Final -
Middle Blackfoot – Nevada TMDL and Water Quality Improvement Plan Addendum

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Steve Bullock, Governor
Tom Livers, Director DEQ

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Prepared by:
Montana Department of Environmental Quality
Water Quality Planning Bureau
Watershed Management Section

Contributors:
Montana Department of Environmental Quality
Water Quality Planning Bureau
Watershed Management Section
Paul Kusnierz, Temperature Project Manager
Information Management and Technical Services Section
Kyle Flynn, Project Model Support

U.S. Environmental Protection Agency
Peter Brumm, Metals and Nevada Lake Project Manager

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

U.S. Environmental Protection Agency, Region 8
10 West 15th Street, Suite 3200
Helena, MT 59626

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TABLE OF CONTENTS

List of Tables

LIST OF FIGURES

ACRONYMS

Acronym	Definition
AML	Abandoned Mine Lands
ARM	Administrative Rules of Montana
BEHI	Bank Erosion Hazard Index
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practices
CWAIC	Clean Water Act Information Center (DEQ)
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
EPA	Environmental Protection Agency (U.S.)
FWP	Fish, Wildlife & Parks (Montana)
GIS	Geographic Information System
GWIC	Groundwater Information Center
LA	Load Allocation
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MDT	Montana Department of Transportation
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSMA	Monosodium Methyl Arsenate
NAIP	National Agricultural Imagery Program
NHD	National Hydrography Dataset
NOAA	National Oceanographic and Atmospheric Administration
NWIS	National Water Information System
PEL	Probable Effects Level
SMES	Small Miner's Exclusion Statement
SNTEMP	Stream Network Temperature Model
SSC	Suspended Sediment Concentration
STORET	EPA STOrage and RETrieval database
SWAT	Soil & Water Assessment Tool
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USFS	United States Forest Service
USGS	United States Geological Survey
UUILT	Ultimate Upper Incipient Lethal Temperature
WLA	Wasteload Allocation

1.0 PROJECT OVERVIEW

This addendum presents total maximum daily loads (TMDLs) for impaired waterbodies in the Middle Blackfoot – Nevada Project Area, including the Blackfoot River, Nevada Lake, Douglas Creek, Murray Creek, and Kleinschmidt Creek.

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. Both the Montana Water Quality Act and the Federal Clean Water Act require DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of pollutant a waterbody can receive and still meet water quality standards. TMDLs provide an approach to improve water quality so that streams and lakes can support and maintain their designated beneficial uses.

The Middle Blackfoot – Nevada Project Area is located in west-central Montana. The drainage area encompasses 1,430 square miles and includes the towns of Helmville, Ovando, and Seeley Lake. The majority of the watershed is within Powell County, with a smaller western portion in Missoula County and an eastern portion in Lewis and Clark County. All surface water flows out of the project area through the Blackfoot River just below the Clearwater River confluence.

In 2008, DEQ established TMDLs addressing 94 waterbody-pollutant combinations in the Middle Blackfoot – Nevada Project Area in the document titled *Middle Blackfoot – Nevada Creek Total Maximum Daily Load and Water Quality Improvement Plan* (Montana Department of Environmental Quality, 2008). Due to insufficient datasets, uncertainties in source determinations, and incomplete assessments, multiple waterbody-pollutant combinations were not addressed through TMDL development in the 2008 document. Seven impairments have remained on subsequent 303(d) lists and one new impairment, iron on lower Douglas Creek, was identified in 2014. These eight waterbody-pollutant combinations are displayed in **Table 1-1**. The purpose of this project is to complete TMDLs for these eight remaining listings in an addendum to the 2008 document. With the approval of this addendum, and in conjunction with another DEQ document under development titled *Blackfoot Headwaters Planning Area Water Quality and Habitat Restoration Plan and TMDL Addendum for Sediment – Sandbar Creek* (Montana Department of Environmental Quality, 2014a), all currently identified impairments in the Blackfoot watershed requiring TMDLs will be addressed.

Table 1-1. Impaired waterbodies and uses with completed TMDLs contained in this addendum

Waterbody & Location Description	Segment ID	TMDL Prepared	TMDL Pollutant Group	Impaired Use(s)
BLACKFOOT RIVER, Nevada Creek to Monture Creek	MT76F001_031	Temperature	Temperature	Aquatic Life
BLACKFOOT RIVER, Monture Creek to Belmont Creek	MT76F001_032	Temperature	Temperature	Aquatic Life
DOUGLAS CREEK, headwaters to Murray Creek	MT76F003_081	Arsenic	Metals	Drinking Water
DOUGLAS CREEK, Murray Creek to mouth (Nevada-Cottonwood Creeks)	MT76F003_082	Arsenic	Metals	Drinking Water
		Iron	Metals	Aquatic Life
KLEINSCHMIDT CREEK, Ward Creek to mouth (Rock Creek)	MT76F004_110	Arsenic	Metals	Drinking Water

Table 1-1. Impaired waterbodies and uses with completed TMDLs contained in this addendum

Waterbody & Location Description	Segment ID	TMDL Prepared	TMDL Pollutant Group	Impaired Use(s)
MURRAY CREEK, headwaters to mouth (Douglas Creek), T12N R12W S6	MT76F003_120	Arsenic	Metals	Drinking Water
NEVADA LAKE	MT76F007_020	Sediment/ Siltation	Sediment	Primary Contact Recreation
				Aquatic Life

This addendum builds off information presented in the *Middle Blackfoot – Nevada Creek Total Maximum Daily Load and Water Quality Improvement Plan* (Montana Department of Environmental Quality, 2008) and therefore contains only the fundamental information necessary to understand the TMDL process. To learn more about the process in detail, including a more comprehensive watershed characterization, water quality standards discussion, and target development explanation, please refer to the 2008 document. The addendum is organized by pollutant group starting with sediment, then progressing to metals and temperature. The sections follow a similar outline that discusses the pollutants' effect on beneficial uses, data sources, and water quality standards, before presenting source assessments, TMDLs, allocations, and implementation recommendations. Following the pollutant group specific sections, the concepts of seasonality, margin of safety, and adaptive management are presented. Lastly, the addendum provides documentation of public comments and DEQ responses.

2.0 Sediment Section

This portion of the document focuses on sediment as a cause of water quality impairment in Nevada Lake (MT76F007_020). It describes: 1) how excess sediment impairs beneficial uses, 2) the currently available data, 3) sediment water quality standards, 4) sources of sediment, 5) the proposed sediment total maximum daily load (TMDL) and rationale, and 6) the recommended implementation strategy. **Figure 2-1** depicts the general location of the impaired lake.

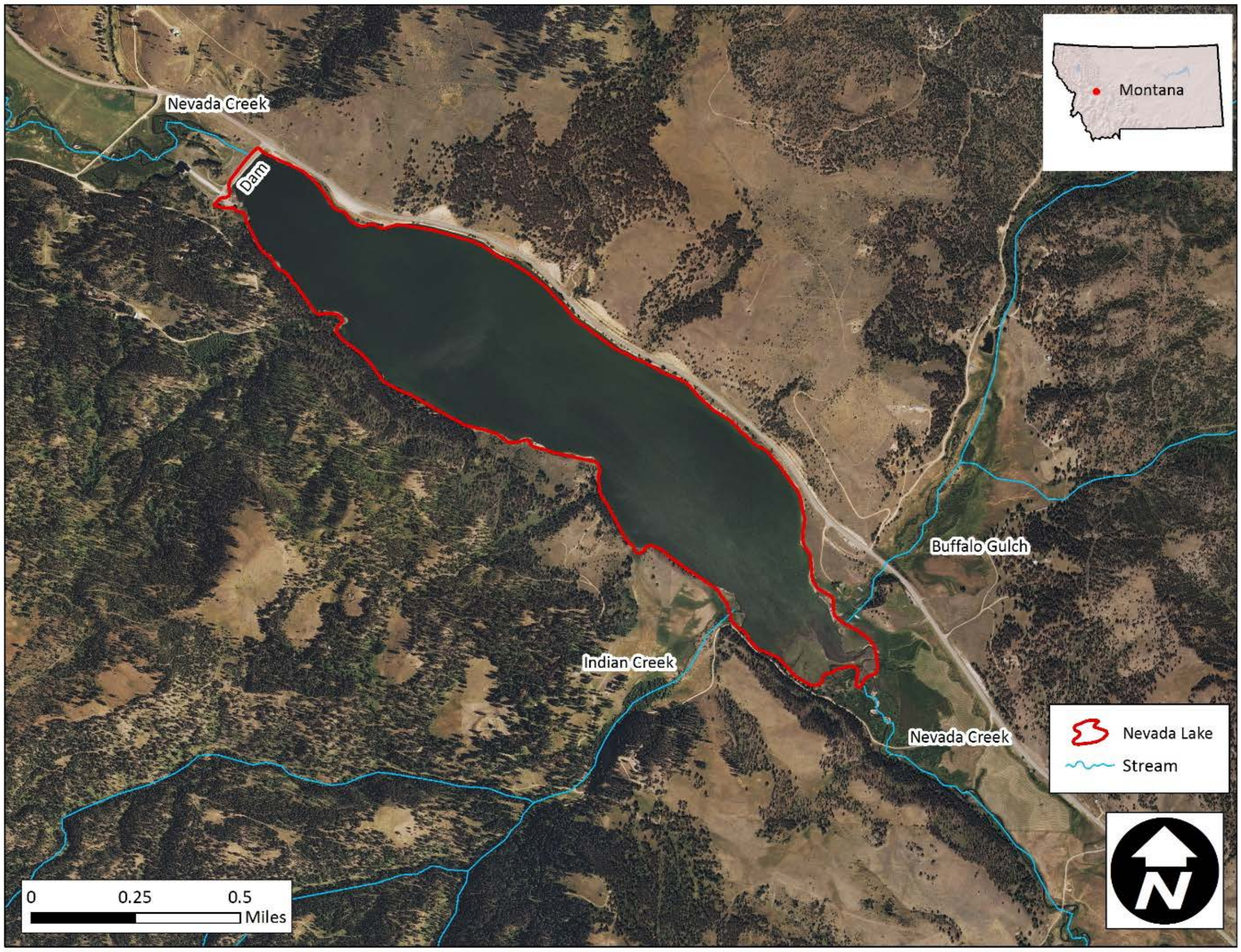

Figure 2-1. Location of Nevada Lake and Major Tributaries

2.1 Effects of Excess Sediment on Beneficial Uses

Nevada Lake is classified as a B-1 water by the state of Montana. By definition (Administrative Rules of Montana (ARM) 17.30.623), it must be maintained suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. Since 1996, the lake has been identified as not supporting the beneficial uses of aquatic life and primary contact recreation due to sedimentation/siltation.

Sediment is a naturally occurring component of healthy lake ecosystems, yet excess sediment can cause undesirable consequences. Specifically, sediment may block light penetration through the water column and cause a decline in primary production thereby affecting the aquatic life food chain (Guildford et al., 1987; Lloyd et al., 1987; Murphy, 1962). It can also interfere with fish and macroinvertebrate survival, reproduction, and foraging behavior, and cause a shift in species composition (Barrett et al., 1992; Blindow et al., 1993; Burton, 1985; Hart.R.C., 1988; Kirk, 1991). The increased rates of deposition affecting aquatic life habitat also cause lakes to fill in (Eckblad et al., 1977). Previous investigations indicate Nevada Lake has lost 12% of its original storage capacity (Dalby, 2006). High concentrations of suspended sediment in lakes can cause water to appear murky and discolored, negatively impacting recreational uses. Sediment can also act as a means of transport for other sediment-bound pollutants such as metals, bacteria and nutrients. The 2008 TMDL document, which established nutrient (total phosphorus, total nitrogen, total kjeldahl nitrogen, and dissolved oxygen) TMDLs for the lake, determined sediment-bound nutrients were a significant source of the nutrient impairment and found the two pollutant groups were closely related. Therefore, implementing load reductions for sediment should help achieve the nutrient TMDLs as well.

2.2 Data and Information Sources

Numerous sources of information were utilized throughout the development of this TMDL addendum. A brief description of the most significant information sources is provided below.

2.2.1 DEQ Monitoring Data and Assessment File

The Montana Department of Environmental Quality (DEQ) has established one monitoring station on Nevada Lake. Data is available at this mid-lake site for the time period 2003-2005, and consists of field parameters, and nutrient and metals samples. The entire sediment-related dataset consists of one total suspended solids (TSS) sample collected on 7/14/2004 with a depth-integrated result of 3.5 mg/L, and seven secchi disk records measuring visible transparency. Secchi depths ranged from 2-8 feet. Both of these measurements are not pure representations of sediment as they include an organic component, such as plankton and algae, thus efforts to isolate sediment conditions in the lake from the nutrient impairment issues based on these parameters can be difficult. A larger dataset of sediment information collected by DEQ is available on Nevada Creek upstream and downstream of the reservoir and on Buffalo Gulch, a tributary to the lake. No new data was collected as part of this addendum effort.

The DEQ assessment file (Montana Department of Environmental Quality, 2014b) contains information used to make the existing sediment impairment determination. The file includes a summary of all known physical, biological, and habitat data collected and/or compiled by DEQ. The file also includes information on sediment water quality characterization and potentially significant sources of sediment. The assessment file is publically available on DEQ's Clean Water Act Information Center (CWAIC) website and related documentation is on file at the Lee Metcalf building in Helena, MT.

2.2.2 Middle Blackfoot – Nevada Creek TMDL 2008 Document

The 2008 TMDL document addressed a multitude of impairments in the Middle Blackfoot-Nevada TMDL Project Area by developing TMDLs for a variety of pollutants including sediment, nutrients, metals and temperature (Montana Department of Environmental Quality, 2008). As part of that effort, DEQ performed water quality monitoring, road assessments, and bank erosion surveys in 2004 and 2005. This information went into designing a watershed computer model to predict nutrient and sediment loading. The Soil and Water Assessment Tool (SWAT) model helped define source assessments and allocations, and allowed for a coarse evaluation of load reduction strategies for meeting water quality standards. For a more detailed description of the SWAT model please refer to Neitsch et al. (2002) or **Appendix I** of the 2008 document for specifics on the Blackfoot watershed simulation (Montana Department of Environmental Quality, 2008). No new model scenarios were run for this addendum.

Nevada Lake has been identified as impaired by sediment since 1996. The sediment impairment was briefly discussed in the 2008 document in context with the lake's closely related nutrient impairment, however, a sediment TMDL was not developed at that time. The 2008 document did establish sediment TMDLs for two major Nevada Lake tributaries: Buffalo Gulch and Nevada Creek above the reservoir, referred to throughout this document as upper Nevada Creek. Additionally, three tributaries to upper Nevada Creek (Jefferson Creek, Washington Creek, and Gallagher Creek) were subject to sediment TMDLs. These TMDLs, along with the watershed-wide source assessments and modeling results included in the 2008 document, were the basis for developing a sediment TMDL for Nevada Lake in this addendum.

2.2.3 USGS Monitoring Data

The United States Geologic Survey (USGS) has established numerous monitoring stations on streams near Nevada Lake. One active site is located three-quarters of a mile above the lake on Nevada Creek (12335500). It records continuous discharge data and is periodically sampled for other field parameters and water quality constituents. This site has records dating back to 1939. Other stations, while no longer active, still provide valuable information. For example, site 464810112490001/12336600 located less than half a mile below the dam, was visited numerous time from 1994-2000 and 2003-2005. In particular, these two USGS stations bracketing the lake with sufficiently robust datasets, help define the lake's influence on water quality by allowing for a comparison between reservoir inputs to outputs.

2.2.4 DNRC Dam-related Information

The Montana Department of Natural Resources and Conservation (DNRC) provided information on the operations and maintenance policy for the Nevada Creek Dam (State Water Projects Bureau, Water Resources Division, Department of Natural Resources, 2001; Montana Department of Natural Resources and Conservation, 2014) and has previously studied the reservoir's sediment budget (Hafferman, 1996; Dalby, 2006). The Nevada Creek Dam, constructed in 1938, provides storage for downstream irrigators in the lower Nevada and Douglas Creek drainages. It is owned by DNRC and managed in consultation with a local water users association. A topographic reservoir survey performed in 1938 estimated the original as-built reservoir capacity at 12,723 acre-feet. A re-survey of the reservoir in 2000 measured a capacity of 11,152 acre feet, which reflects a loss in storage capacity of 1,571 acre feet (12% of total capacity) in 62 years (Dalby, 2006). The outlet works, also known as the dam intake, is located 75 feet below the spillway crest meaning that when flooding is not a concern, water is released downstream to Nevada Creek near the bottom of the 105 feet tall dam (Montana Department of Natural Resources and Conservation, 2014). Accordingly, the dam can be referred to as a bottom release reservoir.

The controlled release of water from Nevada Reservoir for irrigation uses downstream typically begins in mid-May and continues through September 30 (State Water Projects Bureau, Water Resources Division, Department of Natural Resources, 2001). The management of dam releases has altered the hydrology of Nevada Creek below the dam by storing spring runoff and releasing that water later in the irrigation season, resulting in prolonged, above-average streamflows throughout summer months below the reservoir. Further downstream, two major diversions, which feed the Nevada-Douglas Canal and the North Helmville Canal, capture the majority of flows released from Nevada Reservoir. Combined, these diversions are permitted to withdraw up to 65 cfs (Montana Department of Environmental Quality, 2008). The Nevada-Douglas Canal is a trans-basin diversion, crossing Cottonwood Creek before discharging into Douglas Creek. The North Helmville canal crosses several smaller streams including Chimney, Wilson, and Wasson Creeks before discharging into the Blackfoot River upstream of the intersection of Highways 141 and 200. Although there is currently no mandate for minimum flow releases from the dam, DNRC has an agreement with Montana Fish, Wildlife and Parks (FWP) on a recommended minimum outlet discharge of 12-40 cfs (State Water Projects Bureau, Water Resources Division, Department of Natural Resources, 2001) to help maintain the Nevada Creek fishery.

In a 1992 FWP memorandum to DNRC, the state wildlife agency expressed concerns over high turbidity levels in the reservoir discharge. The memo went on to suggest high turbidity was a result of low pool levels, short retention time, headcutting of exposed bottom sediments, and wave action (Hafferman, 1996). DNRC staff also noted the outflow was a brown to brown-green turbid color throughout the year which was not typical of other state reservoirs (Montana Department of Environmental Quality, 2014b). Responding to these concerns, DNRC conducted two years of turbidity monitoring at four sites: Nevada Creek above the reservoir, Nevada Creek below the reservoir, Nevada Creek at Highway 141 crossing, and Washington Creek (Hafferman, 1996). One conclusion drawn from this dataset is that turbidity is often higher in the outflow than the inflow except during spring runoff conditions. DNRC also observed that turbidity was consistently higher at the Nevada Creek station directly above the reservoir than at the Highway 141 station upstream, indicating there are significant sources of turbidity within the reach. Lastly, during the 1994 and 1995 study years, no headcutting or erosion was observed around the dam intake structure during reservoir drawdown and while wave action was not comprehensively assessed, the process did not appear to be a problem (Hafferman, 1996). Around this time DNRC instigated a policy to manage potential bottom erosion and headcutting near the outlet by requiring a minimum reservoir stage that protects the outlet works from freeze and thaw damage during winter months and a maximum winter reservoir stage that protects banks and rip rap from waves and ice (Hafferman, 1996). A structural rehabilitation project was completed on the dam in 2003 that replaced the spillway with a new concrete, uncontrolled crest spillway, added relief wells to reduce foundation pressure, added a toe berm to enhance embankment stability, and extended the outlet works (Montana Department of Natural Resources and Conservation, 2014).

DNRC's most recent investigation into the reservoir's sediment budget is reported in Dalby (2006). This study reviewed suspended sediment concentration (SSC) data collected by USGS from 1980-2000 at gaging stations upstream and downstream of the reservoir, with total suspended solids (TSS) data DNRC collected at the same sites from 1999-2000. Using regression and time-series methods, DNRC was able to develop monthly, seasonal, and annual sediment mass balances for the reservoir that were useful during this TMDL development process. Dalby (2006) indicated the reservoir's mass balance is consistently positive (i.e., more sediment is transported into the lake than is released) from November through June as the reservoir is filling; the balance switches to negative during time periods of reservoir drawdown, from July through September. Throughout the life of the dam, the overall mass balance has been positive as witnessed by the reduced storage capacity of the reservoir.

Nevada Creek below the dam has experienced an altered channel morphology, a degraded fish habitat, and excess streambank sloughing. These issues are generally attributed to the dam's hydrologic modifications and other upstream land use activities in the basin. In 2010, FWP undertook a channel restoration and riparian planting project to help address the degradation in Nevada Creek downstream of the reservoir (Montana Fish, Wildlife and Parks, 2010). To date, no stream restoration work has taken place upstream of the reservoir (Neudecker, Ryen, personal communication 6/10/2014; Schoonen, Jennifer, personal communication 6/13/2014; Ockey, Mark, personal communication 6/25/2014; Neudecker, Greg, personal communication, 6/27/2014; Green, Glen, personal communication, 6/30/2014).

2.3 Sediment Water Quality Standards and Impairment Determination

Montana's water quality standards address bed sediment and suspended sediment via the narrative criteria identified in **Table 2-1**. The standards used in **Table 2-1** are applicable to Nevada Lake and all other B-1 classified waterbodies. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a condition in which any increases in sediment above naturally occurring levels are not harmful, detrimental or injurious to beneficial uses (see definitions in **Table 2-1**).

Table 2-1. Applicable State Rules for Sediment Related Pollutants

Rule(s)	Standard or Definition
17.30.623	B-1 CLASSIFICATION STANDARDS
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1:
17.30.623(2)(d)	The maximum allowable increase above naturally occurring turbidity five nephelometric turbidity units except as permitted in 75-5-318, MCA. Note: 75-5-318, MCA allows for short term variances linked to construction activities, etc.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.60.637	GENERAL PROHIBITIONS
17.30.637(1)(a & d)	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; ….. and (d) create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
17.30.602	DEFINITIONS
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(23)	"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.
17.30.602(27)	"Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water, or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation, or biological activity.

ARM 17.30.602(17) states that "conditions resulting from the reasonable operation of dams in existence as of July 1, 1971 are natural." DEQ encourages the operator to manage the Nevada Creek Dam in a way that strives to minimize sediment transport interruptions caused by the dam in context with the larger Nevada Creek watershed. For example, managment should avoid extended periods of storage followed by abrupt releases that cause spikes in downstream sediment concentrations and loads.

2.3.1 Targets

TMDL water quality targets are a translation of the applicable numeric or narrative water quality standard(s) for each pollutant. For pollutants with established numeric water quality standards, the numeric value(s) are used directly as the TMDL targets. For pollutants with narrative water quality standard(s), such as sediment, the targets provide an interpretation of the narrative standard(s). Water quality targets are typically developed for multiple parameters that link directly to the impaired beneficial use(s) and applicable water quality standard(s). Targets provide a benchmark by which to evaluate attainment of water quality standards. Furthermore, comparing existing conditions to target values allows for a better understanding of the extent and severity of the problem.

The main source of sediment to Nevada Lake is the load delivered by tributaries. Implementing the 2008 TMDLs established for upper Nevada Creek and Buffalo Gulch will help Nevada Lake achieve full beneficial-use support, therefore the lake targets developed in this addendum are linked to the tributary targets found in the 2008 document (Montana Department of Environmental Quality, 2008). DEQ used both modeling and reference condition approaches to estimate naturally occurring sedimentation rates while developing sediment targets and TMDLs for upper Nevada Creek and Buffalo Gulch. Although sediment water quality targets typically relate most directly to the aquatic life use, the targets protect all designated beneficial uses because they are based on the reference approach, which strives for the highest achievable condition. Waterbodies used to determine reference conditions are not necessarily pristine. The reference condition approach is intended to accommodate natural variations from climate, bedrock, soils, hydrology, and other natural physiochemical differences, yet allow for differentiation between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology from human activity. Targets were developed for multiple parameters in the 2008 document such as: width to depth ratio, entrenchment ratio, pool frequency, woody vegetation extent, and fine sediment abundance. While these targets are clearly applicable to stream systems, some, such as the fine sediment targets, also have a direct influence on downstream lake health. Recognizing this relationship, the tributary stream fine sediment targets were adopted as lake targets.

