	337.0	61.6
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	251	14.2	151.2	320.0	61.4
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	5/22/2003	136	9.7	70.3	130.0	23.3
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	143	19.0	113.5	280.0	54.4
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	36	17.4	94.8	248.0	61.7

303(d) listed streams in the Tongue River watershed are in bold.

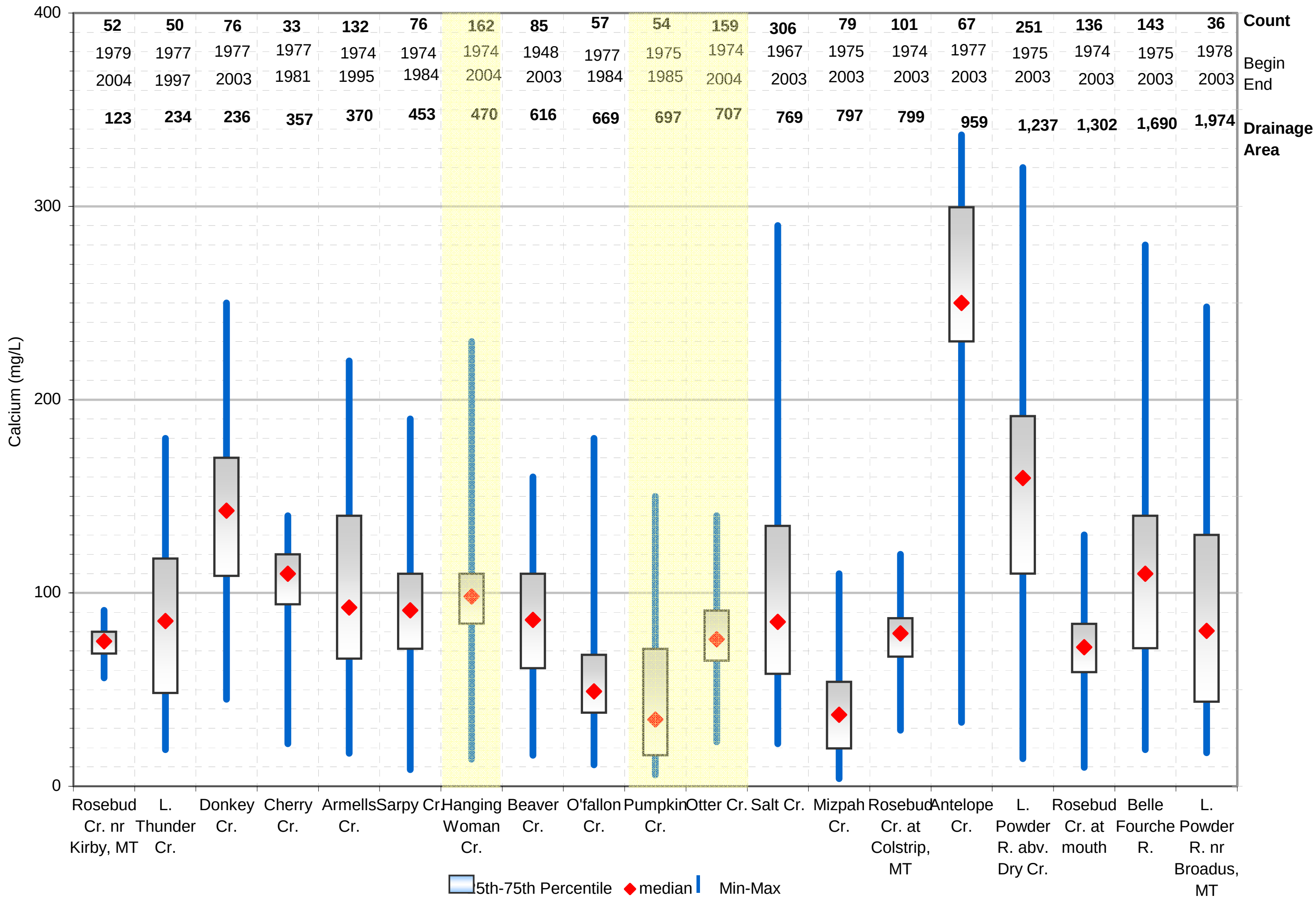


Figure K-7. Calcium Box Plot.

Table K-7. Magnesium Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	52	46.0	77.0	104.0	8.5
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	5/28/1997	49	9.3	52.3	140.0	34.0
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	9/9/2003	76	33.0	131.1	260.0	49.1
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	6.2	76.7	120.0	24.7
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	132	9.7	126.9	280.0	68.8
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	76	6.2	108.1	240.0	50.2
Tongue	**Hanging Woman Cr.**	**06307600**	**470**	**10/2/1974**	**6/22/2004**	**163**	**11.0**	**122.8**	**216.0**	**34.6**
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	85	7.0	77.1	140.0	32.7
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	6/27/1984	57	4.5	59.5	110.0	26.6
Tongue	**Pumpkin Cr.**	**06308400**	**697**	**10/15/1975**	**4/2/1985**	**54**	**2.4**	**46.9**	**200.0**	**54.8**
Tongue	**Otter Cr.**	**06307740**	**707**	**10/2/1974**	**6/23/2004**	**159**	**5.0**	**152.9**	**240.0**	**38.0**
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	306	7.8	60.3	297.0	34.1
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	79	1.9	29.8	200.0	27.7
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	101	19.0	104.2	281.0	35.6
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	7/15/2003	67	13.0	95.1	132.0	27.8
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	253	7.3	99.1	203.0	43.7
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	5/22/2003	136	2.8	95.7	190.0	36.8
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	143	8.8	77.6	180.0	38.1
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	36	9.5	54.8	146.0	37.4

303(d) listed streams in the Tongue River watershed are in bold.