Achieving sediment targets in upper Nevada Creek and Buffalo Gulch is considered a crucial step toward meeting water quality standards in Nevada Lake. Once the excessive tributary sediment load is controlled, determinations regarding beneficial-use support must assess the surplus sediment already in the system. A process to directly gage lake health must be employed before any delisting scenario could occur that would upgrade the lake's impaired status. DEQ does not currently have a standardized methodology for assessing sediment impairments in lakes, therefore, this addendum stresses an adaptive management approach, as described in **Section 6.0**, which allows for target modification as assessment methods are developed and new monitoring data is collected. An in-lake target is not proposed in this addendum due largely to the lack of in-lake sediment data. Future lake monitoring should include parameters such as turbidity, TSS, SSC, secchi depths, bank erosion rates, and sedimentation rates from which additional lake targets can be derived to better assess conditions within the lake. Considering these limitations, DEQ adopted tributary loading targets and tributary fine sediment targets to evaluate TMDL compliance in Nevada Lake.

Loading Targets

As previously mentioned, to address the sediment impairment within Nevada Lake, the excess sediment coming into the lake must be controlled. Specifically, the collective sediment load needs to be reduced from the three major tributaries: Indian Creek, Buffalo Gulch, and Nevada Creek. Two of these tributaries have documented excess sediment problems and TMDL reduction plans already in place. For Nevada Lake, the primary targets chosen to represent TMDL compliance are annual sediment loading limits applied to the three tributaries (see **Table 2-2**).

Table 2-2. Loading targets for Nevada Lake

Tributary	Target (tons/yr)	Target Origin Citation
Indian Creek	110	This Addendum
Buffalo Gulch	391	(Montana Department of Environmental Quality, 2008)
Upper Nevada Creek	2,592	(Montana Department of Environmental Quality, 2008)

The targets for Buffalo Gulch and Nevada Creek are equivalent to the Buffalo Gulch and upper Nevada Creek TMDLs developed in 2008 (Montana Department of Environmental Quality, 2008). Indian Creek does not have an established sediment TMDL and is not listed as impaired on the 303(d) list because it has never been assessed. In order to identify Indian Creek's loading contribution to Nevada Lake, this addendum followed the process used in the 2008 document to estimate existing loads which is described more in **Section 2.4.1**.

No reduction from the Indian Creek watershed is required in this addendum. Because no monitoring has occurred on Indian Creek and it has never been assessed for water quality attainment, DEQ relied on modeling results and reviewed aerial photos and land use patterns to support this decision. The SWAT model, which takes into account subwatershed-specific climate, soil properties, topography, vegetation and land management practices, estimated a lower existing annual sediment load for Indian Creek than similar sized subwatersheds deemed impaired. This model output is underlined by the fact that land cover in the Indian Creek watershed is largely undisturbed forest with some smaller areas recovering from past timber harvest and no land in cultivated crop or hay production – land uses sometimes indicative of higher erosion rates (Montana Natural Heritage Program, 2013). Aerial photos from 2011 also indicate a well-established riparian (Montana State Library, 2011). The Indian Creek target in **Table 2-2** may be modified in the future following monitoring and assessment that compares Indian Creek data to stream targets similar to those established for area streams in the 2008 document.

Fine Sediment Targets

Since quantifying annual sediment loads can be difficult, this addendum also adopts a suite of tributary fine sediment targets as Nevada Lake targets. Because fine sediment (measured as percent fines < 6.35 mm) is easily transported through the stream network, measurements of this indicator are of special concern to a downstream waterbody like Nevada Lake. The fine sediment targets developed for upper Nevada Creek and Buffalo Gulch in **Section 5.1.1** of the 2008 document are applied as targets for Nevada Lake (see **Table 2-3**). These targets were selected as reference values from DEQ's 2004 field monitoring dataset in the Middle Blackfoot – Nevada Project Area and are dependent upon Rosgen channel type classification (Rosgen, 1996). The highest potential for Buffalo Gulch is a B channel type while Nevada Creek has sections of B and C channels. Data collection techniques are described in the document titled *Field Updated Quality Assurance Project Plan and Sampling and Analysis Plan (QAPP/SAP) Middle Blackfoot and Nevada Creek TMDL Planning Areas* (DTM Consulting, Inc., 2004). Note, DEQ's standard sediment data collection techniques for streams (Montana Department of

Environmental Quality, 2013) have evolved since 2004, therefore, the targets presented in **Table 2-3** may need to be modified to reflect these changes when future monitoring and assessment occurs.

Table 2-3. Tributary fine sediment targets for Nevada Lake

Stream	Target
Buffalo Gulch (All) and Nevada Creek (B channel)	Riffle substrate <6mm: ≤20% Riffle substrate <2mm: ≤10% McNeil core <6.35mm: ≤27% McNeil core <2mm: ≤12% McNeil core <0.85: ≤6% Median pool tail surface fines <6mm: ≤17%
Nevada Creek (C channel)	Riffle substrate <6mm: ≤22% Riffle substrate <2mm: ≤7% McNeil core <6.35mm: ≤27% McNeil core <2mm: ≤15% McNeil core <0.85: ≤6% Median pool tail surface fines <6mm: ≤23%

For these fine sediment targets, future surveys should document stable (if currently meeting criterion) or improving trends. The exceedance of one or more target values does not necessarily equate to a determination that the information supports impairment; the degree to which one or more targets are exceeded are taken into account. The combination of target analysis, qualitative observations, and sound, scientific professional judgment is crucial when assessing stream condition. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented here, or special interpretation of the data relative to the sediment target values.

2.3.2 Impairment Determination

Sediment has been listed as impairing the support of primary contact recreation and aquatic life in Nevada Lake since 1996. The assessment record cites a moderately disturbed shoreline and high turbidity levels below the dam as rationale for listing (Montana Department of Environmental Quality, 2014b). DNRC estimates the reservoir has lost 12% of its storage capacity since being built, indicating that excess sediment is slowing filling in the lake (Dalby, 2006). Since the original impairment determination in the 1990s, dam management policies have been modified to reduce the dam’s environmental impact. DNRC and the local water users association established minimum and maximum pool elevations to help prevent excessive sediment entrainment, bank erosion and high turbidity levels downstream (Dalby, 2006; Montana Department of Environmental Quality, 2008). DNRC has also, in consultation with FWP, agreed to maintain a minimum flow at the dam outlet of 12-40 cfs to support the lower Nevada Creek fishery (State Water Projects Bureau, Water Resources Division, Department of Natural Resources, 2001). The dam’s structural rehabilitation project completed in 2003 may have improved conditions in lower Nevada Creek, however, the limited data displayed in **Figure 2-2** indicates that suspended sediment concentrations (SSC) post-2003 changed little from 1996 when the lake was originally listed as impaired. More recent SSC data could help better characterize existing conditions and help define potential improvements following FWP’s 2010 channel restoration work in lower Nevada Creek.

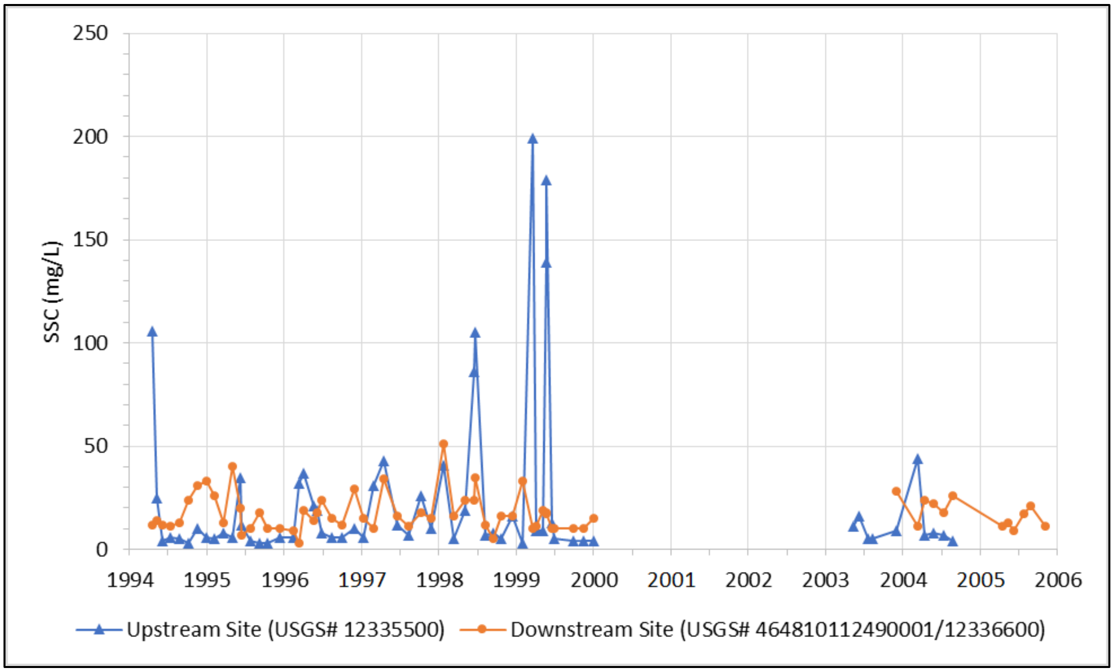

Figure 2-2. Suspended Sediment Concentrations (SSC) in Nevada Creek at USGS sites upstream and downstream of Nevada Lake

Section 5.2 of the 2008 document presents a target departures analysis for Buffalo Gulch and upper Nevada Creek including a comparison between the Nevada Lake targets listed in **Table 2-3** and sampling data collected by DEQ in 2004. The target departures analysis determined both streams were impaired by sediment. **Section 9.1.6** of the 2008 document presents the reductions required in total annual loading for Buffalo Gulch and upper Nevada Creek. No stream restoration work or significant Best Management Practice (BMP) implementation has occurred since the previous tributary impairment determinations that would have significantly altered water quality conditions and required an updated source assessment and target departures analysis (Neudecker, Ryen, personal communication 6/10/2014; Schoonen, Jennifer, personal communication 6/13/2014; Ockey, Mark, personal communication 6/25/2014; Neudecker, Greg, personal communication, 6/27/2014; Green, Glen, personal communication, 6/30/2014). Considering conditions have not changed since the 2008 document which identified sediment impairments on two major tributaries, and given the lake's existing impairment status, a sediment TMDL for Nevada Lake is presented in this addendum. It is possible that DEQ would conclude that Nevada Reservoir is not impaired for sediment if all the necessary data and information to evaluate "harm to use" were available. Any future impairment status update will likely require a combination of standards interpretative work along with additional data and information collection.

2.4 Source Assessment and Quantification

This section summarizes the source assessment approach, current sediment load estimates, and the determination of the allowable load for each source. DEQ determines the allowable load by estimating the obtainable load reduction once all reasonable land, soil, and water conservation practices have been implemented. The reduction forms the basis of the allocations and TMDL provided in **Section 2.5**. This section focuses on five potentially significant sediment sources and the associated controllable human loading for each of these source:

- Indian Creek
- Buffalo Gulch
- Upper Nevada Creek
- Permitted point sources
- Shoreline erosion and lakebed sediment resuspension

Environmental Protection Agency's (EPA) guidance for developing sediment TMDLs states that the basic procedure for assessing sources includes compiling an inventory of all sediment sources to the waterbody. In addition, the guidance suggests using one or more methods to determine the relative magnitude of loading, focusing on the primary and controllable sources (U.S. Environmental Protection Agency, 1999). Federal regulations allow that loadings "may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" (Water quality planning and management, 40 Code of Federal Regulations 130.2(G)).

2.4.1 Indian Creek

Indian Creek is a second order tributary to Nevada Lake that originates southwest of the reservoir (see **Figure 2-1**). It flows mostly through federally owned land managed by the Bureau of Land Management, with a small privately owned portion near the mouth. Unlike Buffalo Gulch and Nevada Creek, Indian Creek has no history of listing for sediment impairment and was not subject to a sediment TMDL in the 2008 document. In order to estimate the existing sediment load coming from this watershed, the same process employed in 2008 for these other streams was applied to Indian Creek in this addendum. The existing sediment load for Indian Creek is considered the sum of four source categories: culvert failure, road crossings, hillslope erosion and streambank erosion. The source assessment process for each category is briefly presented below. Additional details are contained in **Appendix C** and **Appendix J** of the 2008 document (Montana Department of Environmental Quality, 2008).

Culvert Failure

When undersized culverts fail, a large mass of the road fill is introduced to the stream channel. The 2008 document accounted for these episodic contributions by surveying a subset of culverts in the field and then extrapolating an average mass at risk of failure for each culvert in the Middle Blackfoot – Nevada TMDL Project Area (River Design Group, 2006). For this addendum, DEQ performed a Geographic Information System (GIS) analysis that counted the number of intersections between USGS's National Hydrography Dataset High Flowline layer (1:24,000) and Montana's Spatial Data Infrastructure Roads layer. Nineteen road crossings were identified in the Indian Creek watershed. In 2005, 73 culverts were surveyed in the Middle Blackfoot-Nevada Project Area. The average mass at risk per culvert in the Nevada Creek watershed was identified as 62.4 tons. Following the 2008 document, this average mass was multiplied by the number of culverts in each subbasin to arrive at a total mass at risk in the Indian Creek watershed of 1,185 tons. Lastly, applying a one percent failure rate results in an estimated 12 tons of sediment contributed annually from culverts in the Indian Creek watershed.

Road Crossings

The network of unpaved roads also contributes a sediment load by reducing infiltration, concentrating overland flow, increasing surface erosion and acting as a conduit by delivering entrained sediment to streams (Megahan and Kidd, 1972; Trombulak and Frissell, 2000). Sediment contributions from roads are greatest where Best Management Practices (BMPs) that divert flow off the roadbed are lacking (e.g., dips, water bars, outsloped road bed, etc.) or where roads are closest to stream, like at crossings, because vegetated buffers that filter out sediment are minimized at these sites. A subset of road crossings were surveyed during the same field monitoring effort that investigated culverts in 2005 (River Design Group, 2006). Roads were assessed using the Washington Forest Practices Board Watershed Assessment Methodology (Washington Forest Practices Board, 2001). Surveyed road crossings were selected to represent typical conditions across different categories of road ownership, precipitation, and geology. Mean road erosion values were calculated for each road category combination (i.e., ownership, precipitation class, geology) as identified by GIS analysis. These mean erosion values were then extrapolated to unsurveyed road crossings with matching categories. All 19 of the road crossings in the Indian Creek watershed are listed by Montana's Spatial Data Infrastructure Roads layer as privately owned, range in annual precipitation from 18-24 inches, and overlay Tertiary volcanic rocks or alluvium. Forty-one crossings were surveyed in the Middle Blackfoot-Nevada Project Area that met this combination of categories and the mean annual load from each crossing was estimated to be 1.6 tons per year (River Design Group, 2006). Multiplying this load by the number of crossing in the Indian Creek watershed results in 30 tons per year as an estimated annual load from road crossings.

Hillslope Erosion

Hillslope erosion is the wearing away of surface soil by water, wind, ice, or other geological processes. Rates of hillslope erosion are controlled by climatological factors (e.g., precipitation, wind, temperatures, etc.), pedological factors (e.g., compaction, soil saturation, soil erodibility, parent geology, slope, etc.), and environmental factors (e.g., vegetation, roads, land use, disturbance, etc.). Hillslope erosion, which is often a continuous process, differs from episodic mass wasting events or landslides. The 2008 TMDLs estimated hillslope erosion using the SWAT model. The model output tons of hillslope sediment delivered annually from each subbasin. Because of limitations within the SWAT model related to land slope, the assumption was applied within the model that only lands within 350 feet of the stream channel having greater than 3% slope contribute sediment through hillslope erosion. Twenty-nine percent of the Indian Creek watershed met this criteria. This percentage, termed the sheetflow source area fraction, was multiplied by the SWAT model output (139 tons/yr) to arrive at an estimated annual sediment load to Indian Creek from hillslope erosion of 40 tons.

Streambank Erosion

To estimate the sediment load attributed to streambank erosion, DEQ conducted field inventories on a subset of streams in the Middle Blackfoot-Nevada Project Area in 2004 (DTM Consulting, Inc. and Applied Geomorphology, Inc., 2006). Inventories were performed in accordance with the Bank Erosion Hazard Index (BEHI) method (Rosgen, 2001). BEHI provides a qualitative erosion severity, ranging from very low to extreme. These terms were translated into numeric retreat rates in feet per year based literature values from work performed in Idaho (Zaroban and Sharp, 2001). Multiplying the selected retreat rate by the eroding bank length measured in the field, and the soil density provided by the National Resources Conservation Service (NRCS), yields a yearly tonnage of sediment attributable to bank erosion. Next, inventoried bank erosion rates were extrapolated to streams not surveyed using a calculation relating upstream precipitation to streambank erosion rates. Following these steps for Indian Creek, approximately 28 tons per year of sediment is introduced into the system from streambank erosion.

Total Load

By summing the four source categories just discussed (culvert failure, road crossings, hillslope erosion and streambank erosion), DEQ estimates the Indian Creek watershed is contributing 110 tons of sediment to Nevada Lake annually (see **Table 2-4**).

Table 2-4. Indian Creek existing load, target load, and Nevada Lake target – by source category

Source Category	Existing Load (tons/yr)	Percent Reduction From Existing Load	Target Load (tons/yr)
Culvert Failure	12	0%	12
Road Crossings	30	0%	30
Hillslope Erosion	40	0%	40
Streambank Erosion	28	0%	28
Total	110	0%	110†

†Nevada Lake target

For reasons explained in **Section 2.3.1**, no reduction in sediment loading is currently required from Indian Creek. If future monitoring indicates a reduction is justified, the Nevada Lake TMDL target for Indian Creek will be modified.

2.4.2 Buffalo Gulch

Buffalo Gulch is a six mile long tributary to Nevada Lake that originates northeast of the reservoir (see **Figure 2-1**). In its headwaters, Buffalo Gulch is a B channel type bounded by dense conifer forest (see Figure A-20, Montana Department of Environmental Quality, 2008). Aerial assessments indicate that timber harvest of the uplands has been extensive. Roads built for logging and other purposes are widespread throughout the entire drainage, but are especially prevalent in the headwaters region. Roads follow gentler valley bottoms alongside waterways and cross stream channels 39 times. Moving downstream from the headwaters two miles, United States Forest Service (USFS) ownership transitions into private land and vegetative cover changes to sagebrush grasslands. This break also marks a geologic boundary between Proterozoic sediments upstream and Tertiary-age volcanic rocks downstream (see Figure A-31, Montana Department of Environmental Quality, 2008). In the middle Buffalo Gulch reach, historic placer mining left tailings intermittently along the channel margin. Extensive bank trampling in portions of the middle reach caused a shift from a relatively narrow and deep E channel type to a wide, shallow C channel (Pierce et al., 2002). The lowermost portion of Buffalo Gulch flows through a willow-dominated valley bottom that is grazed and cultivated for hay. Montana FWP described this reach as a meandering, gravel dominated channel with low sediment levels bounded by a dense riparian shrub community (Pierce et al., 2002). Fisheries-related impairments identified in the lower 3 miles of Buffalo Gulch include livestock-induced streambank damage, riparian vegetation suppression, and lack of instream wood/complex fish habitat (Pierce, 2002).

The 2008 document estimated existing source category loads for Buffalo Gulch following the same processes described in **Section 2.4.1** for Indian Creek. **Table 2-5** provides Buffalo Gulch's existing load, necessary percent reduction and target load by source category. The total existing sediment load produced in the Buffalo Gulch drainage and delivered to Nevada Lake is estimated to be 571 tons per year. This load needs to be reduced by 32% to meet the Buffalo Gulch sediment TMDL and the loading target established in this addendum for Nevada Lake.

Table 2-5. Buffalo Gulch existing load, target load, and Nevada Lake target – by source category

Source Category	Existing Load (tons/yr)	Percent Reduction From Existing Load	Target Load (tons/yr)
Culvert Failure	24	75%	6
Road Crossings	23	30%	16
Hillslope Erosion	366	34%	242
Streambank Erosion	158	20%	127
Total	571	32%	391†

†Nevada Lake target

Reductions are based on BMP implementation and their effectiveness in controlling sediment for each source category. They reflect reasonable reductions as determined from literature, field assessments, and both agency and industry documentation of BMP effectiveness. Reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. **Section 9.1** of the 2008 document provides more detail on these expected reductions, such as key assumptions and references for the chosen values (Montana Department of Environmental Quality, 2008).

The 2008 document also split loading into five human-influenced categories based on the spatial extent of land use identified from 2004 field observations, interpretations of aerial imagery, and the 2001 National Land Cover Dataset (Montana Department of Environmental Quality, 2008). As shown in **Table 2-6**, the majority of loading comes from the livestock grazing and timber harvest land uses although all land uses are expected to reduce loading by at least 19%.

Table 2-6. Buffalo Gulch existing load, target load, and Nevada Lake target – by land use

Land Use Category	Existing Load (tons/yr)	Percent Reduction From Existing Load	Target Load (tons/yr)
Livestock Grazing	246	20%	196
Hay Production	48	21%	38
Timber Harvest	215	32%	122
Placer Mining	16	19%	13
Roads	47	53%	22
Total*	571	32%	391†

*Category sums may not match Total due to rounding
†Nevada Lake target

2.4.3 Upper Nevada Creek

Upper Nevada Creek extends from its headwaters approximately 19 miles to Nevada Lake. The upper four miles of Nevada Creek is a B channel type that is highly confined, densely forested and completely contained within National Forest boundaries (see Figure A-20 and A-22, Montana Department of Environmental Quality, 2008). Moving two miles downstream, the valley bottom widens, and timber harvest is evident from aerial assessment. Within this reach, roads begin to encroach the creek and the legacy effects of placer mining start to appear. While Nevada Creek was lightly placer mined, more extensive operations occurred in northern tributaries such as American Gulch, Jefferson Creek and Washington Creek (see Figure A-24, Montana Department of Environmental Quality, 2008). To provide an example of how intense placer mining was, in the 1860s, miners dug a 13 mile ditch by hand to divert Nevada Creek water to sluices in the Washington Creek basin (Phillips and Humphrey, 1987). Elsewhere, streams have been straightened, hydraulic mining has created unstable headwalls, and dredge piles have been left eroding within floodplains (Phillips and Humphrey, 1987).

From the USFS boundary to Washington Creek, gazing pressure, bank erosion and width to depth ratios increase relative to the upper 10 miles. A field assessment report from the 1990s noted livestock holding corrals in the stream corridor (McGuire, 1995). In the 3.5 miles from Washington Creek to the mouth, conditions in Nevada Creek generally worsen. Streamside vegetation declines while channelization and widespread bank erosion become problematic. Hay production is the most significant land use in the valley bottom. Investigations into the Nevada Creek fishery identified degradation from excessive livestock access to riparian areas causing bank erosion (Pierce, 2002).

The 2008 document estimated existing source category loads for upper Nevada Creek following the same processes described in **Section 2.4.1** for Indian Creek. **Table 2-7** provides upper Nevada Creek's existing load, necessary percent reduction, and target load by source category. The total existing sediment load produced in the upper Nevada Creek drainage and delivered to Nevada Lake is estimated to be 3,501 tons per year. This load needs to be reduced by 26% to meet the Nevada Creek sediment TMDL and the loading target established in this addendum for Nevada Lake.