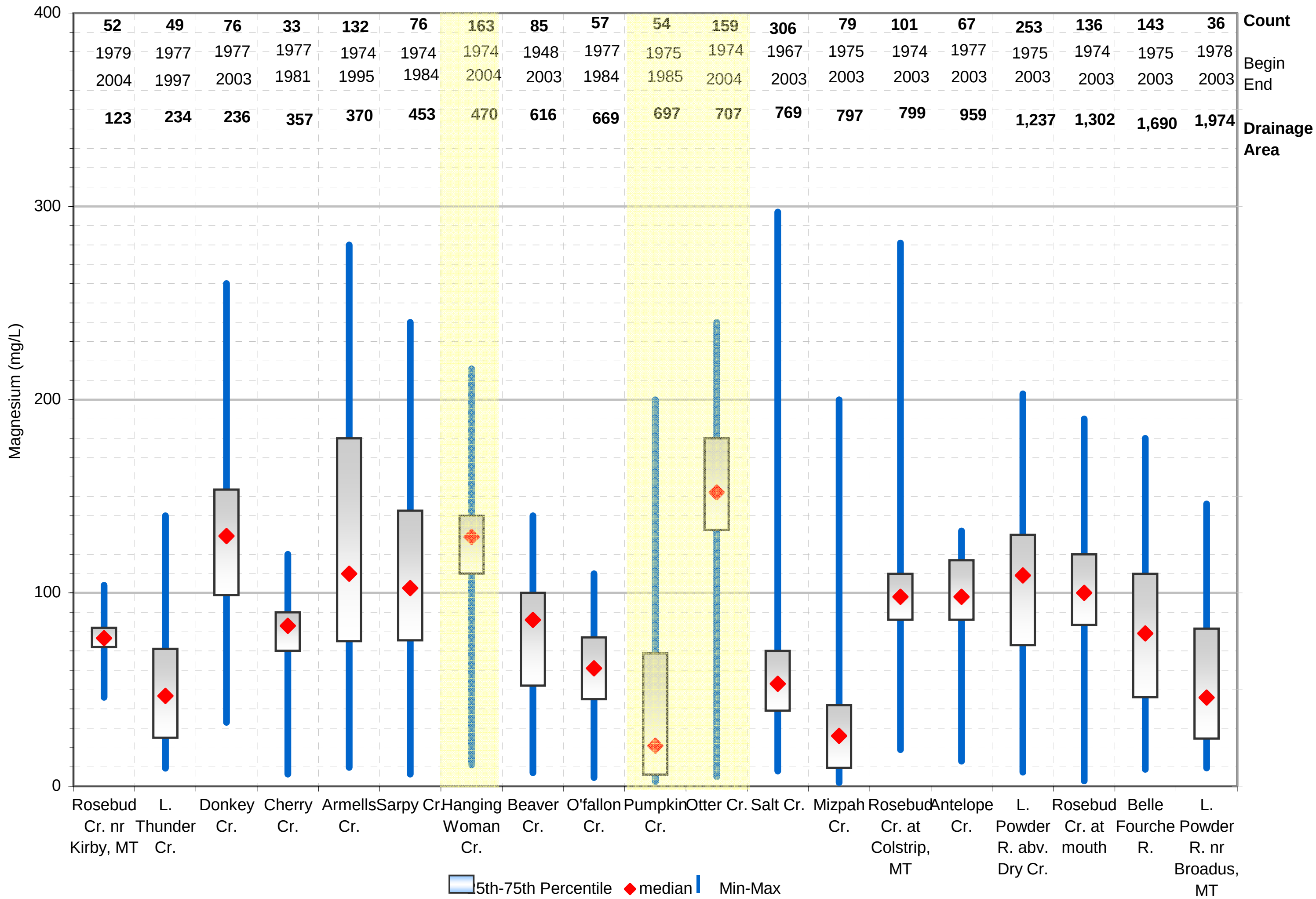


Figure K-8. Magnesium Box Plot.

Table K-8. Sodium Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	52	15	36	60	8
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	5/28/1997	49	15	231	750	196
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	9/9/2003	76	47	480	1,400	280
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	16	399	540	138
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	132	19	693	1,400	267
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	76	14	385	880	164
Tongue	Hanging Woman Cr.	06307600	470	10/2/1974	6/22/2004	162	17	333	615	103
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	85	18	313	570	139
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	6/27/1984	57	22	557	1,200	257
Tongue	Pumpkin Cr.	06308400	697	10/15/1975	4/2/1985	54	24	380	1,800	370
Tongue	Otter Cr.	06307740	707	10/2/1974	6/23/2004	159	26	377	583	85
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	306	290	1,274	2,000	360
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	79	37	451	1,340	286
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	101	13	90	302	48
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	7/15/2003	67	28	207	289	52
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	252	35	405	950	174
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	5/22/2003	136	17	176	622	119
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	142	24	331	740	166
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	36	240	421	736	88

303(d) listed streams in the Tongue River watershed are in bold.

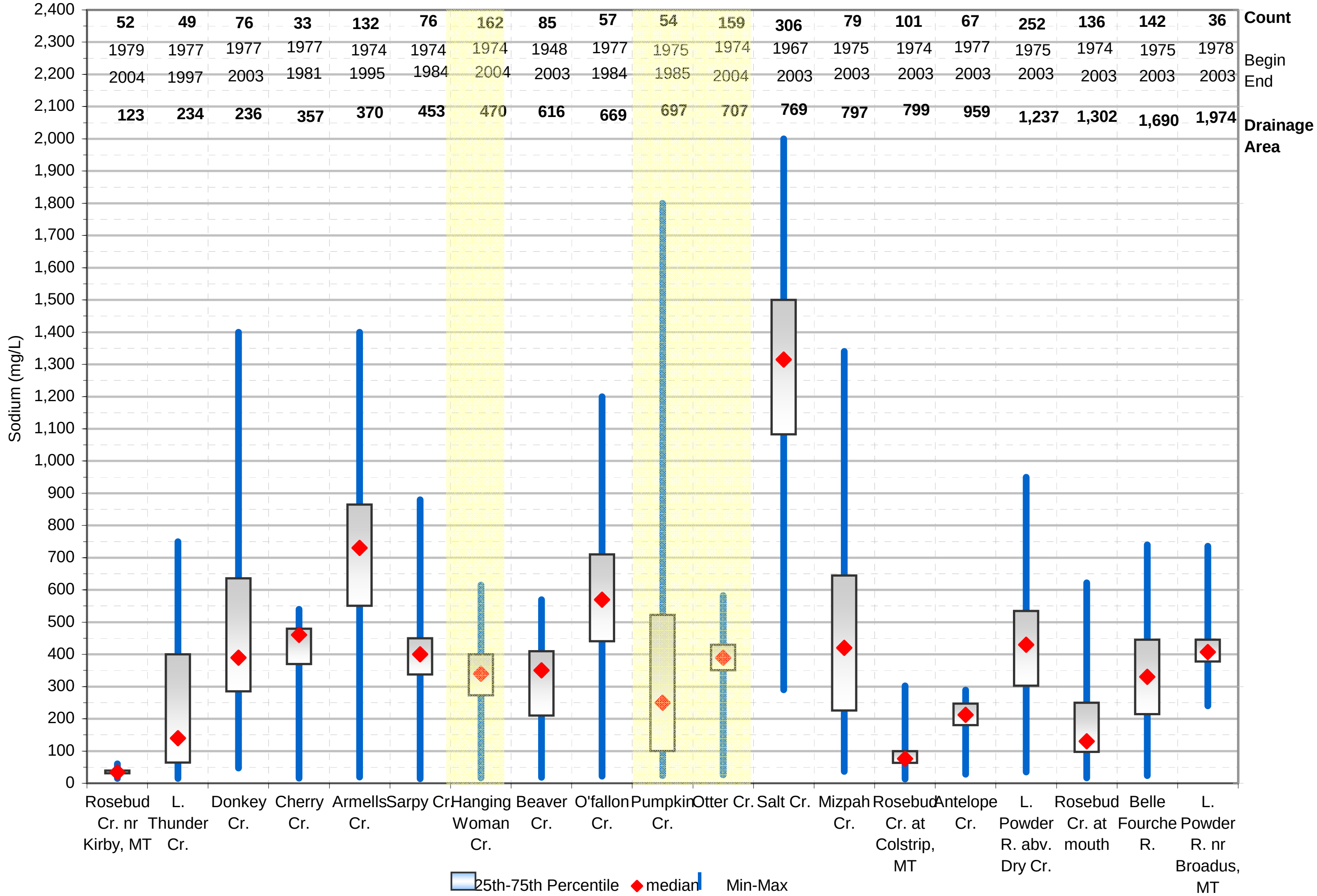


Figure K-9. Sodium Box Plot.

Table K-9. Chloride Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	52	2.1	6.4	88.0	11.8
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	5/28/1997	50	2.0	32.5	290.0	58.4
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	9/9/2003	76	12.0	133.3	270.0	77.7
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	1.9	10.2	23.0	4.2
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	132	3.8	28.7	260.0	24.7
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	75	3.0	15.1	34.0	6.1
Tongue	Hanging Woman Cr.	06307600	470	10/2/1974	6/22/2004	163	2.5	14.2	140.0	11.4
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	84	0.1	9.1	22.0	3.8
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	6/27/1984	57	1.8	9.6	26.0	4.5
Tongue	Pumpkin Cr.	06308400	697	10/15/1975	4/2/1985	54	1.8	8.4	31.0	7.2
Tongue	Otter Cr.	06307740	707	10/2/1974	6/23/2004	157	1.3	14.3	86.0	7.4
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	305	39.2	1,065.3	1,980.0	399.0
Powder	Mizpah Cr.	06326300	797	10/17/1975	9/29/2003	81	2.2	10.2	38.0	6.8
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	10/1/2003	101	1.1	6.9	70.0	6.8
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	7/15/2003	67	3.7	17.3	31.0	6.3
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	9/16/2003	255	2.6	34.2	580.0	50.1
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	5/22/2003	136	1.8	9.3	28.1	5.6
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	144	3.4	84.6	290.0	62.6
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	9/3/2003	35	4.3	28.8	200.0	34.4

303(d) listed streams in the Tongue River watershed are in bold.