Table 2-7. Upper Nevada Creek existing load, target load, and Nevada Lake target – by source category

Source Category	Existing Load (tons/yr)	Percent Reduction From Existing Load	Target Load (tons/yr)
Culvert Failure	11	73%	3
Road Crossings	29	31%	20
Hillslope Erosion	1,826	30%	1,278
Streambank Erosion	1,634	21%	1,290
Total*	3,501	26%	2,592†

*Category sums may not match Total due to rounding
†Nevada Lake target

Reductions are based on BMP implementation and their effectiveness in controlling sediment for each source category. They reflect reasonable reductions as determined from literature, field assessments, and both agency and industry documentation of BMP effectiveness. Reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. **Section 9.1** of the 2008 document provides more detail on these expected reductions, such as key assumptions and references for the chosen values (Montana Department of Environmental Quality, 2008).

The 2008 document also split loading into five human-influenced categories based on the spatial extent of land use identified from 2004 field observations, interpretations of aerial imagery, and the 2001 National Land Cover Dataset (Montana Department of Environmental Quality, 2008). As shown in **Table 2-8**, the majority of loading comes from the livestock grazing and hay production land uses although all land uses are expected to reduce loading by at least 21%.

Table 2-8. Upper Nevada Creek existing load, target load, and Nevada Lake target – by land use

Land Use Category	Existing Load (tons/yr)	Percent Reduction From Existing Load	Target Load (tons/yr)
Livestock Grazing	1,453	27%	1,065
Hay Production	1,943	25%	1,452
Timber Harvest	33	21%	26
Placer Mining	33	21%	26
Roads	40	43%	23
Total*	3,501	26%	2,592†

*Category sums may not match Total due to rounding
†Nevada Lake target

2.4.4 Permitted Point Sources

According to EPA's Integrated Compliance Information System, there are no Montana Pollutant Discharge Elimination System (MPDES) permitted point sources discharging into Nevada Lake or any upstream tributary as of June 2014. Although some mining-related sources (e.g., adit discharges) are considered non-permitted point sources subject to Wasteload Allocations (WLAs) (Dodson, Max H., personal communication 12/22/93), the placer mines in the Nevada Creek basin do not fall into this category.

2.4.5 Shoreline Erosion and Lakebed Sediment Resuspension

Shoreline erosion is another potential source of sediment to Nevada Lake. The DEQ assessment record acknowledges a disturbed, poorly vegetated shoreline and suggests wave action may contribute to the excess sediment problem (Montana Department of Environmental Quality, 2014b). Field efforts to quantify shoreline erosion have been proposed by different entities but never undertaken. In a reservoir built and managed for irrigation purposes, water level manipulation will always occur, however, the level will never exceed the maximum pool elevation under normal circumstances because it is controlled by the spillway elevation. This annually consistent elevation allows for a clear distinction to be made between what is termed shoreline erosion and what DEQ considers lakebed sediment resuspension. Sediment introduced to the lake originating above this line is considered shoreline erosion, if not already captured in previously quantified source categories (i.e., culvert failure, road crossings, hillslope erosion, or tributary bank erosion). Sediments originating below this line are considered a redistribution of sediment already within the lake system and not an external source contributing a “new” load which would need to be captured in a separate source category.

To investigate shoreline erosion in this addendum, DEQ reviewed aerial photography for visible evidence of retreating banks and lake surface area enlargement that would indicate an actively eroding shoreline. Multiple years of National Agriculture Imagery Program (NAIP) orthoimagery (Daumiller, 2014), supplied by the United States Department of Agriculture, provide an eight year window of conditions. These photos were taken during the same growing season time period (July or August) at roughly the same reservoir stage. Aerial photos reveal an indistinguishable amount of shoreline erosion. The south and north shores of the lake are topographically confined by steep hillsides and composed of coarse-sized rock, unlikely to be affected by wave erosion. The north shore is further considered stationary because the lake is closely encroached by Highway 141 and rip rapped. The shoreline on the south-east end of the lake is less distinct because water levels in this flat topographic area of the Nevada Creek delta fluctuate greatly with reservoir stage. Yet even in this region most influenced by reservoir operations, bank sloughing and retreat does not appear prevalent. These observations support DNRC’s findings that the reservoir storage capacity is diminishing (Dalby, 2006) because the lake is filling in, not increasing capacity through lateral expansion.

Three potential situations exist that redistribute sediment within the Nevada Lake system below the maximum pool elevation. First, existing lakebed sediments may become resuspended in the water column as a consequence of the wind shear stress exerted on the water surface. The shallow Nevada Creek delta region of the lake inlet may be particularly susceptible to this phenomena (Dalby, Chuck personal communication 2014). Second, dry lakebed sediments previously underwater may become resuspended by wave action throughout the summer as irrigation drawdown of the reservoir continues. And lastly, during low pool conditions in the Nevada Creek delta region, the creek downcuts through the excess fine sediment deposited by the tributaries and appears incised. These easily entrained and mobile sediments can affect turbidity levels in the lake.

For the reasons stated above, shoreline erosion is not considered a significant source of sediment to Nevada Lake and resuspension of lakebed sediments is not considered an external loading source that would require a separate allocation in the Nevada Lake TMDL. Future investigations studying the interaction between the shoreline and the lake could help better place shoreline erosion into context with the lake’s internal sediment cycling. As with other aspects of this addendum, an adaptive management approach will be followed if the assumptions presented here are found to be inaccurate.

2.5 TMDL AND ALLOCATIONS

A "TMDL" is specifically defined as a "daily load," however expressing a maximum load over a different time scale may be more appropriate for some pollutants to characterize, quantify and manage sources. Such is the case for sediment, which has a cumulative effect on aquatic life and has highly episodic loading tendencies that are strongly tied to snowmelt runoff and stream discharge. A more common presentation of sediment TMDLs is an allowable annual load in terms of tons per year. A maximum annual load for Nevada Lake is established below, as are daily loads in order to satisfy EPA requirements of an approvable TMDL (Grumbles, Benjamin, personal communication 2006).

Cover et al. (2008) observed a correlation between sediment supply and instream measurements of fine sediment in riffles and pools. DEQ assumes that a decrease in sediment supply, particularly fine sediment, will correspond to a decrease in the percent fine sediment deposition within tributary streams and help attain sediment-related water quality standards downstream within Nevada Lake. While annual and daily loads are provided in this addendum, a percent reduction approach is most preferable because there is no numeric sediment standard from which to calculate the allowable load and because of the uncertainty associated with the loads derived from the source assessment (which are used to establish the TMDL), particularly when comparing different load categories, such as road crossings to bank erosion. Additionally, the percent reduction TMDL approach is more applicable for restoration planning and sediment TMDL implementation because this approach helps focus on implementing water quality improvement practices (i.e., BMPs) versus focusing on uncertain loading values. An implicit margin of safety (MOS) is applied and further discussed in **Section 5.0**.

It is important to recognize that the first critical step toward meeting the sediment allocations involves applying and/or maintaining the land management practices, or BMPs, that will reduce sediment loading. Once these actions have been completed at a given location, the landowner or land manager will have taken action consistent with the intent of the sediment allocation for that location. For many nonpoint source activities, it can take several years or decades to achieve the full load reduction at the location of concern, even though full BMP implementation is in effect. For example, it may take several years for riparian areas to fully recover after implementing grazing BMPs or allowing re-growth in areas of past riparian harvest. It is also important to apply proper BMPs and other water quality protection practices for all new or changing land management activities to limit any potential increased sediment loading. Progress toward TMDL and individual allocation achievement can be gaged by implementing BMPs for nonpoint sources, and improving or attaining the water quality targets defined in **Section 2.3.1**. Any effort to calculate loads and percent reductions for comparison with TMDLs and allocations in this document should be accomplished via the same methodology and/or models used to develop the loads and percent reductions presented within this document

2.5.1 Annual Loads

As previously mentioned, an annual expression of the TMDL is the most appropriate timescale because sediment generally has a cumulative effect on aquatic life and other designated uses and because sediment sources are highly episodic and seasonal. The maximum allowable sediment load for Nevada Lake in terms of tons per year, can be estimated by summing the individual sources described in the source assessment section as expressed by the following formula:

$$Load_{IndianCreek} + Load_{BuffaloGulch} + Load_{UpperNevadaCreek} = Load_{NevadaLake}$$

$$110 \text{ tons/yr} + 391 \text{ tons/yr} + 2{,}592 \text{ tons/yr} = 3{,}093 \text{ tons/yr}$$

The maximum allowable sediment load for Nevada Lake expressed on an annual timescale is 3,093 tons per year with an implicit MOS.

2.5.2 Daily Loads

EPA encourages TMDLs to be expressed in the most applicable timescale but also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Daily loads should not be considered absolutely conclusive and may be refined in the future as part of the adaptive management process. The TMDLs may not be feasible at all locations within the watershed but if the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired. It is not expected that daily loads will drive implementation activities.

The preferred approach for calculating a daily sediment lake load is to use a water quality gage at the inlet or outlet with a long-term dataset of streamflow and suspended sediment. Unfortunately, the USGS gages above and below the reservoir do not have daily suspended sediment data. In the absence of paired streamflow and sediment data, daily streamflow can be a useful surrogate for representing daily sediment loading because concentrations within streams and sediment loading to streams (and downstream waterbodies), is strongly related to runoff and streamflow, which increases during spring runoff and storm events. Using the average of daily mean discharge values from 74 years of record (1939 - 2013) at the USGS station on Nevada Creek above the reservoir near Helmville, MT (12335500), a daily percentage relative to the mean annual discharge was calculated for each day (see **Appendix A, Table A-1**). A daily sediment load can be calculated by multiplying the percentages in **Table A-1** by the total annual load. For instance, the total allowable annual sediment load for the Nevada Lake is 3,093 tons. To determine the TMDL at the lake inlet for January 1st, 3,093 tons is multiplied by 0.08% which provides a daily load of 2.47 tons. **Figure 2-3** displays the daily sediment load for Nevada Lake which mimics the annual Nevada Creek hydrograph at USGS gage 12335500.

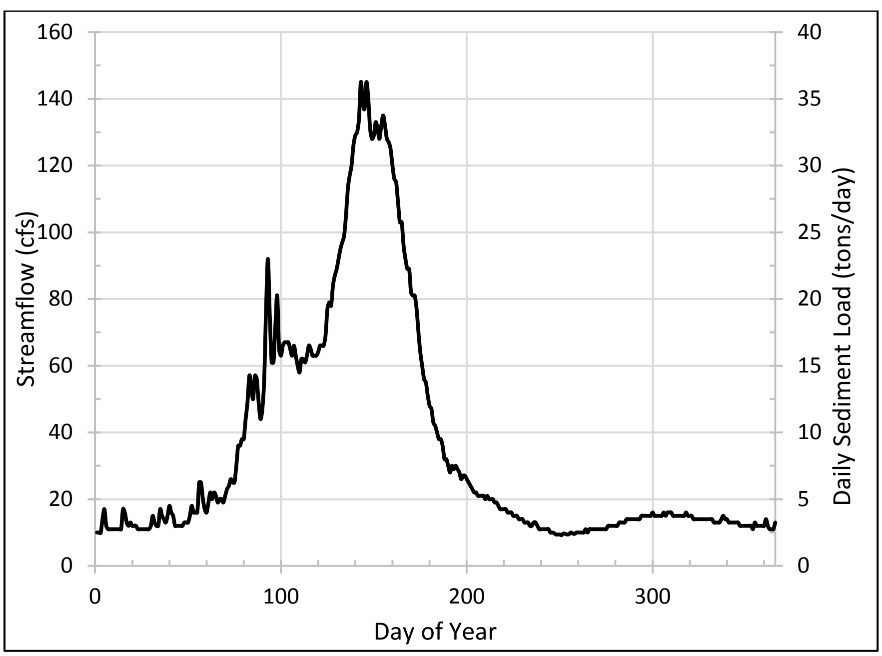

Figure 2-3. Mean Daily Streamflow and Calculated Daily Sediment Load

2.5.3 Percent Reductions

In addition to annual and daily loads, the Nevada Lake sediment TMDL is presented as a percent reduction in total annual loading. This approach is advantageous because there is uncertainty associated with the source assessment loads and because an identified percent reduction is more applicable for restoration planning. The necessary percent reduction is calculated by subtracting the target load (3,093 ton/yr) from the existing load (4,182 tons/yr), and dividing the difference by the existing load. As shown in **Table 2-9**, DEQ estimates a 26% reduction in sediment loading from tributaries is required to meet sediment water quality standards in Nevada Lake. Detailed reductions by source category (i.e., culvert failure, road crossings, hillslope erosion, and streambank erosion) are presented for upper Nevada Creek and Buffalo Gulch in **Section 2.4**.

Table 2-9. Total Percent Reduction for Nevada Lake and Tributaries

Allocation	Existing Load (tons/yr)	Target Load (tons/yr)	Percent Reduction from Existing Load
Nevada Creek	3,501	2,592	26%
Buffalo Gulch	571	391	32%
Indian Creek	110	110	0%
Nevada Lake	4,182	3,093	26%

2.6 IMPLEMENTATION

This addendum relies on the implementation recommendations for Nevada Lake, upper Nevada Creek, and Buffalo Gulch presented in **Section 10.0** of the 2008 document (Montana Department of Environmental Quality, 2008). Implementation is focused on the application of BMPs that improve riparian vegetation and reduce the sediment load contributed from culvert failure, road crossings, hillslope erosion, and streambank erosion. Because the sources of sediment are nonpoint, implementation of this TMDL is voluntary. As such, stakeholders can work cooperatively to determine where, when, and how they will implement BMPs to achieve sediment allocations.

3.0 METALS SECTION

This portion of the document focuses on metals as a cause of water quality impairment. It describes: 1) the mechanisms by which metals impair beneficial uses, 2) the specific stream segments of concern, 3) information used during this investigation, 4) metals sources, 5) metals water quality standards and impairment determinations, 6) total maximum daily load (TMDL) calculations and allocations, 7) stream segment specific discussions, and 8) the implementation strategy.

3.1 EFFECTS OF METALS ON DESIGNATED BENEFICIAL USES

Elevated concentrations of metals can impair the support of numerous beneficial uses including: aquatic life, primary contact recreation, drinking water, and agriculture. Within aquatic ecosystems, metals can have a toxic, carcinogenic, or bioconcentrating effect on biota. Likewise, humans and wildlife can suffer acute and chronic effects from consuming water or fish with elevated metals concentrations. Because elevated metals concentrations can be toxic to plants and animals, high metals concentrations in irrigation or stock water may also affect agricultural uses. Although arsenic is technically a metalloid, it is treated as a metal for TMDL development due to the similarity in sources, environmental effects, and restoration strategies.

3.2 STREAM SEGMENTS OF CONCERN

The scope for this addendum's metals section covers the four project area stream segments included on the 2014 303(d) List for metals-related impairments (see **Table 3-1**). All four of these stream segments had TMDLs developed for other pollutants in 2008 (Montana Department of Environmental Quality, 2008). Multiple existing metal listings were not addressed in the 2008 document due to insufficient datasets and uncertainties in source determinations. The Environmental Protection Agency (EPA) funded additional surface water and streambed sediment sampling in 2013 to address these concerns and data gaps. With the datasets bolstered and more thorough source investigations completed, Department of Environmental Quality (DEQ) reassessed the 303(d) listing status of these waterbodies in 2014. Based on the new information, many waterbody-pollutant combinations remained impaired with their listing status unchanged, however one new waterbody-pollutant was added to the 303(d) list of impaired waters: iron on the lower segment of Douglas Creek. This addendum establishes TMDLs for all metals-impaired stream segments remaining in the Middle Blackfoot – Nevada Project Area as represented in the third column of **Table 3-1**.

Table 3-1. Metals-related stream segments of concern

Waterbody & Location Description	Waterbody ID	TMDLs Established in this addendum	TMDLs Established in 2008 document (Montana Department of Environmental Quality, 2008)
DOUGLAS CREEK, headwaters to Murray Creek	MT76F003_081	Arsenic	Nitrate/Nitrite, TKN, TN, TP, Sedimentation/Siltation, Temperature
DOUGLAS CREEK, Murray Creek to mouth (Nevada-Cottonwood Creeks)	MT76F003_082	Arsenic, Iron	TKN, TN, TP, Sedimentation/Siltation, Temperature
MURRAY CREEK, headwaters to mouth (Douglas Creek), T12N R12W S6	MT76F003_120	Arsenic	Nitrate/Nitrite, TKN, TN, TP, Sedimentation/Siltation, Temperature

Table 3-1. Metals-related stream segments of concern

Waterbody & Location Description	Waterbody ID	TMDLs Established in this addendum	TMDLs Established in 2008 document (Montana Department of Environmental Quality, 2008)
KLEINSCHMIDT CREEK, Ward Creek to mouth (Rock Creek)	MT76F004_110	Arsenic	Sedimentation/Siltation, Temperature

TKN = Total Kjeldahl Nitrogen; TN = Total Nitrogen; TP = Total Phosphorus

3.3 Data and Information Sources

The primary data used in this addendum are metals water column and streambed sediment samples collected in 2013 by DEQ's Water Quality Planning Bureau in partnership with the EPA Region 8 Montana Field Office. That dataset supplemented information the Bureau collected at a reduced number of sites in 2003 and 2005. All data used for analysis throughout this addendum are provided in **Appendix B**. In accordance with DEQ's data quality guidance, only data collected in the last 10 years are used for impairment determinations and target evaluations. Older data are considered descriptive and may be used for source characterization, loading analysis, and trend evaluation.

The Montana Bureau of Mines and Geology (MBMG) completed an environmental survey of abandoned mines in the project area on lands administered by the Bureau of Land Management (BLM) during the 1990s (Montana Bureau of Mines and Geology, 1997). Around the same time, DEQ's Abandoned Mine Lands Program (DEQ AML) investigated mines on both private and public lands across the state in order to both assess potential human health and environmental threats and to help prioritize reclamation (Pioneer Technical Services, Inc., 1995). These reports, along with DEQ's historical mining district narratives, provide the basis for characterizing the extent and condition of abandoned and inactive mines in the region (Montana Department of Environmental Quality, 2009).

Numerous additional sources of information were used to create maps and perform geospatial analyses. Geologic data were digitized by Lewis (1998) of MBMG, and Raines and Johnson (1996) of the United States Geological Survey (USGS). USGS is also the source for mapping streams and lakes (U.S. Geological Survey, 2013). The network of irrigation ditches is described in state water resource surveys of the 1950s and have remained largely unchanged (State Engineer's Office, 1959). Lastly, the locations of permitted point source outfalls were identified using EPA's Integrated Compliance Information System and are current as of January 1, 2014.

3.4 Sources of Metals

Metals sources may be either naturally occurring or anthropogenic (i.e., human-caused). Many metals occur naturally in the environment but their abundance can also be influenced by human activities. Mining is one activity commonly cited for introducing metals into waterways. Exposing underground materials to surface weathering during mining can mobilize metals by creating conditions known as acid mine drainage. People use products containing trace metals for a variety of purposes that can unintentionally pollute surface waters. Iron and steel (an iron-alloy), are widely used in construction materials, and water distribution and household plumbing systems. Four of the five metals TMDLs established in this document are for arsenic; therefore, a more thorough discussion of arsenic-specific sources directly follows. Additionally, source assessments are provided individually for each stream segment later in the addendum.

There are three general pathways whereby arsenic can enter a stream: the atmosphere, groundwater, or overland flow. To a certain degree, inputs from all of these categories are natural, but human actions can alter natural processes affecting the rates at which arsenic is introduced.

Atmosphere

Atmospheric inputs of arsenic to a stream occur by wet and dry deposition. Burning coal, purifying metal ores (smelting), volcanic eruptions and to a lesser extent, wildfires, can contribute arsenic to the atmosphere. Background deposition levels, in the absence of major external contributions, are low and have been measured in the range of 0.02 parts per billion (ppb) (Andreae, 1980). In more heavily human-influenced landscapes, concentrations of arsenic deposition can be three orders of magnitude greater than these background levels. For example, one Washington study measured rainfall containing 16 ppb arsenic at sites downwind of a metals smelting facility (Crecelius, 1975). As a comparison, the most stringent water quality target for arsenic, as described later in **Section 3.5.1,** is 10 ppb. Sustained inputs of arsenic from the atmosphere above background levels can accumulate to levels high enough to affect water quality targets. The Middle Blackfoot – Nevada Project Area landscape is rural and no active volcanoes, smelters, or coal power plants are located directly upwind, therefore DEQ believes that the atmospheric load of arsenic to these streams is nominal compared to other sources and no portion of the TMDL will be set aside for atmospheric contributions.

Groundwater-Geology

Groundwater within the project area, which is strongly influence by geology, is another potentially significant reservoir in the local arsenic cycle that must be investigated. Arsenic is a major constituent in more than 200 rock-forming minerals and concentrations of earth's crust average 5 parts per million (ppm) (Garelick et al., 2008). Numerous studies have identified localized areas throughout the world where arsenic concentrations greatly exceed 5 ppm and in some cases, the elevated levels are attributed to geology (Nicolli et al., 1989; Focazio et al., 2000; Berg et al., 2001; Smedley and Kinniburgh, 2002; Sun, 2004). Often, the geochemical environments of these locations involve geothermal areas; basin-fill deposits of stream or lake origin in semiarid climates; or volcanic deposits (Welch et al., 1988; Smedley and Kinniburgh, 2002).

Multiple studies in known geothermal areas like Yellowstone National Park have consistently reported arsenic concentrations in excess of 1,000 ppb (Stauffer and Thompson, 1984; Ball et al., 1998). No geothermal areas are known near or upstream of waterbodies applicable to this addendum according to the locations listed in MBMG's database of all known geothermal sites in Montana (Montana Bureau of Mines and Geology, 2011) and supported by the fact that no well in the USGS or MBMG datasets had geothermal characteristics - water temperatures greater than 50°C and total dissolved solids greater than 3,000 mg/L.

One non-geothermal region with high arsenic levels that has been intensely studied in the Western United States is the Carson Desert in Nevada (Welch et al., 1988). Here, the geologic setting can be described as Pleistocene lake sediments overlain by unconsolidated material derived from upland volcanic rocks. This is very similar to the conditions present in the Middle Blackfoot – Nevada Project Area. The two sources of geologic mapping used in this addendum show valley bottoms made up of glacial deposits (remnants of Glacial Lake Missoula from the Pleistocene) topped in places by more recent alluvial, or stream-derived, deposits (Raines and Johnson, 1996; Lewis, 1998). Also like the Carson Desert, a significant portion of the bedrock in the Murray and Douglas Creek headwaters is identified as volcanic, with andesite, basalt, and latite dominating the lithology. Another study in Argentina attributed elevated arsenic levels to volcanic ash or tuff, which has also been documented in the project area (Nicolli et al., 1989). Physical weathering and chemical processes release arsenic from soil and parent rock material to groundwater and surface water systems. The three general processes that control this release are redox reactions, desorption-adsorption and evaporation (Welch and Lico, 1998).

Redox reactions, or chemical interactions between compounds that exchange oxygen and hydrogen ions, can contribute arsenic to waterways. For example, sulfide deposits such as arsenopyrite (FeAsS) contain significant amounts of arsenic (Smedley and Kinniburgh, 2002; Garelick et al., 2008). Arsenopyrite is unstable when exposed to oxygen and water, and breaks down into arsenic, iron oxides, sulfate, hydrogen ions, and various trace elements (Smedley and Kinniburgh, 2002). The reducing environments, with low oxygen and low temperatures, found in alluvial aquifers and the sediments of many rivers and lakes, are conditions known to produce pyrite (Welch et al., 1999). Other metal oxide minerals can follow the same oxidation steps as arsenopyrite to mobilize arsenic.