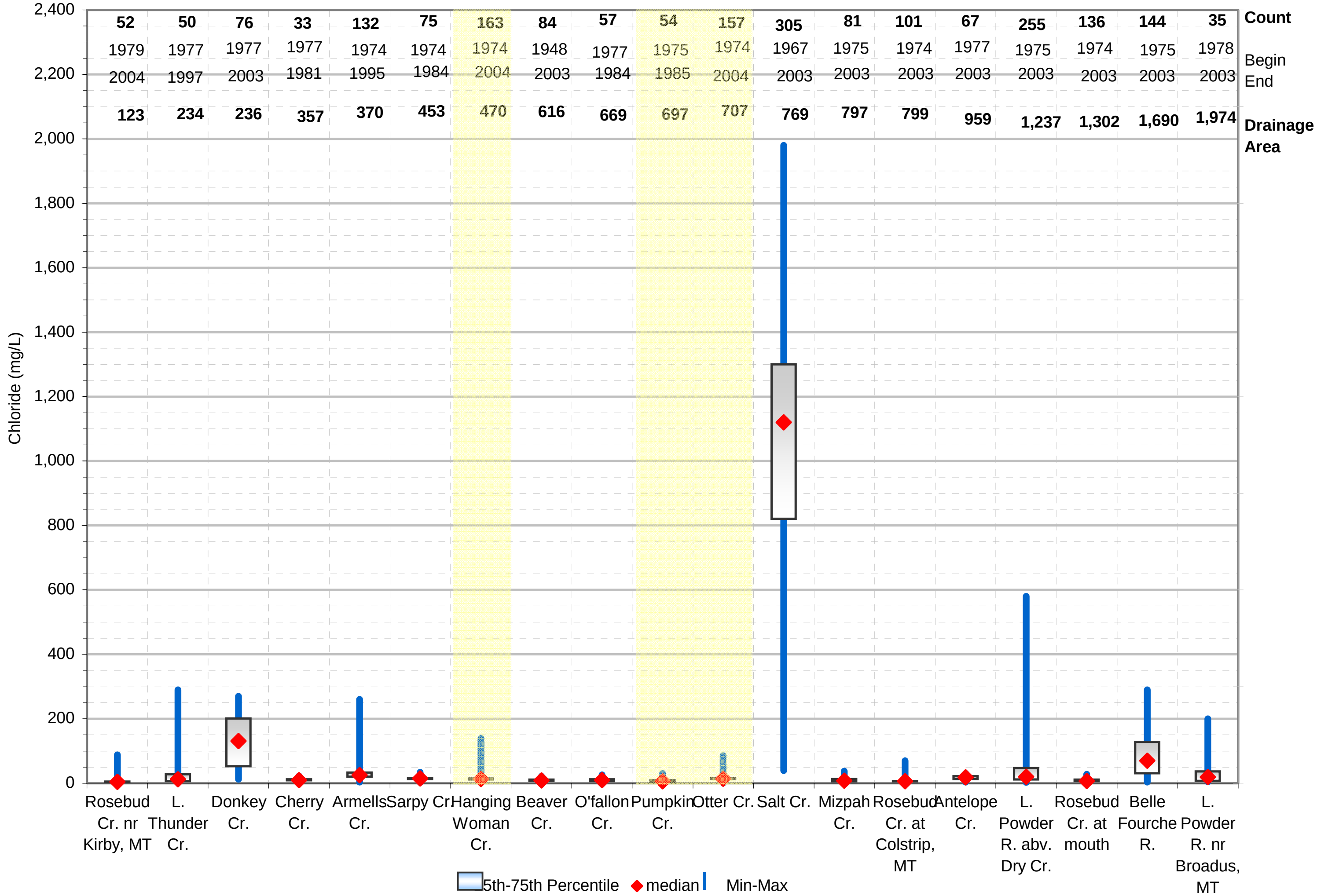


Figure K-10. Chloride Box Plot.

Table K-10.Sulfate Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	6295113	123	10/1/1979	5/12/2004	52	101	155	210	24
Cheyenne	L. Thunder Cr.	6375600	234	12/21/1977	5/28/1997	50	82	649	2,200	501
Belle Fourche	Donkey Cr.	6426400	236	10/27/1977	9/9/2003	76	220	1,321	3,400	716
Lower Yellowstone	Cherry Cr.	6326555	357	10/9/1977	8/24/1981	33	47	1,055	1,500	363
Lower Yellowstone	Armells Cr.	6294995	370	10/8/1974	8/22/1995	132	75	1,779	3,400	735
Lower Yellowstone	Sarpy Cr.	6294940	453	12/3/1974	6/28/1984	76	12	996	2,500	443
Tongue	Hanging Woman Cr.	6307600	470	10/2/1974	6/22/2004	163	57	961	2,060	355
Little Missouri	Beaver Cr.	6336600	616	2/29/1948	7/8/2003	84	49	825	1,400	346
Lower Yellowstone	O'fallon Cr.	6326600	669	11/21/1977	6/27/1984	57	25	1,066	2,800	517
Tongue	Pumpkin Cr.	6308400	697	10/15/1975	4/2/1985	54	11	822	3,900	877
Tongue	Otter Cr.	6307740	707	10/2/1974	6/23/2004	158	80	1,092	1,960	274
Powder	Salt Cr.	6313400	769	10/9/1967	9/22/2003	304	460	1,191	4,350	490
Powder	Mizpah Cr.	6326300	797	10/17/1975	9/29/2003	81	36	784	3,180	542
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	6295250	799	10/9/1974	10/1/2003	101	54	404	1,490	230
Cheyenne	Antelope Cr.	6364700	959	11/4/1977	7/15/2003	67	150	1,082	1,550	298
Powder	L. Powder R. abv. Dry Cr.	6324970	1,237	6/4/1975	9/16/2003	252	76	1,290	2,700	557
Lower Yellowstone	Rosebud Cr. at mouth	6296003	1,302	10/10/1974	5/22/2003	135	16	537	1,290	278
Belle Fourche	Belle Fourche R.	6426500	1,690	7/2/1975	9/8/2003	144	71	846	2,000	412
Powder	L. Powder R. nr Broadus, MT	6325500	1,974	8/30/1978	9/3/2003	36	420	966	2,220	443

303(d) listed streams in the Tongue River watershed are in bold.