Desorption-adsorption is another process that governs the content of trace elements in natural waters and is considered, by some, to be the most significant control on the availability of arsenic in groundwater in the United States (Welch et al., 1999). If adsorption rates are high, more arsenic is bound to geologic material or organic complexes and less is bioavailable. If instead, adsorption rates are low, more arsenic is free to move through the system and groundwater concentrations of arsenic rise. Alkaline aquifers composed of felsic volcanic rocks have exhibited high arsenic concentrations due to low rates of adsorption (Welch et al., 1999; Smedley and Kinniburgh, 2002). Some volcanic rock units in the project area are felsic, but a review of groundwater data downloaded from EPA STOrage and RETrieval database (STORET) and National Water Information System (NWIS) indicates the area aquifers are not alkaline.

Rivers with high arsenic concentrations have been noted in widespread areas of the arid Western United States where surface water is dominated by groundwater baseflow. A river's diminished ability to dilute groundwater inputs during low flow conditions, combined with high evaporation rates, can lead to high instream arsenic levels (Mok et al., 1988; Braumbaugh et al., 1994; Smedley and Kinniburgh, 2002). The theory that arsenic-rich groundwater could disproportionately influence surface water quality during low flow conditions in the Middle Blackfoot-Nevada Project Area is supported by the fact that arsenic exceedances in these TMDL streams were only captured during the late summer time frame; however, neighboring streams within the project area do not exhibit the same elevated arsenic signature. For example, upper Nevada Creek has been sampled for arsenic 24 times in the last 10 years and has never exceeded the 10 µg/L human health criterion. These observations could potentially be explained by a difference in geology, as the upper Nevada Creek basin has a smaller proportion of volcanic rocks like andesite and basalt (Raines and Johnson, 1996; Lewis, 1998). However, streambed sediment samples in upper Nevada Creek are elevated above what is considered background nationally. Flow differences could be another reason why water samples had low arsenic concentrations in upper Nevada Creek; Nevada Creek may transport enough water to dilute the groundwater inputs of arsenic and combat the effects of evaporation during the critical baseflow stage, in contrast to the TMDL streams in this addendum. Based on the dataset contained in **Appendix B,** Nevada Creek averages 49 cfs outside the spring runoff time period while Kleinschmidt Creek averages 6 cfs and normal flows in Murray and Douglas Creeks are around 2 cfs.

The USGS has extensively studied naturally occurring arsenic concentrations using data from public water systems and private wells across the United States (Welch et al., 1999; Focazio et al., 2000; U.S. Geological Survey, 2000). Results of these investigations show that the Western United States region has the highest occurrence of groundwater samples exceeding the 10 µg/L human health criterion (U.S.

Geological Survey, 2000). No sampling wells in the Middle Blackfoot – Nevada Project Area were represented in the USGS dataset, but other locations in Montana were elevated. MBMG's Ground-Water Information Center (GWIC) online database contains information from 60 wells or springs in the project area (see **Figure 3-1**). Arsenic concentrations at six sites were found to be elevated above the human health criterion, with a maximum concentration of 96 µg/L. Because the MBMG groundwater data is reported in the dissolved fraction, instead of the total recoverable fraction as Montana's arsenic surface water standards are written, there may be additional human health exceedances not captured in the figure. Most groundwater exceedances were taken from wells within alluvial sediments but no pattern between well depth and arsenic concentration could be distinguished. Cumulatively these results, although based on limited data, appear to indicate groundwater in the Middle Blackfoot – Nevada Project Area may be naturally elevated. Additional sampling of regional groundwater and geology is advised.

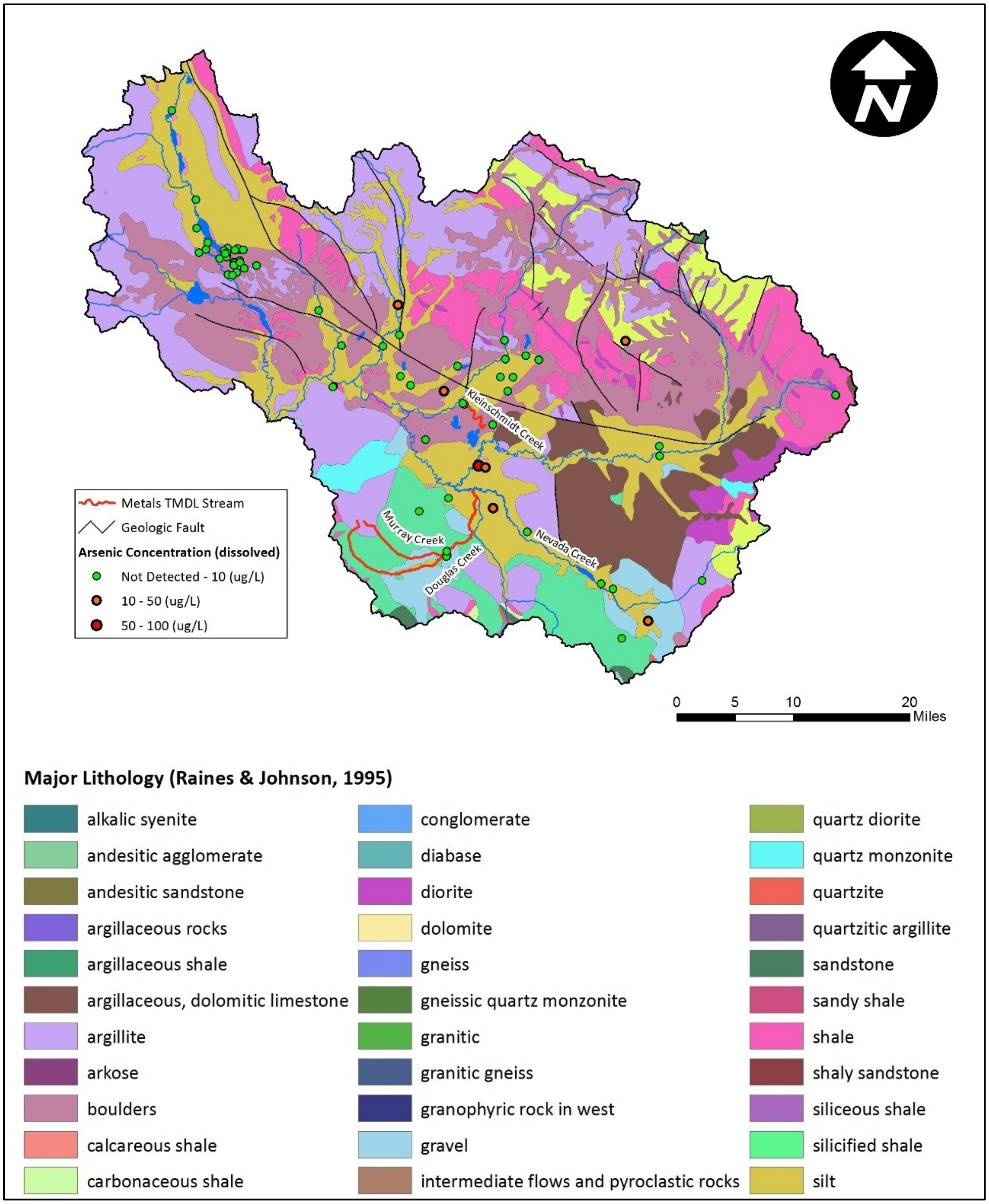

Figure 3-1. MBMG Groundwater Data in the Project Area Overlaying Geology Coverage

Overland Flow

The final source category of arsenic considered are human activities that introduce arsenic into surface waters by overland flow. Some of these activities may also affect groundwater. As described in the groundwater discussion above, arsenopyrite is known to contain significant amounts of arsenic. It is also common in ore bodies and localized areas of mineralization. The distribution of pyrite minerals is closely associated with coal and precious metal deposits. Past and present mining activities that extract these valuable commodities bring excess waste material to the surface which, depending on the composition of the material, can initiate the chemical weather and oxidation of arsenopyrite. There are multiple examples in the Western United States where elevated arsenic concentrations in water have been tied back to sulfide oxidation as a consequence of mining, although these waters tend to be acidic due to the release of hydrogen ions (Smedley and Kinniburgh, 2002). This does not appear to be the case in the Middle Blackfoot – Nevada Project Area. The most acidic water sample in the assessment dataset (**Appendix B**) is a near neutral 6.9 pH. This could either indicate that acid mine drainage and sulfide oxidation is not the source of elevated arsenic, or that the waterbodies are sufficiently buffered against pH fluctuations.

The Middle Blackfoot – Nevada Project Area has a history of mining that continues to this day. According to records kept by MBMG and DEQ AML, 11 abandoned or inactive mines exist in the Middle Blackfoot Planning Area and 67 exist in the Nevada Creek Planning Area. No mine in the project area has been designated high priority status. Numerous mining districts extend into the project area including the Seeley, Bob Marshall, Big Blackfoot, Lincoln, and Finn. The majority of mining has occurred along northern tributaries to Nevada Creek such as Jefferson, Washington, Wilson, and Buffalo Creek. For TMDL streams of concern to this addendum, only the Douglas Creek watershed was historically mined. One placer mine is currently active in the headwaters region of Douglas Creek. More information on this operation is provided in **Section 3.7.1**. Murray Creek has no known history of mining within its watershed; thus, unless abandoned mine records have inadvertently omitted historic activities, there are other processes besides mining at work in the project area introducing arsenic into waterways.

Numerous manufactured products containing arsenic exist that could wash into streams. Arsenic has been used extensively as a preservative, especially in wood products. In 2003, the wood product industry ceased use of arsenic based wood preservatives for residential uses due to environmental and human health concerns (U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, 2007). Certain industrial applications are still allowed. Two log home construction businesses are located in the Kleinschmidt drainage; at least one operated prior to the 2003 ban, but it is not known if arsenic based wood preservative products were used at either site.

Similarly, arsenic was historically common in herbicides and pesticides but its use has been largely phased out. Most commonly applied to fruit tree, cotton, potato, and tobacco crops but also used on sod farms, golf courses, cattle-dips, and highway right-of-ways, these chemicals were used through the 1990s. In one Washington study, decades of application on an apple orchard led to soils with arsenic concentrations exceeding 100 ppm (Davenport and Peryea, 1991). Gradually the use of these chemicals declined. The registration of most products in the U.S. were discontinued by the mid-2000s. In 2009, EPA announced that the last product used in this family of chemicals, monosodium methyl arsenate (MSMA), would also be phased out by the end of 2012. That ban has been delayed while EPA currently undertakes a new risk assessment of MSMA and submits the findings to a peer review process (Federal Register, 2013). If arsenical pesticides and herbicides are a contributing source of arsenic to area streams, they would have likely been used for cattle dipping vats to control infectious livestock pests or road herbicides to manage weeds. Area residents and the Montana Department of Agriculture are not aware of any large stockpiles of arsenical chemicals from herbicides, pesticides, or cattle dipping vats. Additionally, the Montana Department of Transportation (MDT) has never used arsenical herbicides for right-of-ways administered by the state (Miller, Mike, personal communication 3/24/14).

Railroads must also be considered a potential sources because arsenic-laden herbicides were historically sprayed on track right-of-ways and the wood preservatives described above were used to treat railroad ties. In the first part of the 20th Century, a railroad line existed in the Blackfoot Valley but only ran as far upstream as Ovando, MT, therefore railroads, while potentially a significant source of arsenic in other locations, can be ruled out as an arsenic source for the TMDL streams in this addendum.

General Source Assessment Summary

When possible, DEQ accounts for natural background loading separately from human-caused loading. However, because there is uncertainty surrounding the natural background concentration of arsenic in the Middle Blackfoot – Nevada Project Area, natural loading cannot be expressed separately from human-caused loading in this case. The TMDLs presented in this document, therefore, are presented as composite allocations to sources both naturally occurring and human-caused. As with other DEQ TMDLs, adaptive management policies should be followed into the future, revising aspects of the TMDLs no longer accurate as a better understanding of the basin is gained though additional monitoring and investigations.

These TMDLs are written assuming that natural background concentrations alone do not exceed instream water quality standards. If future investigations prove otherwise, a water quality standards revision could be justified. Developing site-specific arsenic standards would likely require additional data collection of surface water, groundwater, and soil or rock samples. To protect these aquatic resources and their designated uses, the ability to confidently say arsenic is naturally elevated in the project area requires a higher burden of proof than that currently provided in this TMDL investigation. Note that some streams, such as the upper segment of Nevada Creek, have an extensive dataset with no arsenic exceedances proving that other regional streams, even those with a history of mining, can meet water quality targets. Therefore, DEQ has decided that writing arsenic TMDLs is the appropriate action at this time. DEQ does not view the establishment of these arsenic TMDLs as drastically affecting land management recommendations besides further encouraging the use of best management practices previously recommended in the 2008 document (Montana Department of Environmental Quality, 2008).

As of January 2014, there is one active point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) with the ability to affect metals-impaired streams in this addendum. The permit, MTR103019, allows MDT to discharge stormwater from highway and street construction projects directly into five different surface waters. A road crossing on upper Douglas Creek is listed as one outfall, as are crossings on two upper Douglas Creek tributaries (Sturgeon Creek and Sheep Creek). The last two outfalls are located at road crossings spanning Cottonwood Creek and Chimney Creek, tributaries to the lower segment of Douglas Creek. This general construction stormwater permit requires the permittee to develop and implement a stormwater pollution prevention plan to minimize or eliminate the potential for pollutants to reach surface waters through stormwater runoff. Sediment is the primary pollutant of concern at these construction sites, therefore a significant part of the plan typically involves various erosion control measures such as the installation of physical controls and best management practices. While the permit does not explicitly set loading limits for metals, sediment bound metals are expected to be effectively controlled using the same measures that limit erosion. As long as the permittee follows the requirements contained in the general permit, this activity is not considered a significant source of metals impairment and it is not given a wasteload allocation in the TMDLs.

3.5 Metals Water Quality Standards and Impairment Determinations

Montana has established numeric water quality criteria for arsenic and iron that are defined in Circular DEQ-7 (Montana Department of Environmental Quality, 2012). All four metals-related stream segments are classified by the state of Montana as B-1, which specifies that the water must be maintained suitable to support drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; the growth and propagation of salmonids fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

The process used to determine which waterbodies require TMDLs follows two steps:

1. Identify targets
   Targets represent a condition that meets Montana's ambient water quality. Arsenic and iron have established numeric water quality criteria that are used directly as the primary TMDL targets. Additional information on these targets is provided below.

2. Determine Impairment
   DEQ compares recent monitoring data to water quality targets to determine whether a waterbody is impaired by a pollutant and thus requires a TMDL. In cases where one or more targets are not met, a TMDL is developed. If data demonstrate that a previously identified impairment is no longer verified, the waterbody-pollutant combination is recommended for removal from the 303(d) list. The impairment determination process is also presented below in further detail.

3.5.1 Targets

Targets for metals-related impairments in the Middle Blackfoot - Nevada Project Area include both water column targets and streambed sediment targets. The water column targets are based on numeric human health criteria and aquatic life criteria. Sediment chemistry targets are adopted from numeric screening values for metals in freshwater sediment established by the National Oceanic and Atmospheric Administration (NOAA) (Buchman, 2008).

Water Chemistry Targets

Arsenic and iron have numeric water quality criteria defined in Circular DEQ-7 (Montana Department of Environmental Quality, 2012). These criteria include values for protecting both human health and aquatic life. Aquatic life criteria are split into acute and chronic categories. Chronic criteria prevent long-term, low level exposure to pollutants while acute criteria protect against short-term exposure. Acute and chronic aquatic life criteria are intended to protect aquatic life beneficial uses; human health criteria are intended to protect drinking water beneficial uses. For any given pollutant, the most stringent of these criteria is adopted as the water quality target in order to protect all beneficial uses.

The aquatic life criteria for some metals are dependent upon water hardness: the criteria increase (i.e., becomes less stringent) as the hardness increases. For the metals of concern to this document however, the aquatic life criteria are constant and do not fluctuate based on hardness. Water quality criteria for arsenic and iron are shown in **Table 3-2**. The targets are expressed in micrograms per liter (µg/L), equivalent to parts per billion (ppb). Note that no human health or acute aquatic life criteria have been developed for iron.

Table 3-2. Numeric water quality targets for metals

Metal of Concern (Total Recoverable)	Aquatic Life Criteria (µg/L)		Human Health Criteria (µg/L)
	Acute	Chronic	
Arsenic	340	150	10
Iron	NA	1,000	NA

Sediment Chemistry Targets
While Montana does not currently have numeric criteria for metals in streambed sediments, narrative criteria found in the state's general water quality prohibitions apply. Specifically, Administrative Rule of Montana (ARM) 17.30.637 states that "…waters must be free from substances…that will: create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life…" In other words, concentrations of metals in stream sediments must not be toxic and the concentrations of these sediments can be used as supplemental indicators of waterbody impairment. In addition to directly impairing aquatic life in contact with stream sediments, high metals in sediment commonly correspond to elevated concentrations of metals in the water column during high flow conditions when the sediment is resuspended. Where instream water quality data exceed water quality targets, sediment data provide supporting information, but are not necessary to verify impairment.

In the absence of numeric criteria for metals in stream sediment, DEQ bases sediment quality targets on values established by NOAA as guidelines for metals in freshwater sediments. These criteria come from numerous toxicity studies and investigations, and are expressed in Probable Effects Levels (PELs). PELs represent the sediment concentration above which toxic effects to aquatic life frequently occur, and are calculated as the geometric mean of the 50th percentile concentration of the toxic effects dataset and the 85th percentile of the no-effect dataset (Buchman, 2008). **Table 3-3** contains the PEL value for arsenic. Iron does not have an established PEL value. The PEL value is expressed in milligrams per kilogram (mg/kg), equivalent to parts per million (ppb).

Table 3-3. Secondary targets for metals in stream sediments

Metal of Concern	PEL (mg/kg)
Arsenic	17.00
Iron	NA

PEL values are used as a supplemental target to evaluate whether streams are meeting Montana's narrative criteria outlined in ARM 17.30.637. If water quality targets are met but sediment concentrations are more than double the PEL (100% exceedance magnitude), the sediment data can be used as an indication of a metals water quality problem. While a TMDL is typically not developed based solely on sediment metals data, it can help identify where additional sampling may be necessary to fully evaluate target compliance.

3.5.2 Impairment Determinations

The evaluation process used to determine the impairment status of each stream is derived from DEQ's guidance for metals assessment methods (Drygas, 2012). A waterbody is considered impaired by a pollutant if at least one of the following scenarios is met:

- A single sample exceeds the human health target
- A single sample exceeds the acute aquatic life target by a factor of two or more
- More than 10% of the samples exceed the chronic or acute aquatic life target

Eight independent samples are regarded as the minimum dataset, although either of the first two bullets can be met with less than eight samples. Additionally for the third bullet, a waterbody may be deemed impaired if the dataset has fewer than eight samples but contains at least two aquatic life exceedances. For a pollutant currently listed as impaired with a dataset not falling into any of the three scenarios listed above but having fewer than eight samples, the status will remain impaired because the dataset is insufficient to prove water quality standards are met. All other scenarios result in a non-impaired status determination. Following these steps, DEQ determined five pollutants on four stream segments in the watershed are impaired and require TMDLs.

3.6 TMDLs and Allocations

TMDLs are provided in this addendum for all waterbody-pollutant combinations identified in **Table 3-1**. The process involves calculating TMDLs to meet water quality standards and then allocating the TMDL to various sources.

3.6.1 Calculating TMDLs

TMDLs are based on the most stringent water quality target and streamflow. Using the most stringent target ensures the TMDLs are protective of all designated beneficial uses. These TMDLs apply to any point along the waterbody and therefore protect beneficial uses along the entire stream. Because streamflow varies seasonally, TMDLs within this addendum should not be considered a static value, but as an equation of the appropriate target multiplied by flow using the following formula:

Equation 1:

$$\textbf{TMDL} = (X)\ (Y)\ (k)$$

TMDL = Total Maximum Daily Load in lbs/day
X = lowest applicable metals water quality target in µg/L
Y = streamflow in cubic feet per second (cfs)
k = conversion factor of 0.0054

Example TMDLs are developed for high and low flow conditions in order to address seasonality. Seasonality is important because metals loading pathways change as flow conditions change. During high flows, loading associated with overland flow tend to be the major cause of elevated metal concentrations. Contributions switch during low flow, as the influence of groundwater and point sources often becomes more apparent. For the purposes of this addendum and based on what DEQ has used in previously approved TMDLs, samples collected within the timeframe April 15 through June 30 are considered high flow; samples collected outside this window are attributed to low flow.

Table 3-4 provides the inputs used to calculate example TMDLs and also displays the total load reductions necessary to meet each example TMDL based on the existing monitoring data. Example TMDLs are calculated by replacing the “X” and “Y” variables in **Equation 1** with the appropriate target value and the streamflow measured in the field. Existing loads are calculated using the same flow values but changing the “X” variable to the observed metal concentration at that site, which was selected as the highest arsenic or iron concentration on record for that flow condition. Existing loads are shown in the stream segment-specific sections below. The required percent reduction in total loading is calculated by subtracting the TMDL from the existing load, and dividing the difference by the existing load. In cases where streams appear to be meeting the TMDL for a certain time period based on the current dataset, the percent reduction is reported as 0%.

Table 3-4. Example TMDLs and Required Percent Reductions

Stream Segment	Station	Discharge (cfs)		Metal	Target Conc. (µg/L)		Existing Conc. (µg/L)		TMDL (lbs/day)		% Total Reduction	
		High Flow	Low Flow		High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow
DOUGLAS CREEK, upper segment	C03DOUGC20	1.51	1	Arsenic	10	10	7	25	0.082	0.054	0%	60%
DOUGLAS CREEK, lower segment	C03DOUGC01/ DCSW-1	15.9	2.55*	Arsenic	10	10	2.5	21	0.859	0.138	0%	52%
				Iron	1,000	1,000	1,410	130	85.860	13.770	29%	0%
MURRAY CREEK	C03MURYC02	0.29	0.2	Arsenic	10	10	2	16	0.016	0.011	0%	38%
KLEINSCHMIDT CREEK	C03KLSMC01	7.14	16.32	Arsenic	10	10	2	22	0.386	0.881	0%	55%

*Streamflow was not measured at the time arsenic and iron samples were collected on 10/1/2003. To estimate the normal low flow discharge, measurements collected from the same site at other times considered “low flow” were averaged (i.e., discharge on 8/25/2009 was 2.69 cfs; discharge on 8/15/2013 was 2.41 cfs; average = 2.55 cfs)

3.6.2 Calculating Allocations

Once a TMDL is calculated, the total load is allocated to all contributing sources. A TMDL is generally broken into one or more wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS). WLAs are allowable pollutant loads that are assigned to permitted and non-permitted point sources. Some mining-related sources (e.g., adit discharges) are considered non-permitted point sources subject to WLAs (Dodson, Max H., personal communication 12/22/93). LAs are allowable pollutant loads assigned to nonpoint sources and may include the pollutant load from naturally occurring sources, as well as human-caused nonpoint source loading. DEQ must also take into account uncertainties encountered while developing TMDLs in a margin of safety. These elements are combined in the following equation:

Equation 2:

$$\mathbf{TMDL = \sum WLA + \sum LA + MOS}$$

WLA = Wasteload allocation or the portion of the TMDL allocated to point sources
LA = Load allocation or the portion of the TMDL allocated to nonpoint sources and naturally occurring background
MOS = Margin of safety or an accounting of uncertainty about the relationship between metals loads and receiving water quality

All metals TMDLs in this addendum are given a single composite LA as shown in **Equation 3** due to uncertainties involved with identifying specific human sources and difficulties estimating natural background loads. Additional monitoring as part of a concentrated inquiry into natural metals levels in the basin could help separate composite LAs. Because the only point source within a metal TMDL stream watershed, MDT's construction stormwater permit (MTR103019), is not considered a significant source and is not provided a WLA, reasonable assurance considerations are not required. The adaptive management policies outlined in **Section 6.0** apply here and allow allocation refinement to occur in the future as new information becomes available

Equation 3:

$$\mathbf{TMDL = LA_{Composite}}$$

LA = Composite allocation to all nonpoint sources both naturally occurring and human-caused

An implicit margin of safety (i.e., MOS = 0) is applied to all TMDLs in this addendum through use of conservative assumptions throughout the TMDL development process as summarized in **Section 5.2**.