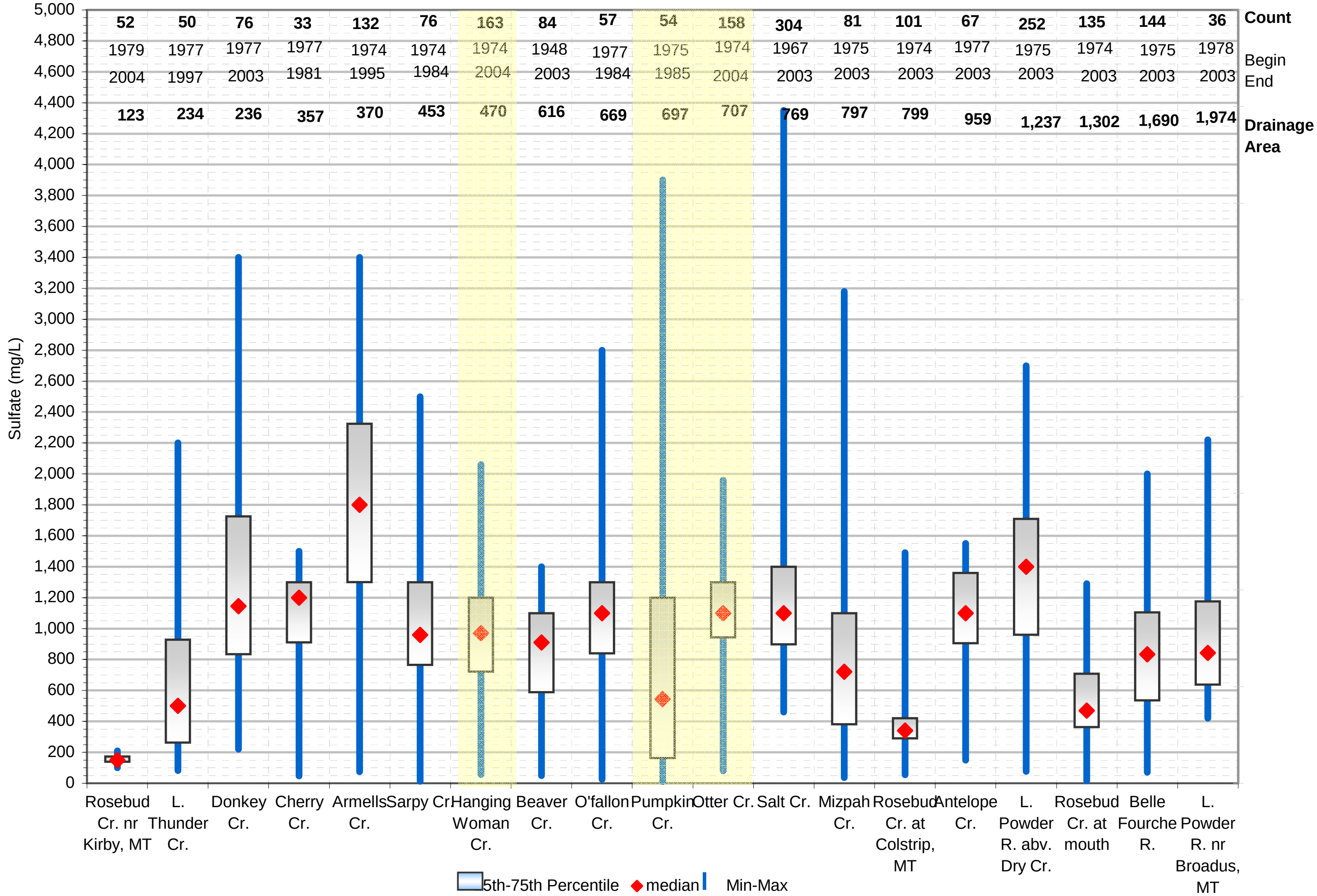


Figure K-11. Sulfate Box Plot.

Table K-11.Hardness Sampling Period of Record and Summary Statistics (mg/L).

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	10/1/1979	5/12/2004	35	330	503	650	56
Cheyenne	L. Thunder Cr.	06375600	234	12/21/1977	8/12/1981	28	95	468	1,000	245
Belle Fourche	Donkey Cr.	06426400	236	10/27/1977	6/9/1981	45	250	953	1,500	315
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	8/24/1981	33	80	560	840	170
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	9/17/1982	79	82	732	1,600	371
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	9/17/1982	64	47	681	1,400	284
Tongue	Hanging Woman Cr.	06307600	470	10/2/1974	5/30/2003	83	110	746	1,200	208
Little Missouri	Beaver Cr.	06336600	616	10/14/1977	3/15/2003	53	190	603	950	193
Lower Yellowstone	O'fallon Cr.	06326600	669	11/21/1977	9/1/1982	44	0	379	710	171
Tongue	Pumpkin Cr.	06308400	697	10/15/1975	6/7/1982	43	25	349	1,100	322
Tongue	Otter Cr.	06307740	707	10/2/1974	5/30/2003	85	120	851	1,220	220
Powder	Salt Cr.	06313400	769	10/9/1967	12/16/1985	170	190	435	970	157
Powder	Mizpah Cr.	06326300	797	10/17/1975	4/23/2003	55	18	246	1,100	181
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	5/31/2003	83	150	591	1,100	124
Cheyenne	Antelope Cr.	06364700	959	11/4/1977	8/11/1981	45	140	910	1,200	221
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	6/4/1975	4/12/1994	130	41	793	1,500	342
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	9/15/1982	84	58	564	1,100	182
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	7/28/1982	80	140	600	1,400	307
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	8/30/1978	10/21/1978	2	530	615	700	120

303(d) listed streams in the Tongue River watershed are in bold.

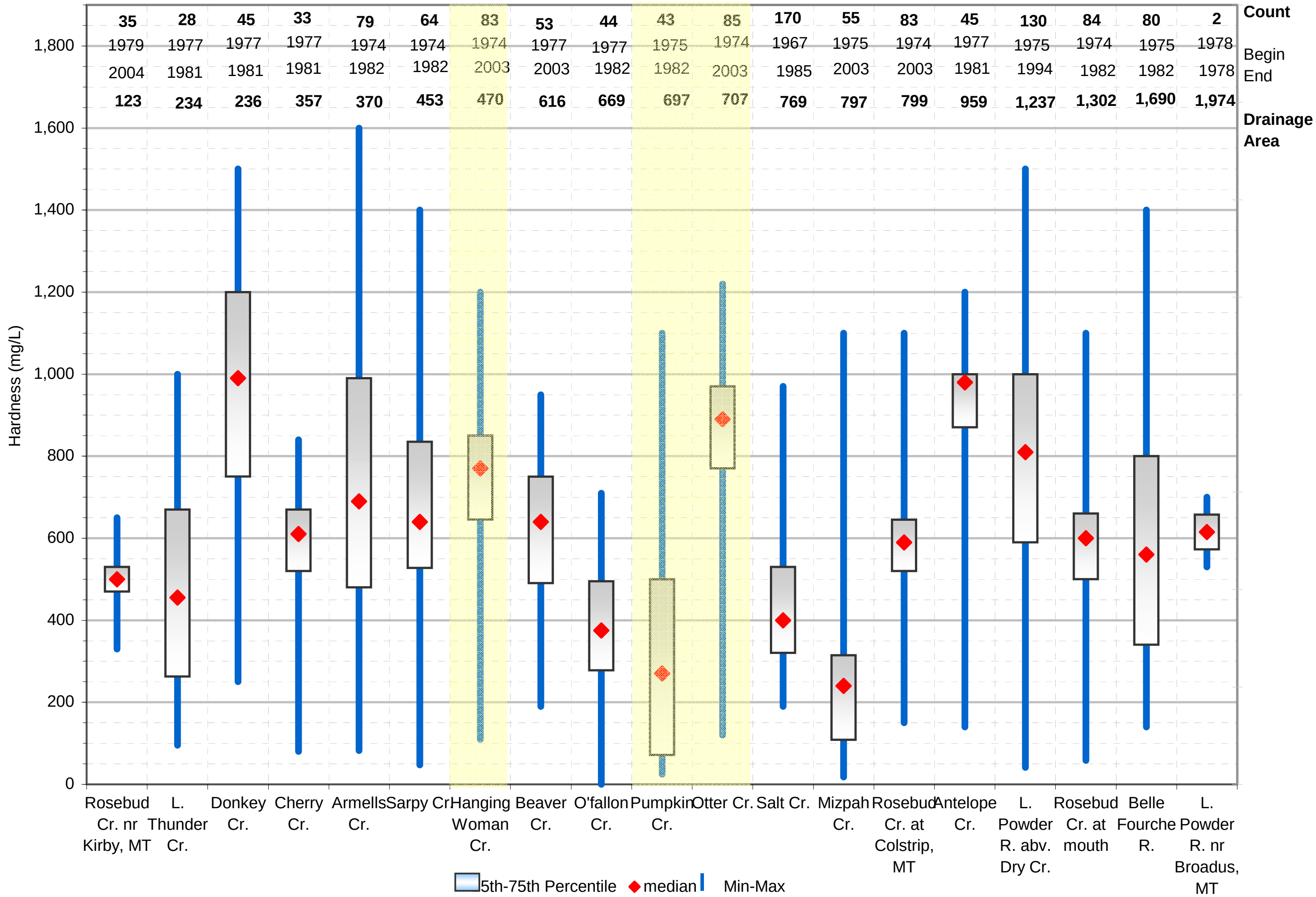


Figure K-12. Hardness Box Plot.