As an example, the steps taken to establish the low flow arsenic TMDL and allocation scheme on upper Douglas Creek is provided below.

1) Establish example TMDL (see **Equation 1**)
   (10 µg/L) x (1 cfs) x (0.0054) = 0.054 lbs/day

2) Calculate existing load
   (25 µg/L) x (1 cfs) x (0.0054) = 0.135 lbs/day

3) Calculate total percent reduction required to meet TMDL
   (0.135 lbs/day – 0.054 lbs/day) ÷ 0.135 lbs/day = 0.60 = 60%

4) Allocate TMDL to sources (see **Equation 3**)
   TMDL = $LA_{Composite}$ = 0.054 lbs/day

3.7 Stream Specific Discussion

The following four sub-sections are organized by waterbody and provide a stream segment-specific description of metals sources, target evaluations, TMDL calculations, and allocations.

3.7.1 Douglas Creek, Upper Segment (MT76F003_081)

Douglas Creek, from the headwaters to Murray Creek (13.02 miles), previously had TMDLs developed for nitrate/nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorus, sedimentation/siltation, and temperature (Montana Department of Environmental Quality, 2008). Arsenic has been included on the 303(d) list since 2006 but was not addressed in the previous TMDL effort. DEQ assessed the waterbody following additional data collection in 2013 and confirmed arsenic is impairing drinking water beneficial uses. This addendum addresses the arsenic impairment by establishing an arsenic TMDL for Douglas Creek's upper segment.

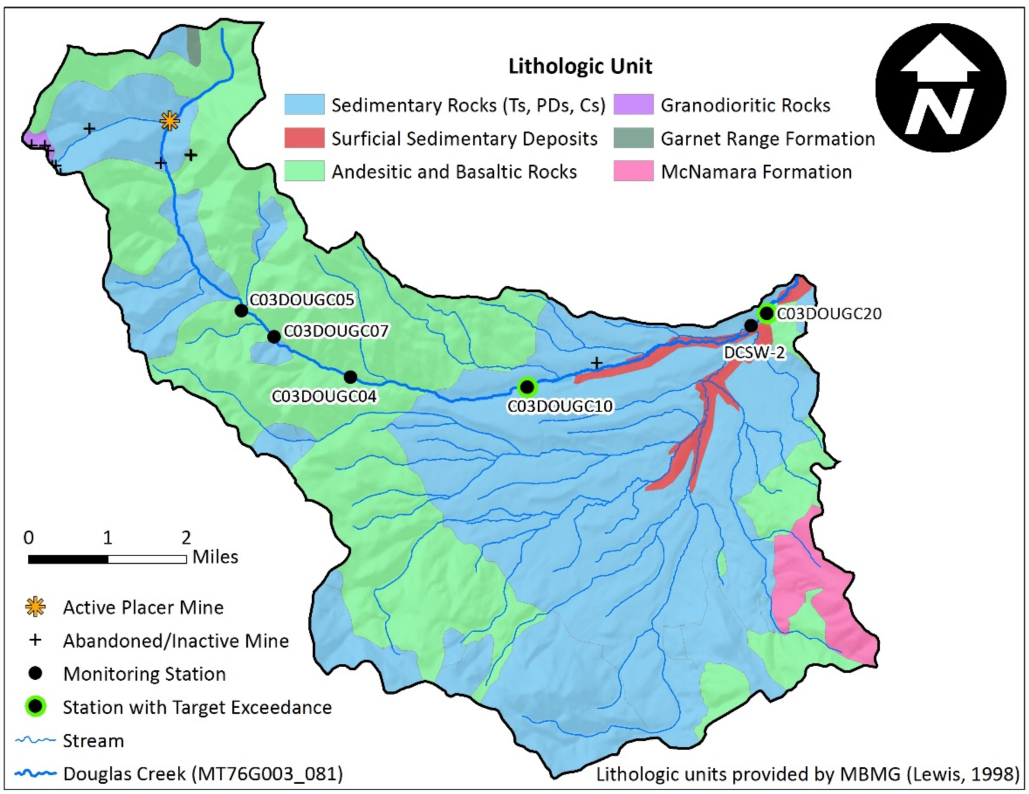

Figure 3-2. Upper Douglas Creek Watershed Map

Sources of Arsenic

The upper Douglas Creek basin contains approximately 12 abandoned mines according to DEQ AML and MBMG databases as shown in **Figure 3-2**. Commodities produced from these placer and lode mines include gold, copper, and silver (Montana State Library, 2006). The watershed falls largely within the boundaries of the Finn Mining District; however, most historical records for the district focus on the extensive placer mining that occurred in northern tributaries to Nevada Creek such as Washington, Jefferson, and Buffalo Gulches and the records do not provide a detailed characterization of mines relevant to Douglas Creek (Montana Department of Environmental Quality, 2009). Neither the DEQ AML nor the MBMG statewide abandoned mine investigations of the 1990s collected water or sediment samples at mines in the upper Douglas Creek watershed (Pioneer Technical Services, Inc., 1995; Montana Bureau of Mines and Geology, 1997).

There is one active mine, the Fork Horn #4 Mine, in the headwaters region of Douglas Creek. This gold placer operation has a current surface disturbance of 4.23 acres that spans both private and public land managed by the Bureau of Land Management (BLM). The Fork Horn #4 Mine is currently operating under the Small Miner Exclusion Statement (SMES), which limits the total surface disturbance to five acres but does not limit the amount of material processed. The mine owner is currently working with BLM to develop a Plan of Operations but intends to remain classified under the SMES with DEQ by reclaiming land before disturbing additional acreage (Miller, Amanda, personal communication, 1/23/14). The site was visited by DEQ in August 2013 while conducting stream monitoring for this addendum. At that time, the mine had diverted Douglas Creek water for use in the trommel and sluice system and then sent the water through a series of settling ponds, eventually infiltrating to groundwater. Douglas Creek was not flowing below the mine at that time and EPA had to move a monitoring location (C03DOUGC05) downstream to where the channel contained flowing water (C03DOUGC07). The mine is not allowed to divert the entirety of Douglas Creek's flow and it is likely portions of upper Douglas Creek naturally go dry in the late summer months. The water observed at the mine site in August had been diverted earlier in the year and stored onsite. As an additional mitigation measure, the mine's surface water diversion has gates designed to prevent fish from being routed out of the stream.

Conditional to the issuance of the SMES, the mine shall not pollute or contaminate any stream; shall salvage and protect all soil material for use in reclamation; and shall reclaim all land disturbed by operations to comparable utility and stability as that of adjacent lands. A 15 foot buffer between excavation trenches and the stream channel has been established. To fulfill reclamation responsibilities after the lifespan of the mine, the owner will be required to backfill excavated areas, recontour slopes, apply sufficient topsoil material and reseed the areas with native, weed-free vegetation. DEQ has collected the maximum $10,000 bond to ensure these activities occur (Miller, Amanda, personal communication, 1/23/14). Surface water samples collected near the mine met arsenic targets and the spatial pattern of exceedances (see **Figure 3-2**) indicates the Fork Horn #4 Mine is not a significant source of arsenic and no allocation is provided.

As described in **Section 3.4**, one MPDES permitted point source (MTR103019) is located in the upper Douglas Creek watershed. MDT is permitted to discharge stormwater into surface waters from highway and street construction projects. Three stream crossings within the upper Douglas Creek watershed are listed as outfalls: Douglas Creek, Sturgeon Creek, and Sheep Creek. This general construction stormwater permit requires the permittee to develop and implement a stormwater pollution prevention plan to minimize or eliminate the potential for pollutants to reach surface waters through stormwater runoff. Sediment is the primary pollutant of concern at these construction sites, therefore a significant part of the plan typically involves various erosion control measures such as the installation of physical controls and best management practices. While the permit does not explicitly set loading limits for metals, sediment bound metals are expected to be effectively controlled using the same measures that limit erosion. As long as the permittee follows the requirements contained in the general permit, this activity is not considered a significant source of arsenic and no WLA is provided.

No clear link can be drawn between the human activities just discussed and the arsenic surface water exceedances based on the current dataset, so the source investigation must focus on background sources such as fires and geology. In the last 120 years, only one small fire has burnt in the Douglas Watershed (Gibson and Morgan, 2009; Geospatial Multi-Agency Coordination Group, 2013; Geospatial Multi-Agency Coordination Group, 2011). Roughly 870 acres of the upper headwaters region burnt in September 2012 (Geospatial Multi-Agency Coordination Group, 2013), but all of the arsenic target exceedances in the dataset were observed in 2003; therefore, wildfires cannot be the source of the arsenic impairment. Both arsenic exceedances were collected from locations in the lower reach of Douglas Creek within sedimentary geologic units and downstream of volcanic units consisting of andesite and basalt. Volcanic ash layers are also present in the sedimentary rock units colored light blue in **Figure 3-2**. The geologic setting of Douglas Creek corresponds to conditions reported in other studies documenting elevated arsenic as described in **Section 3.4**. Redox and desorption processes occurring in the shallow aquifer interacting with Douglas Creek in the hyporheic zone, potentially exacerbated by evaporation during low flow time periods, could be the most significant source of arsenic to Douglas Creek. The topography in the lower reaches may also cause groundwater, originating in the headwaters and flowing through volcanic bedrock, to upwell arsenic-rich water as seeps in the regions were surface water exceedances were observed in the monitoring dataset, however, additional monitoring is required to confirm these hypotheses.

Existing Data and Comparison to Water Quality Targets

The current arsenic dataset consists of 12 water samples collected at six sites by DEQ in 2003, 2005, and 2013 and four sediment samples collected at four sites in 2013 (see **Figure 3-2**). All sediment samples met the arsenic PEL target but two of the 12 water samples exceeded the human health target, indicating the waterbody is impaired. Both arsenic exceedances were collected during low flow conditions in 2003; one at C03DOUGC10 and one at C03DOUGC20. The highest measured concentration, 25 µg/L, is two and a half times greater than the human health target.

Synoptic sampling consistently revealed a significant increase in arsenic concentrations and loads between sites C03DOUGC10 and C03DOUGC20 during both flow conditions. Farther upstream, concentrations between C03DOUGC05 and C03DOUGC04 always decreased or remained constant as flow gradually increased. Samples collected nearest to the active and abandoned mines met arsenic targets. Two large irrigation ponds bracket C03DOUGC10 (see cover page photograph), which may explain the large reduction in streamflow, 81% reduction on average, between that site and the station directly upstream. Whatever streamflow lost to the irrigation pond below C03DOUGC10 is masked by the larger inputs of Sturgeon Creek when streamflow is again measured at C03DOUGC20. **Table 3-5** compares existing arsenic data to the targets described in **Section 3.5.1.**

Table 3-5 Upper Douglas Creek data summary and target exceedances

Parameter	Arsenic
Number of samples	12
Date of samples	2003-2013
% of samples considered high flow	42%
Chronic Aquatic Life criterion exceedance rate > 10%?	No
> 2x acute Aquatic Life criterion exceeded?	No
Human health criterion exceeded?	Yes
NOAA PEL exceeded?	No
Human-caused sources present?	Yes
Impairment Determination	**Impaired**

Upper Douglas Creek TMDLs

Due to uncertainties in defining natural background concentrations of arsenic, the arsenic TMDL in this addendum is presented as a composite load allocation to all naturally occurring sources and human-related nonpoint sources, as expressed by the following formula:

$$TMDL_{UpDouglas} = LA_{Composite}$$

Although there are mines in the basin, the current dataset does not implicate them as a source of arsenic loading. Furthermore, there is no evidence of discharging adits that would require considering mines point sources subject to WLAs as described in EPA guidance (Dodson, Max H., personal communication 12/22/93). TMDLs were calculated using the target concentration and the streamflow values observed at site C03DOUGC20 on September 27, 2003 and May 22, 2013. Existing loads were calculated using the same flow and conversion factor as the TMDLs but using arsenic concentrations observed at C03DOUGC20 on said dates instead of the target concentrations. **Table 3-6** provides example TMDLs, allocations and necessary percent reductions; however because TMDLs are flow dependent, actual TMDLs will not always match **Table 3-6**.

Table 3-6. Upper Douglas Creek example TMDLs and allocations

Metal	Flow	$TMDL_{UpDouglas}$	$LA_{Composite}$	Existing Load	% Reduction
Arsenic	High flow	0.082	0.082	0.057	0%
	Low flow	0.054	0.054	0.135	60%

All units are lbs/day

The current dataset suggests that the arsenic TMDL is met during high flow conditions but a load reduction, up to 60%, is required during low flow time periods. **Table 3-4** lists the inputs used to calculate upper Douglas Creek's example TMDLs.

3.7.2 Douglas Creek, Lower Segment (MT76F003_082)

Douglas Creek, from Murray Creek to the mouth at Nevada Creek (10.9 miles), previously had TMDLs developed for total kjeldahl nitrogen, total nitrogen, total phosphorus, sedimentation/siltation, and temperature (Montana Department of Environmental Quality, 2008). Arsenic has been included on the 303(d) list since 2006 but was not addressed in the previous TMDL effort. DEQ assessed the waterbody following additional data collection in 2013 and confirmed arsenic is impairing drinking water beneficial uses. Additionally, iron was found to be impairing aquatic life beneficial uses and was added to the 303(d) list in 2014. This addendum addresses these impairments by establishing an arsenic and an iron TMDL for Douglas Creek's lower segment.

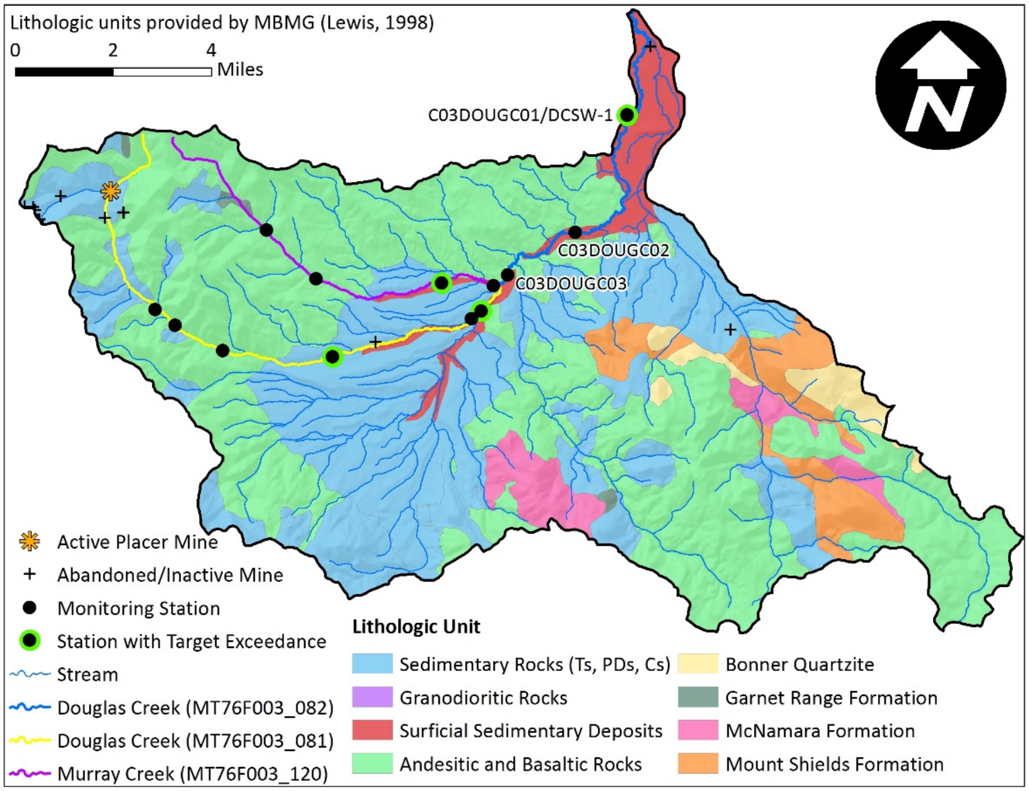

Figure 3-3. Lower Douglas Creek Watershed Map

Sources of Arsenic and Iron

The lower Douglas Creek basin contains two abandoned mines according to DEQ AML and MBMG databases as displayed in **Figure 3-3**. The mine closest to the mouth of Douglas Creek, the Royal Mine, was a small lode mine that produced gold and silver (Montana State Library, 2006). The second mine is the Pioneer Bar placer located near Cottonwood Creek. The Royal Mine is located in the Big Blackfoot Mining District and the Pioneer Bar is in the Finn Mining District. Historical records for these districts do not discuss these mines individually but they do mention that overall, activity was limited by the remote location of the districts making most efforts unprofitable (Montana Department of Environmental Quality, 2009). There are 12 additional abandoned mines in the upper watershed (also shown in **Figure 3-3**) potentially impacting water quality in this lower segment. Sources within the upper Douglas Creek watershed and the Murray Creek watershed are discussed separately in **Sections 3.7.1** and **3.7.3**. Neither the DEQ AML nor the MBMG statewide abandoned mine investigations of the 1990s visited mines in the lower Douglas Creek watershed (Pioneer Technical Services, Inc., 1995; Montana Bureau of Mines and Geology, 1997).

Figure 3-4 shows a graph of total recoverable iron concentrations as a function of total suspended solids (TSS) for data collected on lower Douglas Creek. Similar to the 2008 document findings (Montana Department of Environmental Quality, 2008), a strong linkage exists, with an R^2 value of 0.83, indicating that water column iron concentrations are primarily derived from suspended sediments that vary with stream discharge. If the 130 µg/L data point below the trend line is removed, the R^2 value jumps to 0.99. This relationship shows that control of sediment sources and implementation of the previously established sediment TMDL should also, to a large extent, mitigate iron water quality exceedances. No such relationship is evident between arsenic and TSS.

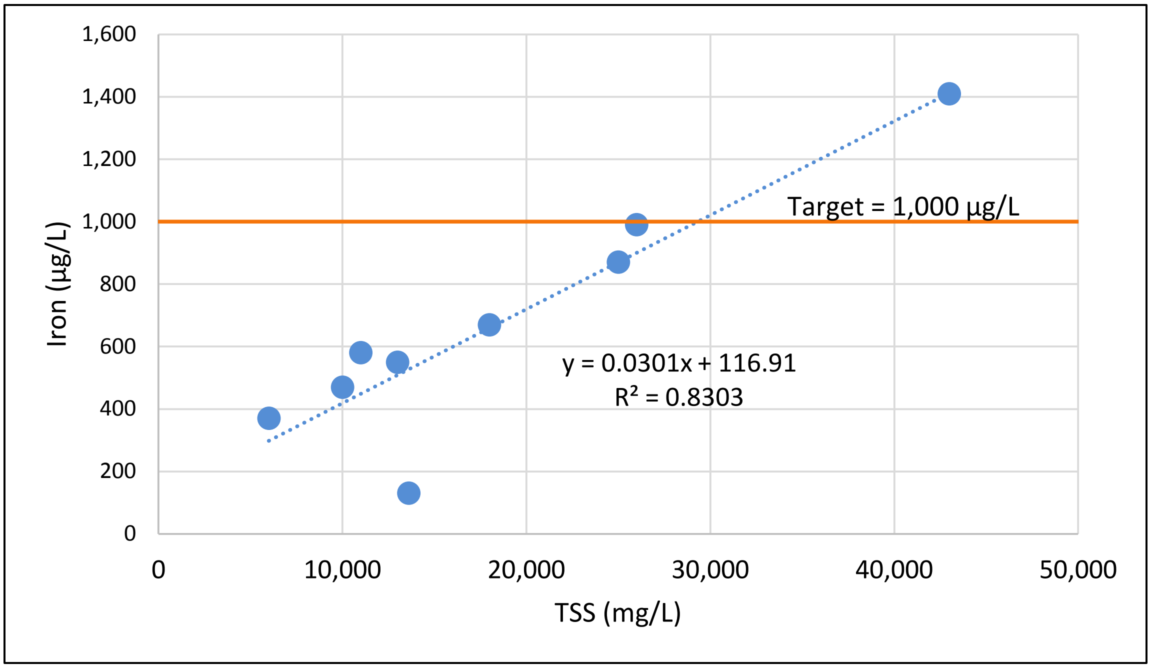

Figure 3-4. Relationship between Total Suspended Solids (TSS) and Iron Concentrations

As described in **Section 3.4**, one MPDES permitted point source (MTR103019) is located in the lower Douglas Creek watershed. MDT is permitted to discharge stormwater into surface waters from highway and street construction projects. Two stream crossings within the lower Douglas Creek watershed are listed as outfalls: Chimney Creek and Cottonwood Creek. This general construction stormwater permit requires the permittee to develop and implement a stormwater pollution prevention plan to minimize or eliminate the potential for pollutants to reach surface waters through stormwater runoff. Sediment is the primary pollutant of concern at these construction sites, therefore a significant part of the plan typically involves various erosion control measures such as the installation of physical controls and best management practices. While the permit does not explicitly set loading limits for metals, sediment bound metal are expected to be effectively controlled using the same measures that limit erosion. As long as the permittee follows the requirements contained in the general permit, this activity is not considered a significant source of metals impairment and no WLA is provided.

Numerous small ditches divert water out of the stream for irrigation and an unknown, but likely minimal volume returns. A more significant canal associated with the Nevada Reservoir water supply project bisects Douglas Creek between monitoring sites C03DOUGC02 and C03DOUGC01/DCSW-1. The canal transports water from the east over ten miles, expanding the potential source area outside the Douglas Creek drainage divide as the water from the canal and creek mix. That said, no apparent human sources of metals exist in the expanded drainage area and metals water quality target exceedances were also observed upstream of the canal in upper Douglas Creek and Murray Creek suggesting the ditch is not the source of metals impairment.

No clear link can be drawn between the human activities just discussed and the arsenic and iron surface water exceedances based on the current dataset, so the source investigation must focus on background sources such as fires and geology. No fires have burnt in the lower Douglas Creek watershed in the last 100 years (Gibson and Morgan, 2009; Geospatial Multi-Agency Coordination Group, 2013; Geospatial Multi-Agency Coordination Group, 2011), therefore wildfires cannot be the source of arsenic impairment. The arsenic exceedance was collected from a location in the lower reach of Douglas Creek within the surficial sedimentary geologic unit and downstream of volcanic units consisting of andesite and basalt. Volcanic ash layers are also present in the sedimentary rock units colored light blue in **Figure 3-3**. The geologic setting of Douglas Creek corresponds to conditions reported in other studies documenting elevated arsenic as described in **Section 3.4**. Redox and desorption processes occurring in the shallow aquifer interacting with Douglas Creek in the hyporheic zone, potentially exacerbated by evaporation during low flow time periods, could be the most significant source of arsenic to Douglas Creek. The topography in the lower reaches may also cause groundwater, originating in the headwaters and flowing through volcanic bedrock, to upwell arsenic-rich water as seeps in the regions were surface water exceedances were observed in the monitoring dataset, however, additional monitoring is required to confirm these hypotheses. The sole iron exceedance was collected from the same site as the arsenic exceedance (C03DOUGC01/DCSW-1) but during high flow conditions. This exceedance was associated with the highest TSS measurement indicating that iron concentrations, unlike arsenic, are closely related to sediment transport.

Existing Data and Comparison to Water Quality Targets

The current arsenic dataset consists of nine water samples collected at three sites by DEQ in 2003, 2005 and 2013 (see **Figure 3-3**). Three arsenic sediment samples were collected in 2013 and one iron sediment sample was collected in 2003. None of the samples exceeded arsenic sediment targets and while iron doesn't have an established sediment target, the concentration is consistent with levels seen elsewhere in the state. A sample site near the mouth was planned but the landowner informed the monitoring crew that the creek was not flowing at that location due to irrigation withdrawals and requested the crew not access the site in during the 2013 field season. One of the nine arsenic samples exceeded the human health target indicating the waterbody is impaired. The single arsenic exceedance occurred at C03DOUGC01/DCSW-1 during October 2003. At 21 µg/L, the concentration is more than double the human health target. One of nine iron samples exceeded the chronic aquatic life target resulting in an 11% exceedance rate and an impairment determination.