Table K-12. Temperature (ºF) Sampling Period of Record and Summary Statistics.

Watershed	Stream	Station ID	Drainage Area (sq. Mi)	Start	End	Count	Min	Avg	Max	StDev
Tongue	Squirrel Cr.	06306100	34	10/6/1975	6/26/1985	89	32.0	47.6	74.3	44.4
Lower Yellowstone	Rosebud Cr. nr Kirby, MT	06295113	123	4/19/1984	4/18/1988	2	51.8	51.8	51.8	32.0
Cheyenne	L. Thunder Cr.	06375600	234	9/30/1977	5/28/1997	63	32.0	50.8	78.8	46.0
Belle Fourche	Donkey Cr.	06426400	236	9/29/1977	9/9/2003	127	32.0	48.8	89.6	47.3
Lower Yellowstone	Cherry Cr.	06326555	357	10/9/1977	6/9/1994	248	32.0	54.8	93.2	47.6
Lower Yellowstone	Armells Cr.	06294995	370	10/8/1974	8/22/1995	176	32.0	50.8	92.3	48.1
Lower Yellowstone	Sarpy Cr.	06294940	453	12/3/1974	6/28/1984	78	32.0	45.0	73.4	45.2
Tongue	Hanging Woman Cr.	06307600	470	10/2/1974	8/5/2003	192	32.0	49.0	82.4	47.5
Little Missouri	Beaver Cr.	06336600	616	2/29/1948	7/8/2003	198	32.0	48.5	79.2	47.1
Lower Yellowstone	O'fallon Cr.	06326600	669	10/24/1977	4/21/1992	119	32.0	50.7	86.0	49.5
Tongue	Pumpkin Cr.	06308400	697	10/15/1975	8/13/1985	60	32.0	50.4	85.1	49.3
Tongue	Otter Cr.	06307740	707	10/2/1974	9/2/2003	180	32.0	50.4	85.1	48.4
Powder	Salt Cr.	06313400	769	10/9/1967	9/22/2003	380	32.0	50.5	87.8	47.5
Lower Yellowstone	Rosebud Cr. at Colstrip, MT	06295250	799	10/9/1974	7/30/2003	219	32.0	48.2	78.8	47.3
Cheyenne	Antelope Cr.	06364700	959	10/3/1977	7/15/2003	74	32.0	51.6	86.0	48.2
Powder	L. Powder R. abv. Dry Cr.	06324970	1,237	1/8/1975	9/16/2003	317	32.0	52.3	86.0	47.7
Lower Yellowstone	Rosebud Cr. at mouth	06296003	1,302	10/10/1974	6/2/2003	257	32.0	49.5	85.1	47.7
Belle Fourche	Belle Fourche R.	06426500	1,690	7/2/1975	9/8/2003	277	32.0	50.9	87.8	48.2
Powder	L. Powder R. nr Broadus, MT	06325500	1,974	3/19/2002	9/3/2003	19	32.0	55.2	84.2	49.5

303(d) listed streams in the Tongue River watershed are in bold.

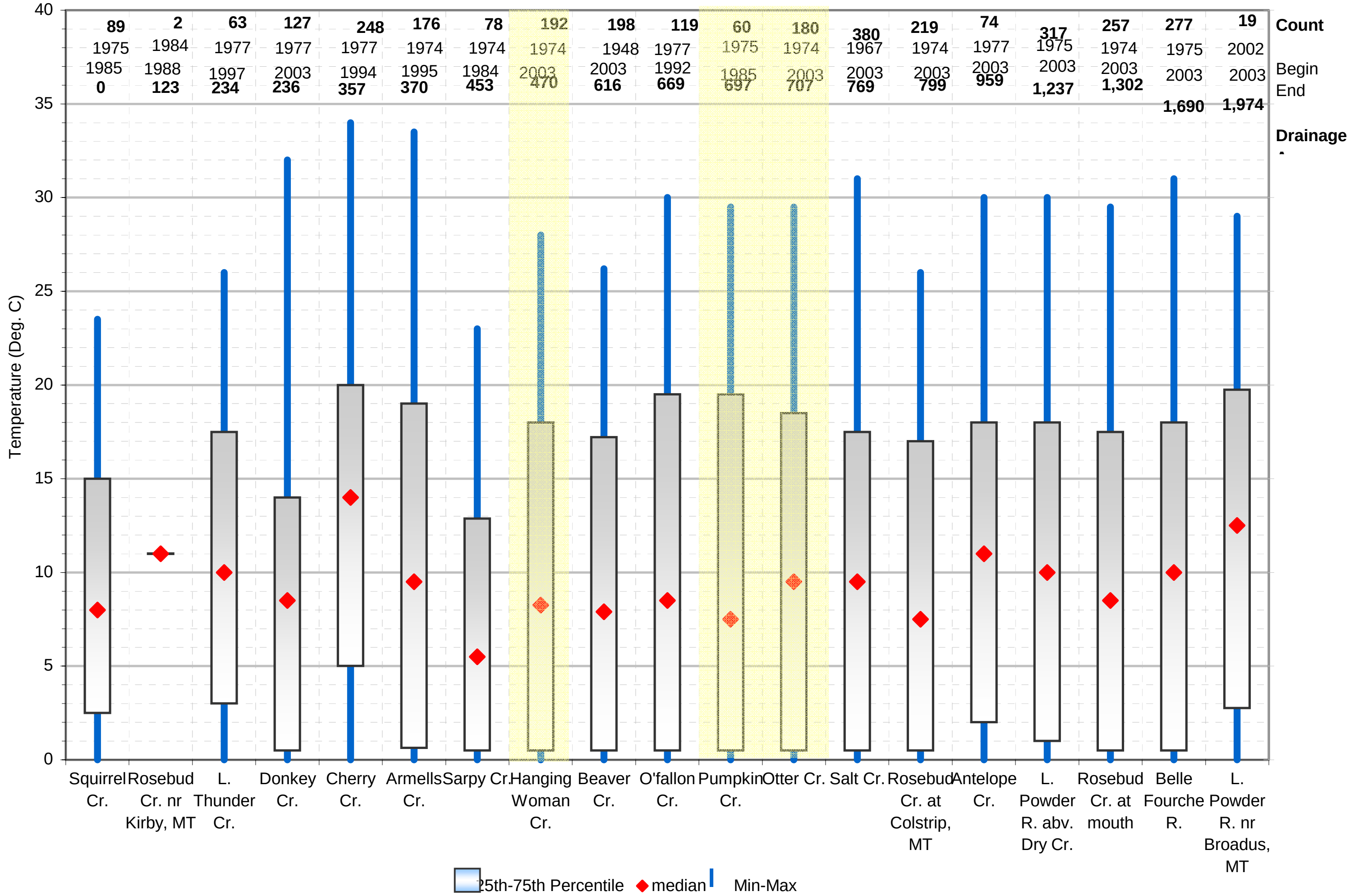


Figure K-13. Temperature Box Plot

K.2 Main Stem Tongue River

The purpose of this section is to compare suspended sediment data from the Tongue River to other large streams that are primarily located in the Northwestern Great Plains ecoregion (Level III Ecoregion 43). 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, with the goal of selecting streams that had characteristics similar to the Tongue River watershed. Based on this, 14 rivers were selected from Montana, Wyoming, North Dakota, and South Dakota – the Belle Fourche River, Cheyenne River, Grand River, Green River, Heart River, Little Missouri River, Little Big Horn River, Moreau River, Musselshell River, Poplar River, Powder River, Tongue River, White River, and Wind River (Figure K-14). Eleven of the selected rivers flow, at least in part, through the Northwestern Great Plains ecoregion (Table K-13). The Poplar River flows entirely through the Northwest Glaciated Plains ecoregion, while the Wind and Green Rivers in Wyoming flow through the Wyoming Basin and Middle Rockies ecoregions. The Wind, Green, and Poplar Rivers were included in this analysis to increase the total number of sites, and because it was felt that these rivers were similar enough to the Tongue River to warrant a data comparison. From the 14 rivers, 25 sampling sites were selected to compare to the five Tongue River sites (Table K-14 and Table K-15).