Synoptic sampling revealed loads for arsenic and iron are often greatest at C03DOUGC02, however spatial trends in concentrations and loads along the lower Douglas Creek segment fluctuate in no consistent seasonal or pollutant-specific pattern. Unfortunately the samples that exceeded arsenic and iron water quality targets at C03DOUGC01/DCSW-1 were not collected synoptically, so a spatial comparison cannot be drawn between this site and sites upstream for these dates. **Table 3-7** compares existing arsenic and iron data to the targets described in **Section 3.5.1.**

Table 3-7. Lower Douglas Creek data summary and target exceedances

Parameter	Arsenic	Iron
Number of samples	9	9
Date of samples	2003-2013	2003-2013
% of samples considered high flow	44%	44%
Chronic Aquatic Life criterion exceedance rate > 10%?	No	Yes
> 2x acute Aquatic Life criterion exceeded?	No	NA
Human health criterion exceeded?	Yes	NA
NOAA PEL exceeded?	No	NA
Human-caused sources present?	Yes	Yes
Impairment Determination	**Impaired**	**Impaired**

Lower Douglas Creek TMDLs

Due to uncertainties in defining natural background concentrations, the arsenic and iron TMDLs in this addendum are presented as composite load allocations to all naturally occurring sources and human-related nonpoint sources, as expressed by the following formula:

$$TMDL_{LwrDouglas} = LA_{Composite}$$

Although there are mines in the basin, the current dataset does not implicate them as a source of arsenic or iron loading. Furthermore, there is no evidence of discharging adits that would require considering mines point sources subject to WLAs as described in EPA guidance (Dodson, Max H., personal communication 12/22/93). TMDLs were calculated using the appropriate target concentration and the streamflow values observed at site C03DOUGC01/DCSW-1 on October 1, 2003 and May 11, 2005. Because streamflow was not measured during the October 2003 site visit, streamflow measurements made during low flow conditions in other years from the same site were averaged to estimate the normal low flow discharge (i.e., 2.55 cfs). Existing loads were calculated using the same flow and conversion factor as the TMDLs but using arsenic and iron concentrations observed at C03DOUGC01/DCSW-1 on the previously mentioned dates instead of the target concentrations. Note that because arsenic was not detected in the sample from May, one half the laboratory detection limit was used to calculate an existing load. **Table 3-8** provides example TMDLs, allocations, and necessary percent reductions; however because TMDLs are flow dependent, actual TMDLs will not always match **Table 3-8**.

Table 3-8. Lower Douglas Creek example TMDLs and allocations

Metal	Flow	$TMDL_{LwrDouglas}$	$LA_{Composite}$	Existing Load	% Reduction
Arsenic	High flow	0.859	0.859	0.215	0%
	Low flow	0.138	0.138	0.289	52%
Iron	High flow	85.860	85.860	121.063	29%
	Low flow	13.770	13.770	1.790	0%

All units are lbs/day

The current dataset suggests that the arsenic TMDL is met during high flow conditions but that a load reduction, up to 52%, is required during low flow time periods. Conversely, iron appears to be meeting the TMDL during low flow conditions but requires up to a 29% reduction during high flow time periods. **Table 3-4** lists the inputs used to calculate lower Douglas Creek's example TMDLs.

As shown in **Figure 3-4**, instream iron concentrations are closely tied to suspended sediment concentrations. The sediment TMDL established for lower Douglas Creek in 2008 called for a 23% reduction in annual sediment loading (Montana Department of Environmental Quality, 2008). Best management practices and restoration projects implemented to meet sediment TMDLs often reduce a higher percentage of sediment loading during high flow conditions, when iron load reductions are also needed. Therefore, meeting the 23% reduction in annual sediment loading will likely reduce sediment loading during high flow conditions by more than 23%, simultaneously achieving the 29% reduction in loading needed to meet the iron TMDL.

3.7.3 Murray Creek (MT76F003_120)

Murray Creek, from the headwaters to the mouth at Douglas Creek (8.8 miles), previously had TMDLs developed for nitrate/nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorus, sedimentation/siltation, and temperature (Montana Department of Environmental Quality, 2008).

Arsenic has been included on the 303(d) list since 2006 but was not addressed in the previous TMDL effort. DEQ assessed the waterbody following additional data collection in 2013 and confirmed arsenic is impairing drinking water beneficial uses. This addendum addresses the arsenic impairment by establishing an arsenic TMDL for Murray Creek.

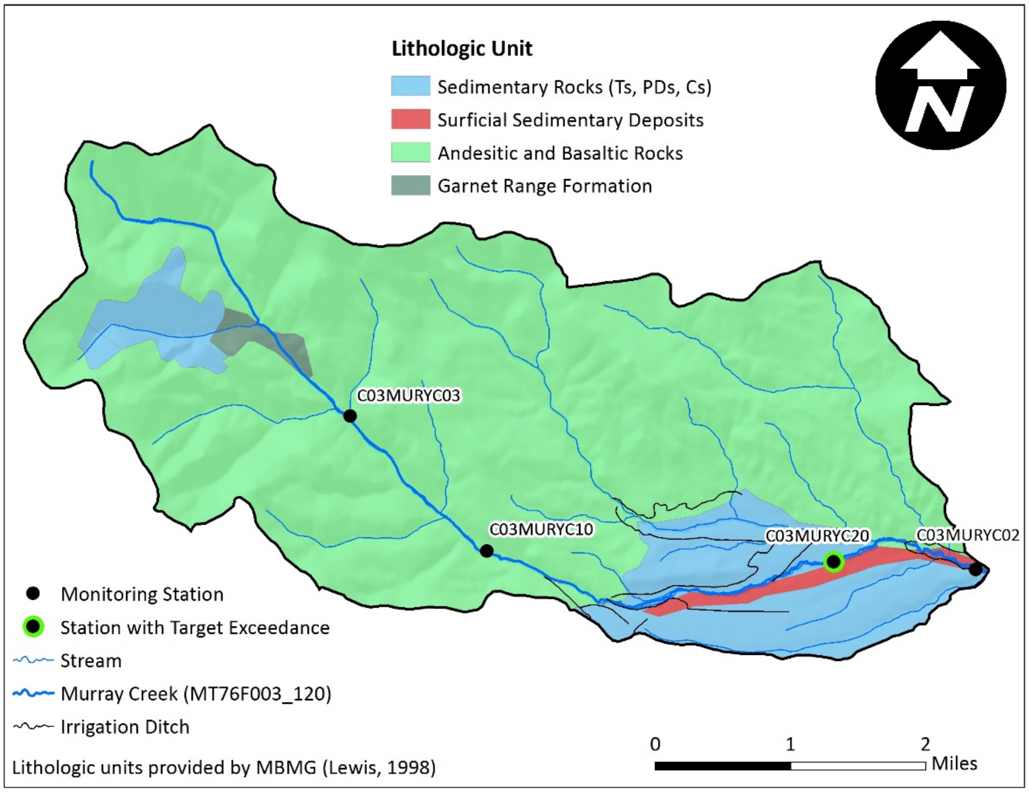

Figure 3-5. Murray Creek Watershed Map

Sources of Arsenic

There are no active or abandoned mines in the Murray Creek watershed according to DEQ AML and MBMG databases. There are also no permitted point sources. The general land cover mapped by the Montana Natural Heritage Program in 2010 can be described as follows: forested headwaters until approximately sample station C03MURYC03, forest-shrub regeneration following timber harvest between C03MURYC03 and C03MURYC10, eventually transitioning to a grassland system below C03MURYC10 with irrigated agriculture and a network of ditches (State Engineer's Office, 1959; Montana Natural Heritage Program, 2009).

No clear link can be drawn between human activities and the arsenic surface water exceedances based on the current dataset, so the source investigation must focus on background sources such as fires and geology. No fire has burnt in the basin within the last 100 years (Gibson and Morgan, 2009; Geospatial Multi-Agency Coordination Group, 2013; Geospatial Multi-Agency Coordination Group, 2011), therefore wildfires cannot be the source of arsenic impairment. The arsenic exceedance was collected at a location in the lower reach of Murray Creek within the sedimentary geologic unit and downstream of volcanic units consisting of andesite and basalt. Volcanic ash layers are also present in the sedimentary rock units colored light blue in **Figure 3-5**. The geologic setting of Murray Creek corresponds to conditions reported in other studies documenting elevated arsenic as described in **Section 3.4**. Redox and desorption processes occurring in the shallow aquifer interacting with Murray Creek in the hyporheic zone, potentially exacerbated by evaporation during low flow time periods, could be the most significant source of arsenic to Murray Creek. The topography in the lower reaches may also cause groundwater, originating in the headwaters and flowing through volcanic bedrock, to upwell arsenic-rich water as seeps in the regions were surface water exceedances were observed in the monitoring dataset, however, additional monitoring is required to confirm these hypotheses.

Existing Data and Comparison to Water Quality Targets
The current arsenic dataset consists of 10 water samples and four sediment samples collected at four sites by DEQ in 2003, 2005, and 2013 (see **Figure 3-5**). All sediment samples were well below the arsenic sediment target but one of the ten water samples exceeded the human health target, indicating the waterbody is impaired. The sole arsenic exceedance was collected during low flow conditions in 2003 at site C03MURYC20. A 16 µg/L, the concentration is over one and a half times the human health target.

Synoptic sampling during low flow time periods revealed arsenic concentrations steadily increased in the downstream direction, however, due to fluctuations in streamflow caused by irrigation withdrawals and groundwater losses, especially between C03MURYC10 and C03MURYC20, the pattern for loads was not consistent. During high flow time periods, arsenic concentrations and loads followed no discernible pattern. Arsenic concentrations are usually higher during baseflow conditions but once streamflow is considered, loading is approximately consistent throughout the year. **Table 3-9** compares existing arsenic data to the targets described in **Section 3.5.1.**

Table 3-9. Murray Creek data summary and target exceedances

Parameter	Arsenic
Number of samples	10
Date of samples	2003-2013
% of samples considered high flow	40%
Chronic Aquatic Life criterion exceedance rate > 10%?	No
> 2x acute Aquatic Life criterion exceeded?	No
Human health criterion exceeded?	Yes
NOAA PEL exceeded?	No
Human-caused sources present?	Yes
Impairment Determination	**Impaired**

Murray Creek TMDLs
Due to uncertainties in defining natural background concentrations of arsenic, the arsenic TMDL in this addendum is presented as a composite load allocation to all nonpoint sources both naturally occurring and human-related, as expressed by the following formula:

$$TMDL_{Murray} = LA_{Composite}$$

TMDLs were calculated using the target concentration and the streamflow values observed at site C03MURYC20 on September 26, 2003 and May 23, 2013. Existing loads were calculated using the same flow and conversion factor as the TMDLs but using arsenic concentrations observed at C03MURYC20 on said dates instead of the target concentrations. **Table 3-10** provides example TMDLs, allocations and necessary percent reductions; however, because TMDLs are flow dependent, actual TMDLs will not always match **Table 3-10**.

Table 3-10. Murray Creek example TMDLs and allocations

Metal	Flow	$TMDL_{Murray}$	$LA_{Composite}$	Existing Load	% Reduction
Arsenic	High flow	0.016	0.016	0.003	0%
	Low flow	0.011	0.011	0.017	38%

All units are lbs/day

The current dataset suggests that the arsenic TMDL is met during high flow conditions but that a load reduction, up to 38%, is required during low flow time periods. **Table 3-4** lists the inputs used to calculate Murray Creek's example TMDLs.

3.7.4 Kleinschmidt Creek (MT76F004_110)

Kleinschmidt Creek, from Ward Creek to the mouth at Rock Creek (4.7 miles), previously had TMDLs developed for sedimentation/siltation and temperature (Montana Department of Environmental Quality, 2008). Arsenic has been included on the 303(d) list since 2000 but was not addressed in the previous TMDL effort. DEQ assessed the waterbody following additional data collection in 2013 and confirmed arsenic is impairing drinking water beneficial uses. This addendum addresses the arsenic impairment by establishing an arsenic TMDL for Kleinschmidt Creek. In 2013, DEQ also revised Kleinschmidt Creek's assessment unit (MT76F004_110), by extending the segment upstream to incorporate a previously unassigned portion of Kleinschmidt Creek and correcting the location description, which erroneously indicated the unit ended at the North Fork of the Blackfoot River. The segment now ends at Rock Creek, which then flows into the North Fork. The old description read, "Kleinschmidt Creek – 1.5 miles upstream to the mouth (North Fork Blackfoot River)." This change reconciled DEQ's geographic database with USGS's National Hydrograph Dataset (NHD).

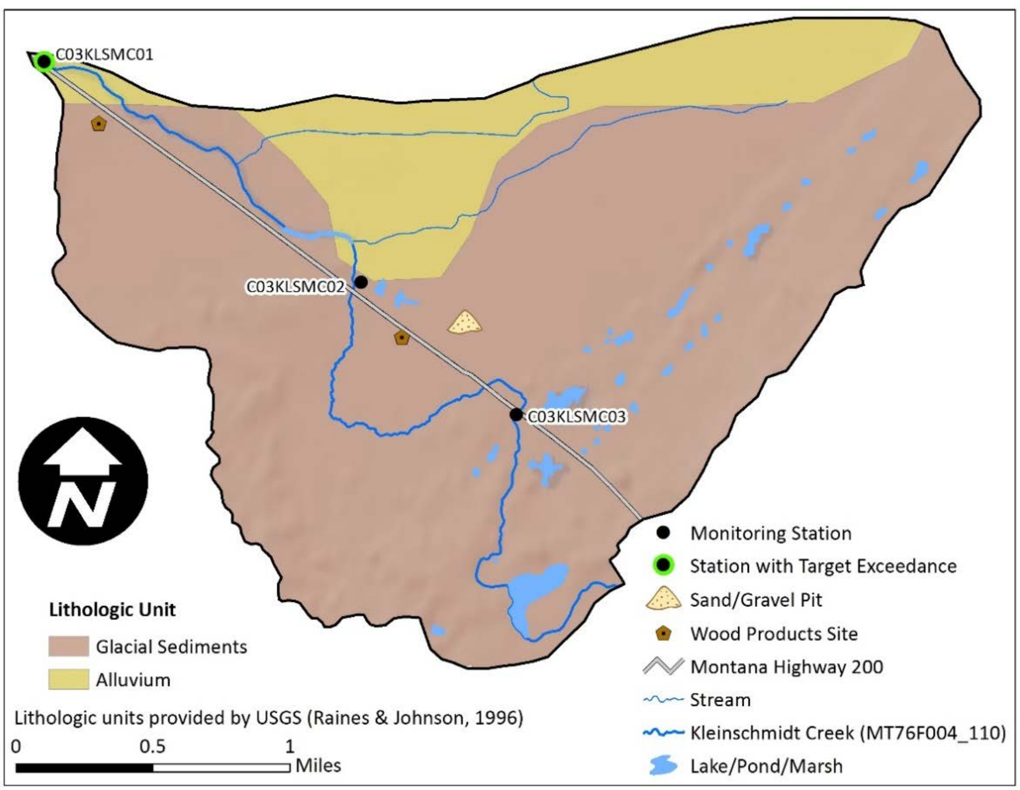

Figure 3-6. Kleinschmidt Creek Watershed Map

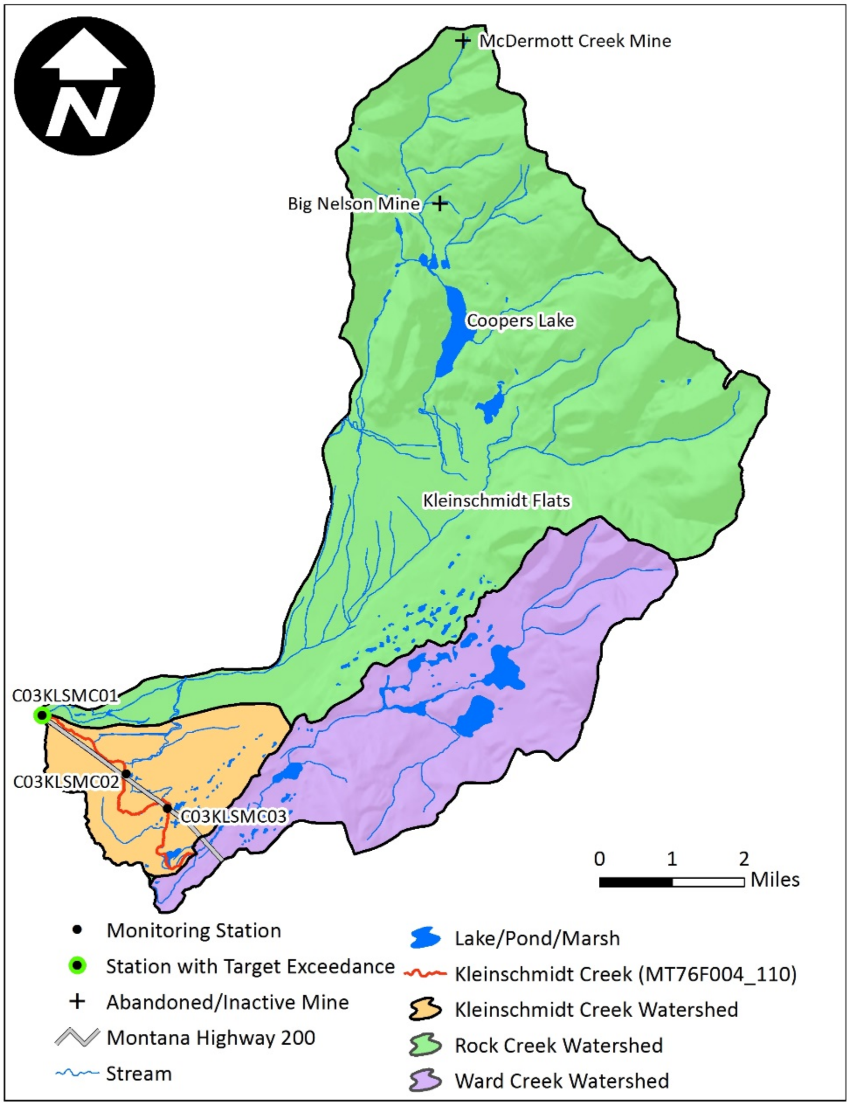

Figure 3-7. Greater Kleinschmidt Creek Source Map

Sources of Arsenic and Copper

There are no permitted point sources in the Kleinschmidt Creek watershed. There are also no abandoned or inactive mines according to DEQ AML and MBMG databases (see **Figure 3-6**). However, these records show two abandoned mines in the headwaters of Rock Creek, which mixes with Kleinschmidt Creek water between C03KLSMC02 and C03KLSMC01 due to a cross-basin irrigation ditch as shown on **Figure 3-7**. One of these mines, the McDermitt Creek Mine, is described in DEQ's historical mining district narratives as a placer operation that developed a 42 foot long adit and a small pit (Montana Department of Environmental Quality, 2009). The second mine, Big Nelson, is located downstream of the McDermitt Creek Mine, however, no further information is included in DEQ AML or MBMG records. Recent aerial photos show an unvegetated surface disturbance of roughly 2 acres at the Big Nelson site. These mines are 12 and 14 miles upstream of Kleinschmidt Creek, and are also separated from the creek by Coopers Lake. DEQ sampled Coopers Lake in July, 2006 and found the lake met all metals surface water targets and arsenic was below detection. USGS's National Hydrography Dataset (1:24,000 scale), which maps the network of surface water connections, does not show the

McDermitt Creek-Coopers Lake basin directly connected to Rock Creek. The flowline stops in the low gradient area known as Kleinschmidt Flats and most of the water discharged from the basin likely goes subsurface at this point (see **Figure 3-7**). Due to the potential pathway disconnect, the distance between the mines and Kleinschmidt Creek and the clean samples from Coopers Lake, the mines are not considered a significant source of arsenic to Kleinschmidt Creek. Future monitoring targeted around these mine sites should occur to verify this determination. No mining is known to have occurred in the Ward Creek watershed.

Other human land use activities in the Kleinschmidt Creek basin include two log home construction businesses and a sand/gravel quarry (see **Figure 3-6**). As described in **Section 3.4**, many wood products were historically treated with arsenic based preservatives. It is unknown whether these operations worked with these chemicals in the past (arsenic based wood preservatives for residential uses have been banned since 2003) but if the local sediments or groundwater is contaminated, arsenic could migrate to surface waters, especially since both sites are located within 1,000 feet of Kleinschmidt Creek. Future monitoring targeted around these log home construction sites is recommended to definitively rule them out as a source of arsenic. Quarry operations spanning the alluvial silt and glacial gravel lithologies also have the potential to influence metal concentrations in surface waters if iron oxide or sulfide bearing compounds are exposed to surface weathering. Unfortunately, sample site C03KLSMC02 was located just upstream of where flooded quarry pits discharge into Kleinschmidt Creek so contributions from this source cannot be separated from effects of the lower log home construction site and inputs from the Rock Creek basin via the trans-basin irrigation ditch using the current dataset. Additional surface water and sediment samples surrounding the quarry are recommended to improve the source assessment.

The source investigation also focused on background sources such as fires and geology. Within the last 100 years, one fire has burnt in the Kleinschmidt Creek watershed. That fire occurred in 1945 and burnt approximately 80 acres on the southeast side of the basin ((Gibson and Morgan, 2009; Geospatial Multi-Agency Coordination Group, 2013; Geospatial Multi-Agency Coordination Group, 2011). A broader look at the Ward and Rock Creek watersheds shows the Meadow Creek fire, which burnt 223 acres of the Rock Creek headwaters in 2012, as the only recent fire disturbance (Geospatial Multi-Agency Coordination Group, 2013). The timing of these events does not support a correlation between fires the 2003 arsenic target exceedance. The arsenic exceedance was collected at the site nearest to the mouth (C03KLSMC01) within the alluvial geologic unit and downstream of diorite and gabbro in the Rock Creek watershed. If arsenic can be traced back to this igneous geology from Rock Creek, the location of the cross-basin irrigation ditch could explain why arsenic exceedances were only observed at C03KLSMC01. Redox and desorption processes occurring in the shallow aquifers of the region could be a significant source of arsenic to Kleinschmidt Creek and the effects may be exacerbated by evaporation during low flow time periods. However, the wood product sites and quarry make Kleinschmidt Creek unique compared to other TMDL streams in this addendum, and the sites should not be ruled out as a potential source of arsenic until further monitoring is conducted.

Existing Data and Comparison to Water Quality Targets

The current arsenic dataset consist of nine water samples and three sediment samples collected at three sites by DEQ in 2003, 2005, and 2013 (see **Figure 3-6**). An additional sediment sample was collected in 2003 but because it was analyzed for a sample fraction that differs from NOAA's PELs, it cannot be used for target comparisons. One of the nine arsenic water samples exceeded the human health target and all three sediment samples exceeded the sediment target, indicating the waterbody is impaired. Kleinschmidt Creek in the only TMDL stream in this addendum exceeding arsenic sediment targets, which potentially signifies a different source than Douglas or Murray Creek. The sole surface water arsenic exceedance was collected at the site nearest the mouth during low flow conditions in 2003. At 22 µg/L, the concentration is more than double the human health target. The most elevated sediment sample was collected from the middle site and was more than double the arsenic sediment target.