It should be noted that the rivers selected for this analysis are not meant to represent “reference conditions” in the Tongue River. In fact, several of the rivers are themselves listed as impaired because of siltation or TSS (see Table K-13), and several of the rivers have major dams and reservoirs that complicate river hydrology and sediment transport. It is beyond the scope of this analysis to conduct a detailed sediment assessment for each of the 14 rivers. Rather, the purpose of this analysis is to put suspended sediment data in the Tongue River into context with similar neighboring rivers to better understand existing conditions.

Table K-13. Summary of the selected rivers for the suspended sediment analysis.

River	Sediment 303(d) Listings (2004 or 2006 Lists)				Ecoregions	Major Reservoirs Impacting Sampling Sites
	MT	WY	ND	SD		
Belle Fourche River	NA	No	NA	Yes	NW Great Plains Middle Rockies	Keyhole Reservoir
Cheyenne River	NA	No	NA	Yes	NW Great Plains Middle Rockies	None
Grand River	NA	NA	NA	Yes	NW Great Plains	Shadehill Reservoir
Green River (WY)	NA	No	NA	NA	Wyoming Basin	Fontenelle Reservoir
Heart River	NA	NA	Yes	NA	NW Great Plains	Patterson Reservoir
L. Missouri River	No	No	No	No	NW Great Plains	None
Little Big Horn River	No	No	NA	NA	NW Great Plains Middle Rockies	None
Moreau River	NA	NA	NA	Yes	NW Great Plains	None
Musselshell River	Yes	NA	NA	NA	NW Great Plains	None
Poplar River	Yes	NA	NA	NA	NW Glaciated Plains	Morrison Dam (Canada)
Powder River	Not Assessed	No	NA	NA	NW Great Plains Middle Rockies	None
Tongue River	Not Assessed	No	NA	NA	NW Great Plains Middle Rockies	Tongue River Reservoir
White River	NA	NA	NA	Yes	NW Great Plains	None
Wind River	NA	No	NA	NA	Wyoming Basin Middle Rockies	Boysen Reservoir

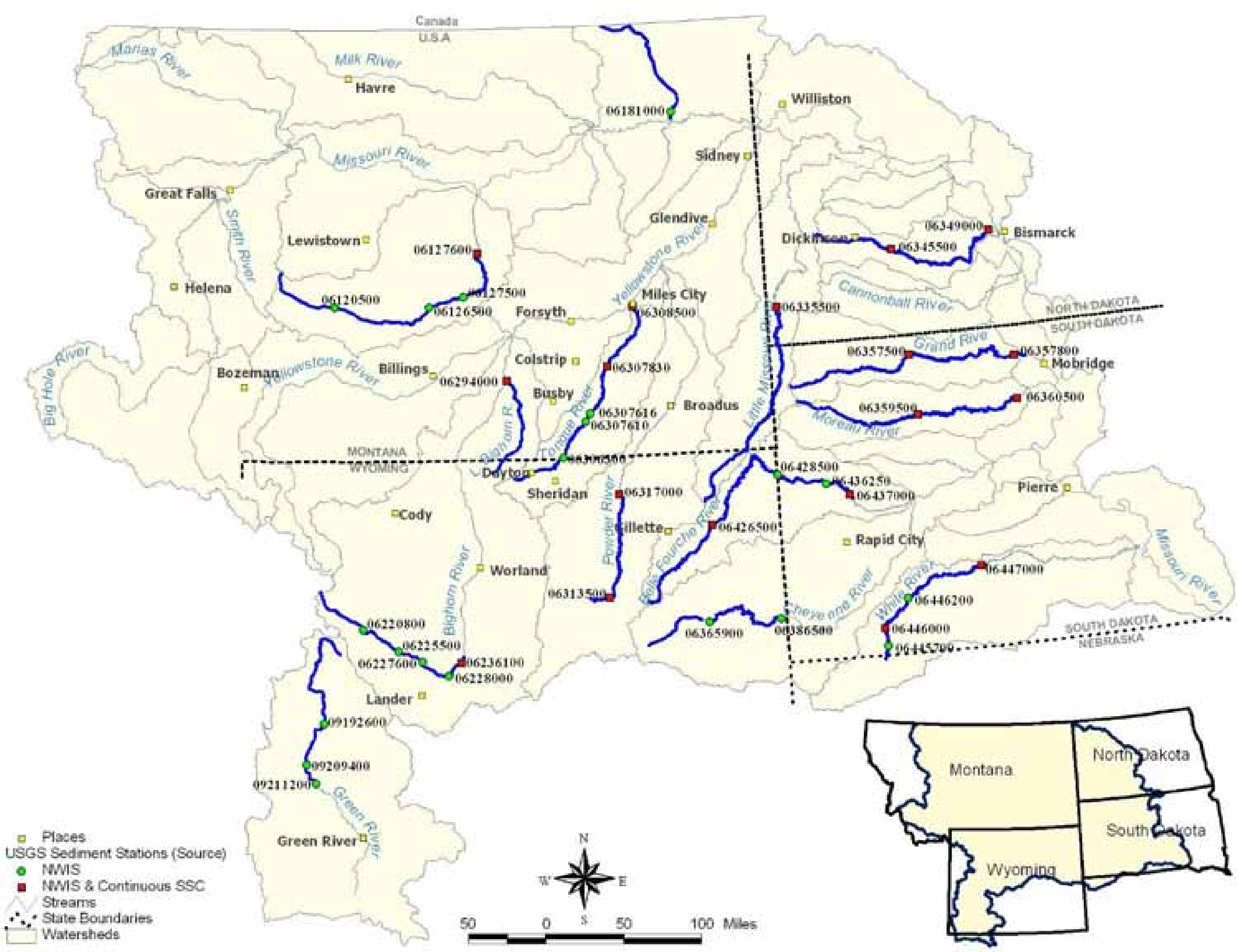


Figure K-14. Location of Great Plains streams used in the Tongue River sediment comparison analysis.

Suspended sediment data were downloaded from USGS's National Water Information System (NWIS) and Suspended Sediment Database. Grab sample data are summarized in Figure K-15 and Table K-14, and continuous data are summarized in Table K-15. The periods of record for each site vary. As a result, direct comparison from one site to another is complicated by the fact that the data from each site do not necessarily reflect similar climatic and hydrologic conditions. Nonetheless, this comparison is presented to put suspended solids concentrations in the Tongue River into perspective with other Great Plains streams. Median suspended sediment 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.

Count	110	173	194	84	30	135	70	60	23	50	57	50	116	150	119	128	105	86	86	53	311	90	62	223	103	60	89	60	83	42	23
Begin	1968	1955	1974	1973	1971	1949	1972	1949	1987	1991	1975	1977	1975	1975	1972	1975	1967	1964	1979	1975	1949	1950	1990	1970	1976	1975	1964	2000	1971	1975	1987
End	1996	2002	2004	1990	2004	1997	1994	1951	1991	2002	1980	1981	2004	1994	1993	2004	1987	1967	2004	1979	2002	1997	2002	2000	1999	1987	1997	2004	2001	1978	1991
Drain Area	6050	5870	5379	5370	5270	5000	4880	4640	4568	4390	4280	4023	3948	3910	3310	3174	3090	3000	2621	2533	2309	2200	2194	1891	1690	1527	1500	1453	1294	1260	1125

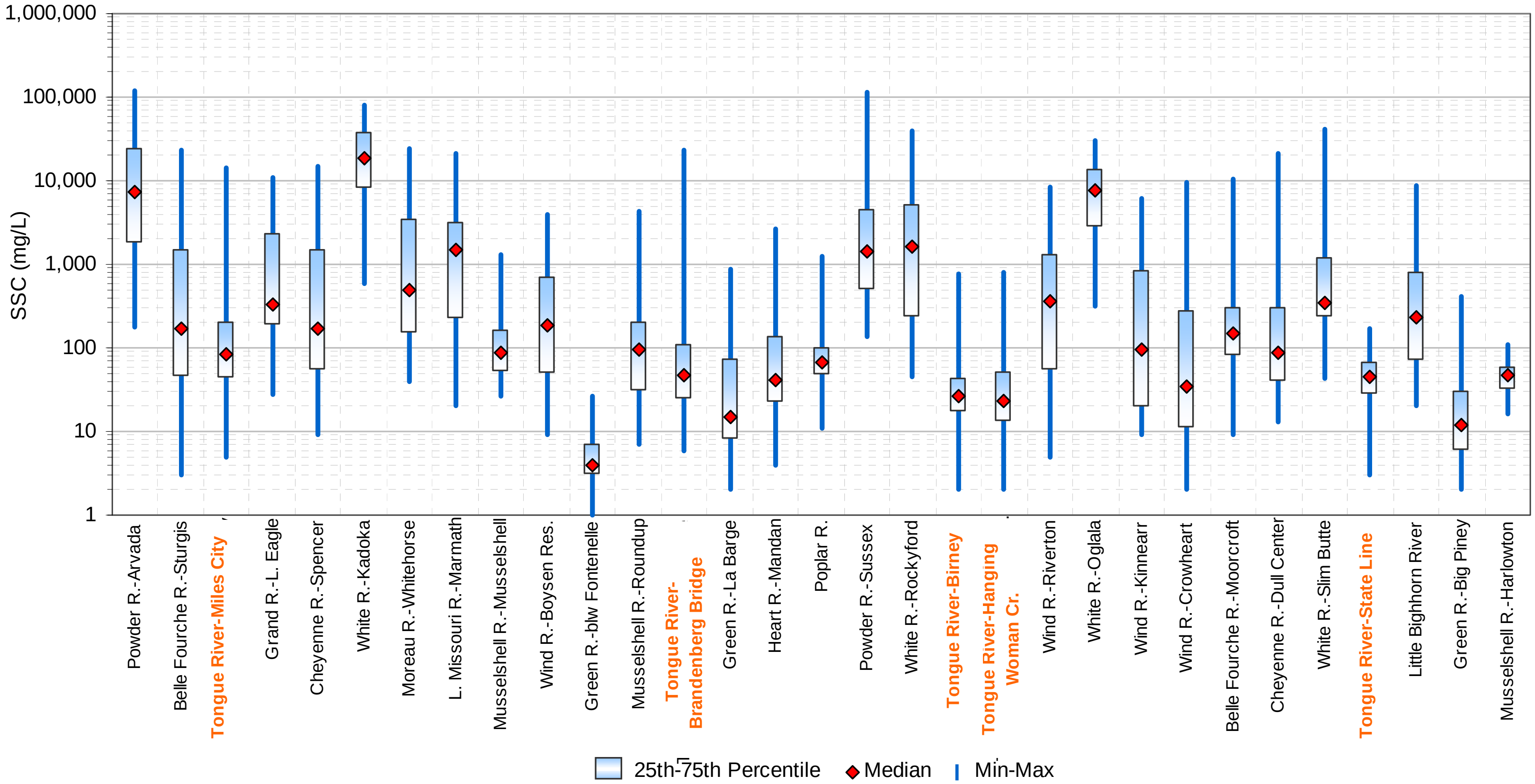


Figure K-15. Box plots of SSC data for selected Great Plains streams (sorted by drainage area).

Table K-14. Summary of grab sample SSC data for selected Great Plains streams.

Waterbody	Station ID	Drainage Area (mi^2)	Count	Median[a] (mg/L)	Min (mg/L)	Max (mg/L)	Period of Record
Green River – below Fontenelle Reservoir	9211200	4,280	57	4	1	27	1975-1980
Green River –- La Barge	9209400	3,910	150	15	2	880	1975-1994
Tongue River – Hanging Woman Cr.	**6307610**	**2,533**	**53**	**23**	**2**	**812**	**1975-1979**
Tongue River – Birney	**6307616**	**2,621**	**86**	**27**	**2**	**780**	**1979-2004**
Wind River – Crowheart	6225500	1,891	223	34	2	9,360	1970-2000
Heart River – Mandan	6349000	3,310	119	42	4	2,690	1972-1993
Tongue River – State Line	**6306300**	**1,453**	**60**	**45**	**3**	**170**	**2000-2004**
Tongue River – Brandenberg Bridge	**6307830**	**3,948**	**116**	**47**	**6**	**23,100**	**1975-2004**
Musselshell River – Harlowton	6120500	1,125	23	48	16	108	1987-1991
Poplar River	6181000	3,174	128	66	11	1,270	1975-2004
Tongue River – Miles City	**6308500**	**5,379**	**194**	**84**	**5**	**14,000**	**1974-2004**
Cheyenne River – Dull Center	6365900	1,527	60	86	13	21,500	1975-1987
Musselshell River – Musselshell	6127500	4,568	23	89	27	1,320	1987-1991
Wind River – Kinnearr	6227600	2,194	62	94	9	6,590	1990-2002
Musselshell River – Roundup	6126500	4,023	50	96	7	4,230	1977-1981
Belle Fourche River - Moorcroft	6426500	1,690	103	151	9	10,500	1976-1999
Cheyenne River – Spencer	6386500	5,270	30	168	9	14,800	1971-2004
Belle Fourche River – Sturgis	6437000	5,870	173	171	3	42,000	1955-2002
Wind River – Boysen Res.	6236100	4,390	50	182	9	3,920	1991-2002
Little Big Horn River	6294000	1,294	83	237	20	8,670	1971-2001
Grand River – Little Eagle	6357800	5,370	84	331	28	11,000	1973-1990
White River – Slim Butte	6445700	1,500	89	344	43	41,400	1964-1997
Wind River – Riverton	6228000	2,309	311	354	5	8,320	1949-2002
Moreau River – Whitehorse	6360500	4,880	70	488	40	24,500	1972-1994
Powder River – Sussex	6313500	3,090	105	1,395	138	113,000	1967-1987
L. Missouri River – Marmath	6335500	4,640	60	1,510	20	21,600	1949-1951
White River – Rockyford	6446200	3,000	86	1,640	46	38,600	1964-1967
Powder River – Arvada	6317000	6,050	110	7,200	179	122,000	1968-1996
White River – Oglala	6446000	2,200	90	7,740	319	30,800	1950-1997
White River – Kadoka	6447000	5,000	135	18,700	576	81,600	1949-1997

[a]Data sorted by median concentration. Stations in the Tongue River are highlighted.

Table K-15. Summary of continuous SSC data for selected Great Plains streams.

Waterbody	Station ID	Drainage Area (mi^2)	Count	Median[a] (mg/L)	Min (mg/L)	Max (mg/L)	Period of Record
Wind River - Riverton	6228000	2,309	1,561	32	3	11,900	1948-1958
Heart River - Mandan	6349000	3,310	1,826	40	1	3,460	1971-1976
Tongue River - Brandenberg Bridge	**6307830**	**3,948**	**2,455**	**46**	**1**	**6,400**	**1974-1981**
Heart River - Richardton	6345500	1,240	1,919	56	4	6,500	1946-1952
Tongue River - Miles City	**6308500**	**5,379**	**3,018**	**66**	**3**	**14,200**	**1977-1985**
Moreau River - Faith	6359500	2,660	909	66	1	41,100	1946-1949
Grand River - Shadehill	6357500	3,120	1,333	77	2	18,600	1946-1950
Little Big Horn River	6294000	1,294	2,557	109	7	6,660	1969-1977
Musselshell River - Mosby	6127600	5,941	1,415	110	1	27,000	1962-1966
L. Missouri River - Marmath	6335500	4,640	734	147	21	27,000	1952-1954
Moreau River - Whitehorse	6360500	4,880	1,346	220	17	20,300	1971-1976
White River - Oglala	6446000	2,200	1,931	245	9	34,400	1947-1952
Wind River - Boysen Res.	6236100	4,390	187	299	20	2,810	1994-1995
Grand River - L. Eagle	6357800	5,370	1,827	350	85	19,000	1971-1976
Powder River - Sussex	6313500	3,090	899	589	38	111,000	1951-1984
Belle Fourche River - Sturgis	6437000	5,870	1,074	1,000	7	78,000	1955-1958
White River - Kadoka	6447000	5,000	1,791	1,340	14	76,200	1949-1954

[a]Data sorted by median concentration. Stations in the Tongue River are highlighted.