Synoptic sampling shows a large spike in streamflow over both flow conditions between sites C03KLSMC02 and C03KLSMC01. This may be due to both overland flow and groundwater supplements in the area north of Kleinschmidt Creek from irrigating hay pasture with water originating in Rock Creek. As a result of the greater flow, arsenic loads were always greatest at C03KLSMC01 even though concentration trends fluctuated between the sites. At each individual site, arsenic concentrations and streamflow (and therefore loads) remained relatively constant throughout the year. This is likely because snowmelt runoff does not affect Kleinschmidt Creek to the degree seen in most western Montana streams, due to its location in the middle of a large valley and the nature of its source, a diversion of Ward Creek. While no targets were exceeded in 2013, concentrations were actually highest at the middle sample site, not C03KLSMC01 where previous exceedances were observed. Unfortunately, the single arsenic sample that exceeded surface water targets at C03KLSMC01 in 2003 was not paired with any other samples so loading trends cannot be analyzed from that time and it is not known whether arsenic exceeded targets farther upstream. **Table 3-11** compares existing arsenic data to the targets described in **Section 3.5.1.**

Table 3-11. Kleinschmidt Creek data summary and target exceedances

Parameter	Arsenic
Number of samples	9
Date of samples	2003-2013
% of samples considered high flow	44%
Chronic Aquatic Life criterion exceedance rate > 10%?	No
> 2x acute Aquatic Life criterion exceeded?	No
Human health criterion exceeded?	Yes
NOAA PEL exceeded?	Yes
Human-caused sources present?	Yes
Impairment Determination	**Impaired**

Kleinschmidt Creek TMDLs

Due to uncertainties in defining natural background concentrations of arsenic, the arsenic TMDL in this addendum is presented as a composite load allocation to all naturally occurring sources and human-related nonpoint sources, as expressed by the following formula:

$$TMDL_{Kleinschmidt} = LA_{Composite}$$

Although there are mines in the basin, the current dataset does not implicate them as a source of arsenic loading. Furthermore, there is no evidence of discharging adits that would require considering mines point sources subject to WLAs as described in EPA guidance (Dodson, Max H., personal communication 12/22/93). TMDLs were calculated using the target concentration and the streamflow values observed at site C03KLSMC01 on September 11, 2003 and May 21, 2013. Existing loads were calculated using the same flow and conversion factor as the TMDLs but using arsenic concentrations observed at C03KLSMC01 on said dates instead of the target concentrations. **Table 3-12** provides example TMDLs, allocations and necessary percent reductions; however, because TMDLs are flow dependent, actual TMDLs will not always match **Table 3-12**.

Table 3-12. Kleinschmidt Creek example TMDLs and allocations

Metal	Flow	$TMDL_{Kleinschmidt}$	$LA_{Composite}$	Existing Load	% Reduction
Arsenic	High flow	0.386	0.386	0.077	0%
	Low flow	0.881	0.881	1.939	55%

All units are lbs/day

The current dataset suggests that the arsenic TMDL is met during high flow conditions but that a load reduction, up to 55%, required during low flow time periods. **Table 3-4** lists the inputs used to calculate Kleinschmidt Creek's example TMDLs.

3.8 Implementation

Since the sources of arsenic and iron impairments in the Middle Blackfoot – Nevada Project Area are unclear, the metals restoration approach cannot be well defined until additional monitoring and source assessment work has been completed to further refine the list of sources leading to impairment. **Section 6.0** describes potential future efforts that can be done to strengthen source assessment and increase available metals related data.

4.0 TEMPERATURE SECTION

This portion of the Middle Blackfoot-Nevada Creek Total Maximum Daily Load (TMDL) Addendum contains temperature TMDLs for the following two segments of the Blackfoot River: Blackfoot River (Nevada Creek to Monture Creek; MT76F001_031) and Blackfoot River (Monture Creek to Belmont Creek; MT76F001_032; note that this segment extends into the Lower Blackfoot TMDL Planning Area). These TMDLs provide an additional layer of water quality protection to the Blackfoot River by increasing awareness of factors contributing to elevated temperatures in the Blackfoot River and by increasing focus on meeting the tributary temperature and sediment TMDLs contained within the 2008 Middle Blackfoot-Nevada Creek TMDL document (Montana Department of Environmental Quality, 2008). This section includes: 1) the effects of temperature on designated beneficial uses; 2) the stream segments of concern; 3) a summary of the 2008 Middle Blackfoot-Nevada Creek TMDL document (Montana Department of Environmental Quality, 2008); 4) data and information sources; 5) temperature targets; 6) an assessment of sources contributing to excess thermal loading; 7) temperature TMDLs and allocations; 8) seasonality and margin of safety (MOS); 9) uncertainty and adaptive management; and 10) implementation.

4.1 EFFECTS OF TEMPERATURE ON DESIGNATED BENEFICIAL USES

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the capacity of the stream to buffer incoming solar radiation all increase stream temperatures (see Montana Department of Environmental Quality, 2008). Warmer temperatures can negatively affect aquatic life, including fish that depend upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increase metabolism and reduce the amount of available oxygen in the water. In turn, coldwater fish, and other aquatic species, may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, sometimes creating lethal conditions for a percentage of the fish population. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). Although these TMDLs will address increased summer temperatures as the most likely to cause detrimental effects on fish and aquatic life, sources of increased temperature, such as the reduction of riparian vegetation, can lead to lower minimum temperatures during the winter (Hewlett and Fortson, 1982). These lower winter temperatures can lead to the formation of anchor and frazil ice, which can harm aquatic life by causing changes in movement patterns (Brown, 1999; Jakober et al., 1998), reducing available habitat, and inducing physiological stress (Brown et al., 1993). Addressing the issues associated with increased summer temperatures will also address these potential winter problems. Assessing thermal effects upon a beneficial use is an important initial consideration when interpreting Montana's water quality standard and subsequently developing temperature TMDLs.

4.2 STREAM SEGMENTS OF CONCERN

Two waterbody segments of the Blackfoot River within the Middle Blackfoot-Nevada Project Area appeared in the 2012 Montana impaired waters list as having temperature limiting a beneficial use: Blackfoot River (Nevada Creek to Monture Creek; MT76F001_031) and Blackfoot River (Monture Creek to Belmont Creek; MT76F001_032) (**Table 4-1**; **Figure 4-1**). Both segments have a B-1 use class designation. As such, the temperature water quality standard for both segments is as follows: the maximum allowable increase over the naturally occurring temperature is 1°F when the naturally occurring temperature is less than 66°F; within the naturally occurring temperature range of 66 – 66.5°F, the allowable increase cannot exceed 67°F; and if the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F [**ARM 17.30.623(e)**].

Table 4-1. Waterbody segments with temperature impairment causes addressed via TMDL development within this addendum

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Addendum Resolution	Included in 2012 Integrated Report
BLACKFOOT RIVER, Nevada Creek to Monture Creek	MT76F001_031	Temperature	TMDL Completed	Yes
BLACKFOOT RIVER, Monture Creek to Belmont Creek	MT76F001_032	Temperature	TMDL Completed	Yes

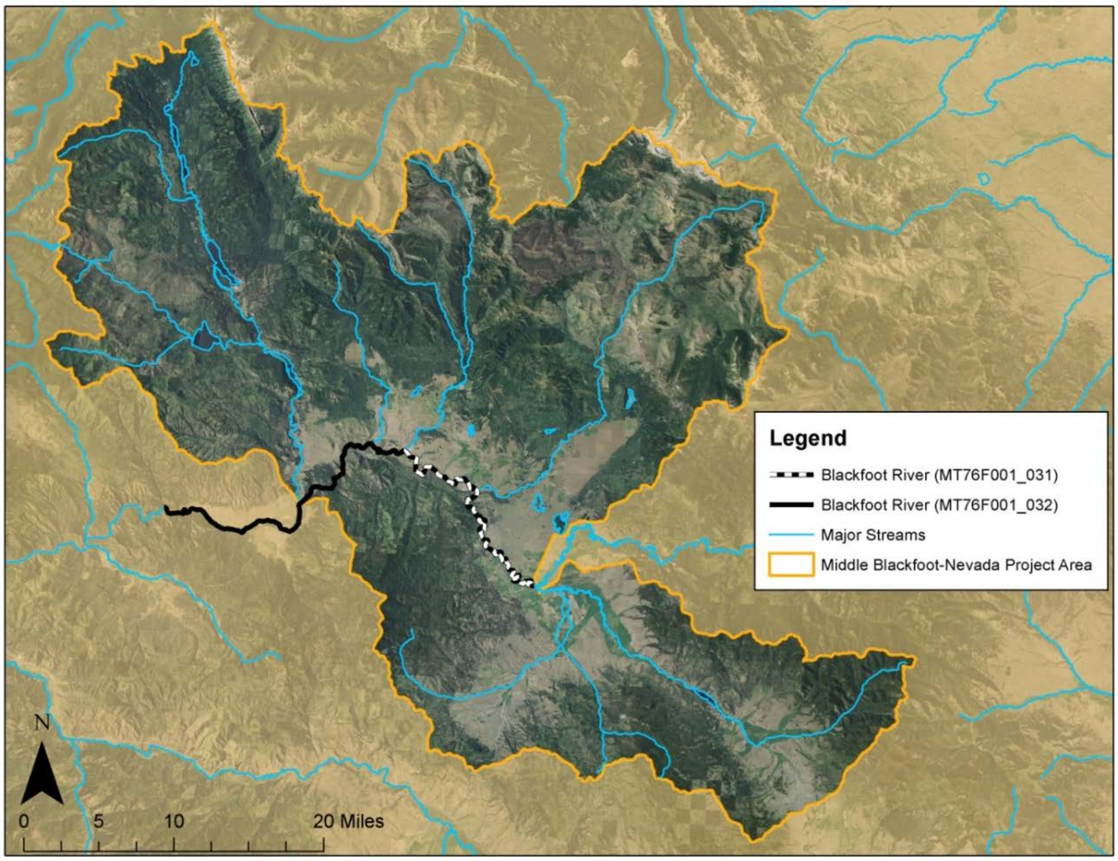

Figure 4-1. The two waterbody segments of the Blackfoot River for which temperature TMDLs are presented in this document

4.3 Summary of the 2008 Middle Blackfoot-Nevada Creek TMDL Document

Temperature TMDLs were written for most of the waterbody segments with temperature impairment causes in the Middle Blackfoot-Nevada Project Area in 2008 (Montana Department of Environmental Quality, 2008). Temperature TMDLs were written for the following segments in that document: Upper Nevada, Lower Nevada, Cottonwood, Murray, Upper Douglas, Lower Douglas, and Kleinschmidt creeks. The Blackfoot River from its confluence with Nevada Creek downstream to its confluence with Belmont

Creek was discussed in the document but no TMDLs were written for the two temperature impaired waterbody segments within that reach.

A temperature model called the Stream Network Temperature Model (SNTEMP) was used to determine average and maximum temperatures for the 2008 document (DTM and Applied Geomorphology, 2006; **Attachment A**). SNTEMP uses information about meteorological conditions, shading, channel morphology, and tributary temperatures to derive average and maximum stream temperature values. For TMDL development, this model was used to construct two scenarios that simulate the 1) current condition and 2) naturally occurring (called 'natural' in **Attachment A**) condition. Based on the findings in **Attachment A**, the naturally occurring condition scenario for the Blackfoot River from its confluence with Nevada Creek downstream to its confluence with Belmont Creek consisted of Nevada Creek discharging to the Blackfoot River at 69.2°F, the temperature resulting from temperature targets being met in Nevada Creek (Table 8-2 in Montana Department of Environmental Quality, 2008). Because the Blackfoot River is naturally wide, does not appear to be overwidened, and shade is limited even when vegetative cover is high, the values for shade and channel width were the same for the Blackfoot River in both scenarios. This means that according to the 2008 document (Montana Department of Environmental Quality, 2008), once targets in Nevada Creek are met, the Blackfoot River temperatures are at naturally occurring values.

The 2008 document (Sections 9.4.7 and 9.4.8 in Montana Department of Environmental Quality, 2008) indicated that temperature TMDLs and allocations for the two segments of the Blackfoot River were not required. This decision was based on the model results for both segments of the Blackfoot River, which indicated that they both exhibit temperatures that were less than the 0.5°F increase above the naturally occurring temperate and thus were currently meeting the water quality standard for temperature (**Tables 4-2** and **4-3**).

Table 4-2. Modeled mean daily and daily maximum Blackfoot River (Nevada Creek to Monture Creek; MT76F001_031) temperature differences at Raymond Bridge.

Table adapted from Table 4-9 in **Attachment A**

Parameter	Current Condition[1]	Naturally Occurring Condition[2]	Difference	Temperature Increase Allowed by the Standard
Modeled Mean Daily Temperature (°F)	68.66	68.43	0.23	0.5
Modeled Maximum Daily Temperature (°F)	74.19	73.99	0.20	0.5

[1] Simulated temperature with current stream conditions; Nevada Creek at 70.9°F

[2] Nevada Creek temperature reduced to 69.2°F

Table 4-3. Modeled mean daily and daily maximum Blackfoot River (Monture Creek to Belmont Creek; MT76F001_032) temperature differences below the mouth of the Clearwater River.

Table adapted from Table 4-10 **Attachment A**

Parameter	Current Condition[1]	Naturally Occurring Condition[2]	Difference	Temperature Increase Allowed by the Standard
Modeled Mean Daily Temperature (°F)	66.60	66.58	0.02	0.5
Modeled Maximum Daily Temperature (°F)	70.14	70.12	0.02	0.5

[1] Simulated temperature with current stream conditions; Nevada Creek at 70.9°F

[2] Nevada Creek temperature reduced to 69.2°F

The SNTEMP model used for the Blackfoot River analysis relied on improving conditions in Nevada Creek to decrease temperatures. This makes sense as Nevada Creek is a substantial contributor of flow (about 11%; **Table 4-5** in **Attachment A**) to the Blackfoot River and has the potential for a substantial decrease in water temperature. Uncertainty in the model lies within the consideration of Blackfoot River tributaries other than Nevada Creek. Other tributaries to these segments of the Blackfoot River with temperature data include Yourname, Wales, Frazier, Warren, Monture, and Chamberlain creeks and the North Fork Blackfoot and Clearwater rivers. With the exception of the Clearwater River, all of these tributaries discharge water that is similar to or colder than the Blackfoot River (Figure 4-28 in **Attachment A**). Although these tributaries are cooler than the Blackfoot River they may actually have elevated temperatures due to nonpoint sources. The potential for decreasing water temperatures in these streams as well as any other tributaries to the Blackfoot River was not evaluated as part of the model simulations. As such, the SNTEMP modeled naturally occurring scenario is incomplete and the potential for further decreasing Blackfoot River temperatures are unknown.

In addition to the uncertainty of the model, special temperature considerations are warranted for westslope cutthroat trout, which are listed in Montana as a species of concern and for bull trout, which are also a species of concern and are listed as threatened under the Endangered Species Act. Both of these species are present in the Blackfoot River (MFISH Database; http://fwp.mt.gov/fishing/mFish/). Research by Bear et al., (2007) found that the maximum growth of westeslope cutthroat trout occurs around 56.5°F with an optimum growth range (based on 95% confidence intervals) from 50.5 – 62.6°F. The ultimate upper incipient lethal temperature (UUILT) is the temperature considered to be survivable by 50% of the population over a specified time period. Bear et al., (2007) found the 60-day UUILT for westslope cutthroat trout to be 67.3°F and the 7-day UUILT to be 75.4°F. The lethal temperature dose for westslope cutthroat that will kill 10% of the population in a 24-hour period is 73.0°F (Liknes and Graham, 1988).

Bull trout require cold water to thrive and survive with maximum growth occurring around 55.8°F and an optimum growth range (based on 95% confidence intervals) from 51.6 – 59.7°F (Selong et al., 2001). Water temperatures important to bull trout for spawning, incubation, and rearing typically range from the upper 30s to low 50s Fahrenheit (U.S. Fish and Wildlife Service, 2002). As water temperatures increase, conditions become more adverse. Selong et al., (2001) found the 60-day UUILT to be 69.6°F and predicted the 7-day UUILT to be 74.3°F. The critical thermal maximum is the arithmetic mean of collected thermal points at which locomotor activity becomes disorganized such that the organism loses its ability to escape lethal conditions (Cowells and Bogert, 1944). According to Selong et al., (2001), the critical thermal maximum for bull trout is in the range of 76.6 – 84.0°F depending on age.

Data collected from the Blackfoot River during 2000 (Figures 4-18 and 4-22 in **Attachment A**) indicate that temperatures commonly exceed the optimal growth range of westslope cutthroat trout (> 63°F) and the thermal niche of bull trout (> 58°F). In addition, temperatures > 70°F were observed on multiple days.

Despite the finding in 2008 that these two segments were not impaired by temperature, they were not removed from the 303(d) list as impaired for temperature. Department of Environmental Quality (DEQ) has elected to write TMDLs for these two waterbody segments of the Blackfoot River (MT76F001_031; MT76F001_032) based on uncertainty in the SNTEMP model, the presence of westlope cutthroat trout and bull trout, and because summer temperatures in the Blackfoot River enter the range where they may stress westslope cutthroat trout and bull trout.

4.4 Data and Information Sources

The data and information sources used in this addendum come directly from the 2008 Middle Blackfoot-Nevada Creek TMDL document (Montana Department of Environmental Quality, 2008) and **Attachment A**. The targets to meet the temperature TMDLs within this document are found in DEQ (2008). Table 4-5 of **Attachment A** contains the flow values used to calculate TMDLs and allocations. The modeled temperature values used to calculate the TMDLs and allocations are found in Tables 4-9 and 4-10 of **Attachment A**.

4.5 Temperature Targets

As noted in **Section 4.3**, modeled current condition temperatures are within approximately 0.2°F of naturally occurring levels in segment MT76F001_031 and 0.02°F of naturally occurring levels in segment MT76F001_032, suggesting compliance with Montana's temperature standard. Because Nevada Creek was the only tributary considered for a temperature reduction in the SNTEMP model and because summer temperatures in the Blackfoot River below Nevada Creek reach levels that can be harmful to westslope cutthroat trout and bull trout, DEQ has developed temperature TMDLs that can be achieved via implementation of the Blackfoot River tributary temperature and sediment TMDLs contained within DEQ (2008). These include temperature TMDLs for Nevada Creek, several Nevada Creek tributaries, and Kleinschmidt Creek and sediment TMDLs for 15 waterbody segments in the Middle Blackfoot TMDL Planning Area.

The primary temperature target for these TMDLs is to meet the SNTEMP modeled naturally occurring scenario temperature for the Blackfoot River. This can be achieved by meeting the temperature targets for all the streams identified in **Table 8-2** of DEQ (2008). Additional temperature improvements can be achieved by implementing the 15 sediment TMDLs for waterbodies in the Middle Blackfoot TMDL Planning Area (Table 9-6 ofMontana Department of Environmental Quality, 2008). The sediment targets for these waterbody segments include improvements to riparian health and width to depth ratios (Table 5-3 in Montana Department of Environmental Quality, 2008), both of which can lead to reduced temperatures.

4.6 Assessment of Sources Contributing to Excess Thermal Loading

Nevada Creek is a source of human-caused thermal loading to the Blackfoot River as demonstrated in **Tables 4-2** and **4-3**. Other tributaries to the Blackfoot River (**Table 4-4** and others not identified in this document) may also contribute human-caused thermal loading though the thermal load of each tributary to the Blackfoot River has not been calculated. Due to the small size of most tributaries within these two segments of the Blackfoot River, it is likely that these other tributaries have less of an effect than Nevada Creek (**Table 4-4**). Two of these tributaries, the North Fork Blackfoot River and Monture Creek both contribute relatively large amounts of water that is substantially cooler than the mainstem Blackfoot River (**Table 4-4**). It is expected that those tributaries with established sediment TMDLs (see Table 9-6 ofMontana Department of Environmental Quality, 2008) have existing temperatures at least slightly above naturally occurring; these temperatures are expected to decrease when sediment Best Management Practices (BMPs) associated with established TMDLs are implemented. Note that the North Fork Blackfoot River is considered fully supporting of all uses (Clean Water Act Information Center (CWAIC) database; http://svc.mt.gov/deq/olqs/CWAIC/Query.aspx) and therefore has naturally occurring temperatures and no sediment TMDL developed. Also note that the Clearwater River has not been fully assessed and a sediment TMDL was not written for this waterbody.

Table 4-4. SNTEMP model input/current condition value for Blackfoot River and tributary discharge and temperature and tributary percent contribution of discharge to the Blackfoot River at selected locations

Waterbody	Discharge (cfs)	Temperature (°F)	Percent contribution of Blackfoot River discharge at Raymond Bridge	Percent contribution of Blackfoot River discharge below the Clearwater River
Nevada Creek	22	70.9	11	3
Yourname Creek	5	59.9	2	1
Wales Creek	4	59.1	2	1
Blackfoot River at Raymond Bridge (MT76F001_031)	203	68.66[1]	NA	NA
North Fork Blackfoot River	219	55.7	NA	34
Warren Creek	8	63.9	NA	1
Monture Creek	81	58	NA	13
Chamberlain Creek	5	64.2	NA	1
Cottonwood Creek	27	60.8	NA	4
Clearwater River	73	69.9	NA	11
Blackfoot River below the Clearwater River (MT76F001_031)	636	66.6[1]	NA	NA

[1]Current condition average modeled value

There are no point sources to the applicable segments of the Blackfoot River; thus there are no Montana Pollutant Discharge Elimination System (MPDES) permits and wasteload allocations are not required. Additional source assessment information can be found in **Section 8.1.3** of DEQ (2008).

4.7 Temperature TMDLs and Allocations

The temperature TMDLs in this section consist of the sum of the load allocation (LA) for all nonpoint sources (including natural sources) and an explicit margin of safety (MOS) that accounts for the uncertainty in the temperature loads entering the Blackfoot River. The load allocation for each TMDL will be based on the naturally occurring temperature as determined by the SNTEMP model. The explicit MOS will be the temperature increase (and associated thermal load) above naturally occurring allowed by the standard (0.5 – 1.0°F depending on the naturally occurring temperature).

Because of the dynamic temperature conditions throughout the course of a day, the temperature TMDL is the thermal load, at an instantaneous moment, associated with the stream temperature when in compliance with Montana's water quality standards. As stated earlier, the temperature standard for the Blackfoot River is defined as follows: the maximum allowable increase over the naturally occurring temperature is 1°F when the naturally occurring temperature is less than 66°F; within the naturally occurring temperature range of 66 – 66.5°F, the allowable increase cannot exceed 67°F; if the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F. Montana's temperature standard for B-1 classified waters, relative to naturally occurring temperatures, is depicted in **Figure 4-2**.

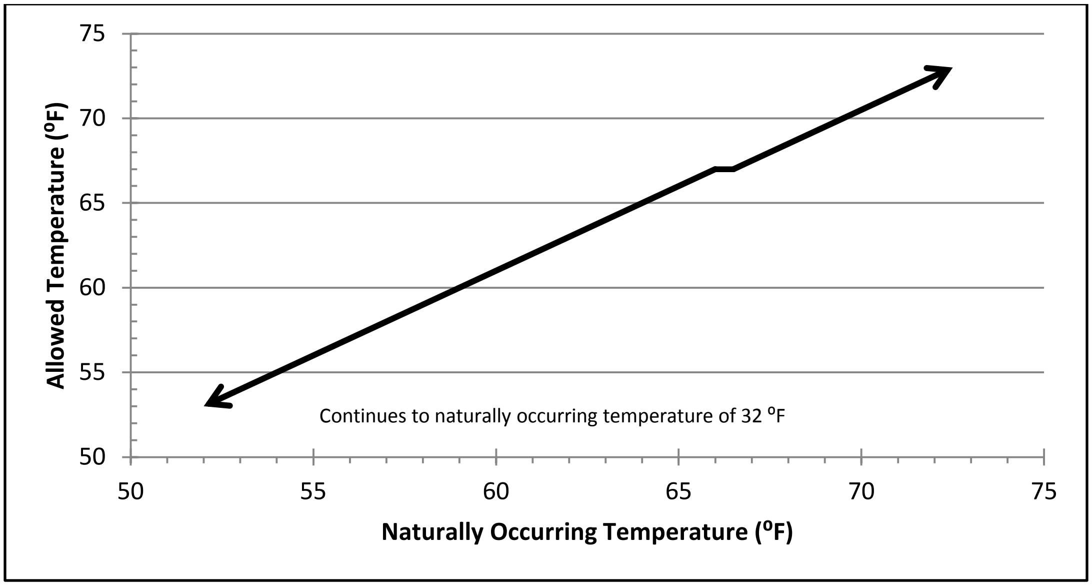

Figure 4-2. Instream Temperatures Allowed by Montana's B-1 classification temperature standard

An instantaneous load is computed by the second and applied at all times. The allowed temperature can be calculated using Montana's B-1 classification standard and using a modeled, measured, or estimated naturally occurring instantaneous temperature. The allowable instantaneous total maximum load (per second) at any location in the waterbody is provided by **Equation 4-1**. This equates to the heat load (kcal/s) increase associated with the warming of the water from 32°F (i.e., water's freezing point) to the temperature that represents compliance with Montana's temperature standard, as determined from **Figure 4-2**.