K.3 References

USEPA. 2007. Level III Ecoregions for the Conterminous United States (Revision March 2007) [Computer File]. U.S. Environmental Protection Agency [Producer and Distributor]. Corvallis, Oregon. Available online at http://www.epa.gov/wed/pages/ecoregions/level_iii.htm.

APPENDIX L – 2003 WATER QUALITY SAMPLING DATA

L.0 2003 WATER QUALITY SAMPLING DATA

USEPA collected water quality data at 14 sites in the Tongue River watershed in 2003 (Table L-1). Data were collected to fill in gaps in the available water chemistry data. Table L-2 shows the sampled parameters, and the frequency of data collection at each site. Six sampling events occurred at approximately one month intervals: April 23-26; May 29-30; June 23-27; July 28-August 1; August 20-22; October 1-3. Data were then submitted to Northern Analytical Laboratories for analysis, and all results were submitted to the Montana DEQ STORET coordinator on December 28, 2004.

Table L-1. Location of 2003 sampling sites.

Station ID	Station Name	Primary Type	Lat Degrees	Long Degrees	State	County	HUC
Y15HNGWC01	Hanging Woman Ck. Near Birney, MT	River/Stream	45.29547	106.5029	MT	Rosebud	10090101
Y15HNGWC02	Hanging Woman Ck. Below Horse Creek near Birney	River/Stream	45.13481	106.48379	MT	Big Horn	10090101
Y15TNGR01	Tongue River at the TRR Dam near Decker, MT	River/Stream	45.14144	106.77111	MT	Big Horn	10090101
Y15TNGRR01	Tongue River Reservoir, South end	Reservoir	45.0701	106.7996	MT	Big Horn	10090101
Y15TNGRR02	Tongue River Reservoir, Middle of Reservoir near boat launch	Reservoir	45.10018	106.78454	MT	Big Horn	10090101
Y15TNGRR03	Tongue River Reservoir near dam	Reservoir	45.12099	106.78092	MT	Big Horn	10090101
Y16OTTRC01	Otter Creek Near Ashland, MT	River/Stream	45.58775	106.25426	MT	Rosebud	10090102
Y16OTTRC02	Otter Creek Below Taylor Ck. Near Otter, MT	River/Stream	45.29208	106.14763	MT	Powder River	10090102
Y16PMPKC01	Pumpkin Creek near the mouth at the Tongue River 12-Mile Dam fishing access	River/Stream	46.24725	105.74617	MT	Custer	10090102
Y16PMPKC02	Pumpkin Creek Off Hwy. 232 Approx. 1.5 miles upstream of mouth	River/Stream	46.23375	105.71127	MT	Custer	10090102
Y16TNGR01	Tongue River below Hanging Woman Creek near Birney, MT	River/Stream	45.33971	106.52488	MT	Rosebud	10090102
Y16TNYID01	T&Y Irrigation Ditch Near Diversion	Canal	46.25333	105.748611	MT	Custer	10090102
Y16TNYID02	T&Y Irrigation Ditch Near VA Cemetery	Canal	46.3791666	105.82555	MT	Custer	10090102
Y16TNYID03	T&Y Irrigation Ditch near Yellowstone River	Canal	46.507222	105.7097222	MT	Custer	10090102

Table L-2. Water quality parameters and number of samples collected during the 2003 field season.

Parameter	Y15TNGRR01	Y15TNGRR02	Y15TNGRR03	Y16OTTRC02	Y15TNGR01	Y15HNGWC02	Y15HNGWC01	Y16TNGR01	Y16OTTRC01	Y16PMPKC01	Y16PMPKC02	Y16TNYID01	Y16TNYID02	Y16TNYID03
Arsenic Dissolved (µg/L As As)					1		6	5	6	6				
Arsenic Total (µg/L As As)					1		6	5	6	6				
Cadmium Dissolved (µg/L As Cd)					1		6	5	6	6				
Cadmium Total (µg/L As Cd)					1		6	5	6	6				
Calcium Dissolved (mg/L As Ca)				6	6	6	6	1	6	6		5	2	3
Chloride Dissolved (mg/L As Cl)				6	6	6	6		6	6		5	2	3
Chlorophyll a, Periphyton, Spectrophotometric, Corrected (mg/Sq meter)					1		1		1	1				
Chlorophyll a, Phytoplankton, Spectrophotometric, Uncorrected					2		1		1	1				
Chromium Dissolved (µg/L As Cr)					1		5	5	5	5				
Chromium Total (µg/L As Cr)					1		5	5	5	5				
Copper Dissolved (µg/L As Cu)					1		6	5	6	6				
Copper Total (µg/L As Cu)					1		6	5	6	6				
Discharge, Instantaneous, Cubic Feet Per Second				6		4	4	1	6	3		5		4
Hardness Total (mg/L As $CaCO_3$)				1	2	1	2		2	2				
Iron Dissolved (µg/L As Fe)					1		6	5	6	6				
Iron, Total, (µg/L As Fe)					1		6	5	6	6				
Lead Dissolved (µg/L As Pb)					1		6	5	6	6				
Lead Total (µg/L As Pb)					1		6	5	6	6				
Magnesium Dissolved (mg/L As Mg)				6	6	6	6		6	6		5	2	3
Nickel Dissolved (µg/L As Ni)					1		6	5	6	6				
Nickel Total (µg/L As Ni)					1		6	5	6	6				
Nitrogen Ammonia Plus Organic Total (mg/L As N)					6		6		6	6				
Nitrogen Nitrite Plus Nitrate Total (mg/L As N)					6		6		6	6				
Oxygen Dissolved (mg/L)				6	6	6	6	5	6	6		5	1	4
Ph, Water, Whole, Field, Standard Units				6	6	6	6	5	6	6		5	1	4
Phosphorus Orthophosphate Dissolved (mg/L As P)					6		6		6	6				
Phosphorus Total (mg/L As P)					6		6		6	6				
Residue, Total Non Filterable (mg/L)				5	6	5	6	6	6	6		1	1	

Table L-2. Water quality parameters and number of samples collected during the 2003 field season.

Parameter	Y15TNGRR01	Y15TNGRR02	Y15TNGRR03	Y16OTTRC02	Y15TNGR01	Y15HNGWC02	Y15HNGWC01	Y16TNGR01	Y16OTTRC01	Y16PMPKC01	Y16PMPKC02	Y16TNYID01	Y16TNYID02	Y16TNYID03
Selenium Dissolved (µg/L As Se)					1		6	5	6	6				
Selenium Total (µg/L As Se)					1		6	5	6	6				
Silver Dissolved (µg/L As Ag)					1		6	5	6	6				
Silver Total (µg/L As Ag)					1		6	5	6	6				
Sodium Dissolved (mg/L As Na)				6	6	6	6	1	6	6		5	2	3
Total Dissolved Solids (mg/L)				6	6	6	6		6	6		5	2	3
Specific Conductance, µS/cm @ 25 Degrees Celsius				6	6	6	6	5	6	6		5	1	4
Sulfate Dissolved (mg/L As SO_4)				6	6	6	6		6	6		5	2	3
Turbidity (NTU)				6	6	5	6	5	5	6		5	1	4
Water Temperature, Degrees Celsius				6	6	6	6	5	6	6	1	5	1	4
Zinc Dissolved (µg/L As Zn)					1		6	5	6	6				
Zinc Total (µg/L As Zn)					1		6	5	6	6				