Equation 4-1:

$$\mathbf{TMDL_{(instantaneous)} = ((T_{NO} + \Delta) - 32)*(5/9) * Q * 28.3}$$

Where:

T_{NO} = naturally occurring water temperature (°F)
Δ = allowable increase above naturally occurring temperature (°F)
Q = streamflow (cfs)
28.3 = conversion factor

The instantaneous load is the most appropriate expression for a temperature TMDL because water temperatures fluctuate throughout the day and an instantaneous load allows for evaluation of human-caused thermal loading when fish are most distressed by elevated water temperatures and when human-caused thermal loading would have the most effect. Although Environmental Protection Agency (EPA) encourages TMDLs to be expressed in the most applicable timescale, it also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Any instantaneous TMDL calculated using **Equation 4-1**, which provides a load per second, can be converted to a daily load (kcal/day) by multiplying by 86,400 (i.e., the number of seconds in a day). Daily loads are provided for all example TMDLs and allocations in **Sections 4.7.1** and **4.7.2**.

For the two segments of the Blackfoot River, the load allocations for all nonpoint sources will be based on the naturally occurring temperature (**Equation 4-2**). This results in the entire temperature change allowed by the standard (0.5 – 1.0°F depending on the naturally occurring temperature) to be applied as an explicit MOS. Once the TMDL and LA have been calculated, the MOS (as a load) can be determined using **Equation 4-3**.

Equation 4-2:

$$\mathbf{LA}_{(instantaneous)} = (T_{NO} - 32)*(5/9) * Q * 28.3$$

Where:

T_{NO} = naturally occurring water temperature (°F)
Q = streamflow (cfs)
28.3 = conversion factor

Equation 4-3:

$$\mathbf{TMDL}_{(instantaneous)} = \mathbf{LA}_{(instantaneous)} + \mathbf{MOS}_{(instantaneous)}$$

Where:

$LA_{(instantaneous)}$ = Composite Load Allocation to all nonpoint sources including natural background sources
$MOS_{(instantaneous)}$ = explicit margin of safety load based on the allowable increase above the naturally occurring temperature

To provide an example estimate of the total existing loading from all sources combined, the following equation will be used:

Equation 4-4:

$$\text{Total Existing Load}_{(instantaneous)} = ((T_{meas}) - 32)*(5/9) * Q * 28.3$$

Where:

T_{meas} = measured or modeled existing water temperature (°F)
Q = streamflow (cfs)
28.3 = conversion factor

4.7.1 Blackfoot River from Nevada Creek to Monture Creek (MT76F001_031)

The temperature TMDL for the Blackfoot River from Nevada Creek to Monture Creek is based on **Equation 4-1** and the load allocation to nonpoint sources is based on **Equation 4-2**. An explicit MOS of 0.5 – 1.0°F will be used in this waterbody segment depending on the naturally occurring temperature. The following example TMDL for the Blackfoot River from Nevada Creek to Monture Creek uses a flow of 203 cfs and the modeled naturally occurring average temperature of 68.43°F at the Raymond Bridge. At this temperature the allowable increase above the naturally occurring temperature is 0.5°F based on the water quality standard for temperature [**ARM 17.30.623(e)**].

The example TMDL is therefore:

TMDL (instantaneous) = ((68.43 + 0.5) - 32)*(5/9) * 203 * 28.3 = 117,866 kcal/s

Converted to a daily load the TMDL is:

TMDL = 117,866 kcal/s * 86,400 s/day = 10,183,622,400 kcal/day

Equation 4-2 is the basis for the example load allocation for temperature. To continue with the example at a naturally occurring average temperature of 68.43°F, flow of 203 cfs, and an explicit MOS of 0.5°F, this allocation is as follows:

$$LA_{(instantaneous)} = (68.43 - 32)*(5/9) * 203 * 28.3 = 116,270 \text{ kcal/s}$$

Converted to a daily load the LA is:

$$\textbf{LA = 116,270 kcal/s * 86,400 s/day = 10,045,728,000 kcal/day}$$

Using **Equation 4-3** the resulting explicit MOS at 203 cfs is:

$$\textbf{MOS}_{\text{(instantaneous)}} \textbf{ = 117,866 kcal/s - 116,270 kcal/s = 1,596 kcal/s}$$

Converted to a daily load the MOS is:

$$\textbf{MOS = 1,596 kcal/s * 86,400 s/day = 137,894,400 kcal/day}$$

The instantaneous existing load at Raymond Bridge based on **Equation 4-4**, a modeled average existing temperature of 68.66°F and flow of 203 cfs is:

$$\textbf{Existing Load}_{\text{(instantaneous)}} \textbf{ = (68.66-32)*(5/9) * 203 * 28.3 = 117,004 kcal/s}$$

The example temperature TMDL, load allocation, and MOS are summarized in **Table 4-5**. The temperature targets in **Table 8-2** of DEQ (2008) and sediment targets in **Tables 5-2** and **5-3** of DEQ (2008) serve as surrogates to the numeric allocations. Meeting these targets will result in meeting the numeric allocations under all conditions including the examples in **Table 4-5**. As demonstrated in **Table 4-6**, the existing temperature loading to the Blackfoot River from Nevada Creek to Monture Creek is greater than the LA to all nonpoint sources and a reduction is needed; implementation of BMPs on tributaries of the Blackfoot River is necessary to meet the water quality targets for temperature. The source assessment for the Blackfoot River from Nevada Creek to Monture Creek indicates that Nevada Creek contributes a measureable amount of human-caused temperature loading with additional thermal loading likely coming from tributaries to the Blackfoot River and Nevada Creek with sediment TMDLs; therefore, load reductions should be sought on these waterbodies. Meeting load allocations for the Blackfoot River from Nevada Creek to Monture Creek may be achieved through a variety of water quality planning and implementation actions, which are addressed in **Section 10.0** of DEQ (2008).

Table 4-5. Blackfoot River from Nevada Creek to Monture Creek example instantaneous and daily TMDL, LA, and explicit MOS

Category	Instantaneous Load (kcal/s) / Temperature (°F)[1]	Daily Load (kcal/day)[1]
All nonpoint sources LA	116,270 / 68.43°F	10,045,728,000
Explicit MOS	1,596 / 0.5°F	137,894,400
TMDL	117,866 / 68.93°F	10,183,622,400

[1] *Based on a naturally occurring temperature of 68.43°F, flow of 203 cfs, and an explicit MOS of 0.5°F*

Table 4-6. Blackfoot River from Nevada Creek to Monture Creek example reduction based on the modeled instantaneous existing condition and example LA and an explicit MOS

Category	Instantaneous Existing Load (kcal/s) / Temperature (°F)	LA (kcal/s) / Temperature (°F)	Percent Reduction Needed
All nonpoint sources	117,004 / 68.66 °F	116,270 / 68.43°F	0.6%

4.7.2 Blackfoot River from Monture Creek to Belmont Creek (MT76F001_032)

The temperature TMDL for the Blackfoot River from Monture Creek to Belmont Creek is based on **Equation 4-1** and the load allocation to nonpoint sources is based on **Equation 4-2**. An explicit MOS of 0.5 – 1.0°F will be used in this waterbody segment depending on the naturally occurring temperature. The following example TMDL for the Blackfoot River from Monture Creek to Belmont Creek uses a flow of 636 cfs and the modeled naturally occurring average temperature of 66.58°F downstream of the

Clearwater River. At this temperature the allowable increase above the naturally occurring temperature is 0.5°F based on the water quality standard for temperature [**ARM 17.30.623(e)**].

The example TMDL is therefore:

TMDL (instantaneous) = ((66.58 + 0.5) - 32)*(5/9) * 636 * 28.3 = 350,777 kcal/s

Converted to a daily load the TMDL is:

TMDL = 350,777 kcal/s * 86,400 s/day = 30,307,132,800 kcal/day

Equation 4-2 is the basis for the example load allocation for temperature. To continue with the example at a naturally occurring temperature of 66.58°F, flow of 636 cfs, and an explicit MOS of 0.5°F, this allocation is as follows:

$LA_{(instantaneous)}$ **= (66.58 - 32)*(5/9) * 636 * 28.3 = 345,777 kcal/s**

Converted to a daily load the LA is:

LA = 345,777 kcal/s * 86,400 s/day = 29,875,132,800 kcal/day

Using **Equation 4-3** the resulting explicit MOS at 636 cfs is:

$MOS_{(instantaneous)}$ **= 350,777 kcal/s - 345,777 kcal/s = 5,000 kcal/s**

Converted to a daily load the MOS is:

MOS = 5,000 kcal/s * 86,400 s/day = 432,000,000 kcal/day

The instantaneous existing load downstream of the Clearwater River based on **Equation 4-4**, a modeled average existing temperature of 66.6°F and flow of 636 cfs is:

Existing Load $_{(instantaneous)}$ **= (66.6-32)*(5/9) * 636 * 28.3 = 345,977 kcal/s**

The example temperature TMDL, load allocation, and MOS are summarized in **Table 4-7**. The temperature targets in **Table 8-2** of DEQ (2008) and sediment targets in **Tables 5-2** and **5-3** of DEQ (2008) serve as surrogates to the numeric allocations. Meeting these targets will result in meeting the numeric allocations under all conditions including the examples in **Table 4-7**. As demonstrated in **Table 4-8**, the existing temperature loading to the Blackfoot River from Monture Creek to Belmont Creek is greater than the LA to all nonpoint sources and a reduction is needed; implementation of BMPs on tributaries of the Blackfoot River is necessary to meet the water quality targets for temperature. The source assessment for the Blackfoot River from Monture Creek to Belmont Creek indicates that Nevada Creek contributes a measurable amount of human-caused temperature loading with additional loading likely coming from tributaries to the Blackfoot River and Nevada Creek with sediment TMDLs; therefore, load reductions should be sought on these waterbodies. Meeting load allocations for the Blackfoot River from Monture Creek to Nevada Creek may be achieved through a variety of water quality planning and implementation actions, which are addressed in **Section 10** of DEQ (2008).

Table 4-7. Blackfoot River from Monture Creek to Belmont Creek example instantaneous and daily TMDL, LA, and explicit MOS

Category	Instantaneous Load (kcal/s) / Temperature (°F)[1]	Daily Load (kcal/day)[1]
All nonpoint sources LA	345,777 / 66.58°F	29,875,132,800
Explicit MOS	5,000 / 0.5°F	432,000,000
TMDL	350,777 / 67.08°F	30,307,132,800

[1] *Based on a naturally occurring temperature of 66.58°F, flow of 636 cfs, and an explicit MOS of 0.5°F*

Table 4-8. Blackfoot River from Monture Creek to Belmont Creek example reduction based on the modeled instantaneous existing condition and example LA and an explicit MOS

Category	Instantaneous Existing Load (kcal/s) / Temperature (°F)	LA (kcal/s) / Temperature (°F)	Percent Reduction Needed
All nonpoint sources	345,977 / 66.6 °F	345,777 / 66.58°F	0.06%

4.8 IMPLEMENTATION

Implementation and monitoring recommendations presented in **Section 10.0** of DEQ (2008) provide a basic framework for reducing uncertainty and achieving the temperature TMDLs in this addendum. Implementation is focused on the application of BMPs that improve streamside shading and increase streamflow on the sediment- and temperature-impaired streams captured in the 2008 TMDL document (Montana Department of Environmental Quality, 2008). Because the sources of increased temperature loading in the two segments of the Blackfoot River are nonpoint, implementation of these TMDLs is voluntary. As such, stakeholders can work cooperatively to determine where, when, and how they will implement BMPs and achieve temperature allocations.

5.0 Seasonality and Margin of Safety

Seasonality and margin of safety are both required elements of total maximum daily load (TMDL) development. This section describes how seasonality and margin of safety (MOS) were applied during the development of TMDLs contained in this addendum.

5.1 Seasonality

Seasonality addresses the need to ensure year-round designated use support. Seasonality must be considered when assessing loading conditions and while developing water quality targets, TMDLs, and allocation schemes. Seasonality was addressed for each pollutant group in this document as follows:

Sediment

- The applicable narrative water quality standards apply year round.
- The secondary fine sediment target parameters for tributary streams are measured during summer or autumn low-flow conditions which represents the most practical time period for assessing substrate and habitat conditions, and is consistent with the time of year when reference stream measurements are conducted. The health of aquatic life in tributaries is most likely to be negatively affected by fine sediment in riffles or pool tails during low flow time periods. Additionally, the fine sediment measured in tributaries during the summer is likely transported to Nevada Lake during times of high flow when suspended sediment levels in the lake are at their highest. Thus the fine sediment targets incorporate for the protection of aquatic life during sensitive time periods.
- A standard modeling approach, such as Soil and Water Assessment Tool (SWAT), incorporates the yearly hydrologic cycle specific to the project area. The resulting loads are expressed as average yearly loading rates to fully assess loading throughout the year.
- The TMDL and necessary loading reduction is presented on an annual timescale which captures the variability between high and low flow reductions.

Metals

- Metals concentrations and loading conditions are evaluated for both high flow and low flow conditions. Department of Environmental Quality's (DEQ) assessment method requires a combination of both high and low flow sampling for target evaluation since abandoned mines and other metals sources can differ between high and low flow conditions. Targets, example TMDLs, and load reduction needs are developed separately for both high and low flow conditions.
- Metals TMDLs incorporate streamflow as part of the TMDL equation thereby incorporating all potential flow conditions that may occur during any season.
- Metals water quality standards apply year round, however, monitoring for target attainment is performed at designated times to address seasonal water quality extremes associated with loading and hardness variations.
- A sediment chemistry target is applied as a supplemental indicator to help capture impacts from episodic metals loading events that could be attributed to high flow seasonal runoff conditions.

Temperature

- Temperature monitoring occurred during the summer and modeling simulated the warmest time of the year when instream temperatures are most stressful to aquatic life.

- A warmer than average year (2000) was used to calibrate the model and run scenarios.
- Although the average and maximum daily temperatures were examined in the model, sources affecting average and maximum stream temperatures can also alter daily minimum temperatures; restoration approaches will help to stabilize stream temperatures year round.
- Temperature exceedances occur mostly during the summer, but targets, example TMDLs, and load allocations apply year round.

5.2 Margin of Safety

Natural systems are inherently complex. Any approach used to quantify or define the relationship between pollutant loading rates and the resultant water quality effects, no matter how rigorous, will include some level of uncertainty or error. To compensate for this uncertainty and ensure water quality standards are attained, a MOS is required as a component of each TMDL. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (U.S. Environmental Protection Agency, 1999). This document incorporates an implicit MOS for sediment and metal TMDLs while establishing an explicit MOS for temperature TMDLs as follows:

Sediment

- Secondary fine sediment targets on tributaries are used to assess a broad range of physical parameters known to effect conditions downstream in Nevada Lake. These targets serve as indicators of potential impairment from sediment and also help signal recovery, and eventual standards attainment, after TMDL implementation. Conservative assumptions were used during development of these targets. An effort was made to select targets that are achievable, but in all cases, the most protective statistical approach was used.
- Targets are based on a reference condition approach which strives for conditions that are likely superior to the minimum conditions necessary to support beneficial uses.
- Because quantifying sediment loads is difficult and involves significant uncertainty, DEQ focuses on percent reductions and Best Management Practices (BMPs) implementation when judging TMDL compliance.
- A 350 foot buffer surrounding the stream channel was selected as the contributing area for sheetflow erosion. Values in literature for this distance are quite variable, ranging from 100 feet to 400 feet. A length of 350 feet is conservatively high and potentially overestimates the hillslope erosion load.
- A base erosion rate of 10 tons per acre of road prism per year was used to normalize road surface erosion estimates from different data sources (i.e., United States Forest Service (USFS) and private timber). Research in western Montana (Sugden and Woods, 2007) has indicated this rate is an order of magnitude too large, thereby providing an implicit margin of safety in the calculations based on the 10 tons per acre per year rate.
- The TMDL uses an adaptive management approach to refine components of this addendum.

Metals

- DEQ's assessment process includes a mix of high and low flow sampling since abandoned mines and other metals sources can lead to elevated metals loading during high and/or low flow stream conditions. The seasonality considerations help identify the low range of hardness values and thus the lower range of applicable TMDL values.

- Although a 10% exceedance rate is allowed for chronic and acute based aquatic life targets, the TMDLs are set so the lowest applicable target is satisfied 100% of the time. This focuses remediation and restoration efforts toward 100% compliance with all targets, thereby providing a margin of safety for the majority of conditions where the most protective (lowest) target value is linked to the numeric aquatic life standard. As part of this, the existing water quality conditions and needed load reductions are based on the highest measured value for a given flow conditions in order to consistently achieve the TMDL.
- The monitoring results used to estimate existing water quality conditions are instantaneous measurement used to estimate a daily load, whereas chronic aquatic life standards are based on average conditions over a 96-hour period. This provides a margin of safety since a four-day loading limit could potentially allow higher daily loads in practice.
- The lowest or most stringent numeric water quality standard was used for TMDL target and impairment determination for all waterbody – pollutant combinations. This ensures protection of all designated beneficial uses.
- Sediment metals criteria are used as a supplemental indicator target. This helps ensure that episodic loading events were not missed as part of the sampling and assessment activity.
- The TMDLs are based on numeric water quality standards developed at the national level via Environmental Protection Agency (EPA) and incorporate a MOS necessary for the protection of human health and aquatic life.
- Target attainment, refinement of load allocations, and, in some cases, impairment validations and TMDL-development decisions are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.

Temperature

- Although there is an allowable increase from human sources beyond those applying all reasonable land, soil, and water conservation practices, the targets (and thus the allocations) for nonpoint sources are expressed (via an explicit MOS) so that all reasonable land, soil, and water conservation practices must be applied to satisfy the targets.
- Compliance with targets and refinement of load allocations are all based on an adaptive management approach (**Section 6.0**) that relies on future monitoring and assessment for updating planning and implementation efforts to ensure that temperatures are suitable to support all applicable beneficial uses.

6.0 Adaptive Management

Section 5.2 discusses the fact that some level of uncertainty is inherent to the total maximum daily load (TMDL) process and explains how the concept of MOS can address uncertainty when developing TMDLs. Department of Environmental Quality (DEQ) utilizes another tool to compensate for uncertainty after TMDLs have been developed called adaptive management. Adaptive management as discussed throughout this document is a systematic approach for improving resource management by incorporating new information and learning from past management outcomes. This approach can help reduce uncertainty encountered while establishing TMDL targets, calculating existing loads, calculating allocations, performing source assessments, and determining effects of Best Management Practice (BMP) implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments as well as achieve success in meeting the water quality standards and supporting all water quality beneficial uses. This approach further allows for adjustments to restoration goals, TMDLs, and/or allocations, as necessary. By allowing TMDL assumptions to be revisited, confirmed, or updated, DEQ recognizes the dynamic nature of pollutant loading and water quality response to remediation.

In accordance with the Montana Water Quality Act (MCA 75-5-703 (7) and (9)), DEQ is required to assess the waters for which TMDLs have been completed and restoration measures, or BMPs, have been applied to determine whether compliance with water quality standards has been attained. This statute aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process.

Another concept that aligns well with adaptive management, which is another a required element of TMDLs (U.S. Environmental Protection Agency, 2002), is termed reasonable assurance. When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. Where there is a combination of nonpoint sources and one or more permitted point sources discharging into an impaired stream reach, the permitted point source WLAs are not dependent on implementation of the LAs. Instead, DEQ sets the WLAs and LAs at levels necessary to achieve water quality standards throughout the watershed. Under these conditions, the LAs are developed independently of the permitted point source WLA such that they would satisfy the TMDL target concentration within the stream reach immediately above the point source. In order to ensure that the water quality standard or target concentration is achieved below the point source discharge, the WLA is based on the point source's discharge concentration set equal to the standard or target concentration for each pollutant.

Because there are no WLAs established in this document for point sources, the above reasonable assurance considerations were not required. Nevertheless, nonpoint source LAs are developed in a way that, if implemented, will achieve water quality standards. Additionally, the nonpoint source LAs represent achievable implementation of water quality protection and improvement practices. The aspects of adaptive management specific to each pollutant group in this addendum are as follows:

Sediment

This addendum assumes the source assessments provided in the 2008 document (Montana Department of Environmental Quality, 2008) based on prior data collection and the Soil and Water Assessment Tool (SWAT) watershed model, accurately characterize existing conditions today. This is supported by the fact that no stream restoration work or significant BMP implementation has occurred in the last ten years that would have significantly altered water quality conditions. That said, the source assessment and resultant loading scenarios could be improved through:

- A more thorough and targeted road system loading analysis that assesses more road crossings and culverts specific to each stream and significant tributary stream. The 2008 document sampled a subset of road crossings and extrapolated loading rates to sites not visited in the field. Future monitoring could also verify the one percent failure rate used in culvert loading calculations is consistent with the existing road system.
- A more thorough and targeted streambank loading analysis that assesses conditions specific to each stream and significant tributary. Future monitoring could also verify the bank retreat rate chosen from literature values is consistent with existing conditions or derive a rate specific to the Middle Blackfoot-Nevada Project Area.
- A focused data gathering in the Indian Creek watershed that concludes in a full assessment and impairment determination of the waterbody.
- A detailed investigation into in-lake sediment processes. The lack of in-lake monitoring data should be addressed by collecting information on turbidity, suspended sediment concentration (SSC), total suspended solids (TSS), secchi depths, shoreline erosion and sedimentation rates.
- Confirmation that the dam is being operated “reasonably” per ARM 17.30.602(17).

Metals

The metals TMDLs developed in this addendum are based on future attainment of water quality standards. In order to achieve this, all significant sources of metals loading must be addressed via all reasonable land, soil, and water conservation practices. DEQ recognizes however, that in spite of all reasonable efforts, this may not be possible due to natural background conditions and/or the potential presence of unalterable human-caused sources that cannot be fully addressed via reasonable remediation approaches. For these reasons, an adaptive management approach is adopted for all metals targets described within this document. Under this adaptive management approach, all metals impairments that required TMDLs will ultimately fall into one of the categories identified below:

- Restoration achieves the metal pollutant targets and all beneficial uses are supported.
- Targets are not attained because of insufficient controls; therefore, impairment remains and additional remedies are needed.
- Targets are not attained after all reasonable BMPs and applicable abandoned mine remediation activities are applied. Under these circumstances, site-specific standards may be necessary.
- Targets are unattainable due to naturally-occurring metals sources. Under this scenario, site-specific water quality standards and/or the reclassification of the waterbody may be necessary. This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target would reflect the background condition.

Due to the difficulties encountered identifying human-caused sources and separating out naturally occurring concentrations, the fourth bullet listed above may be especially relevant to the arsenic TMDLs provided in this addendum. Further study is warranted before it can be determined that site-specific standards or a reclassification is necessary. Additional field monitoring and investigations that could help define future managment approaches and improve source assessments include:

- Investigate and measure arsenic concentrations in the regional groundwater and geology to better estimate natural background levels.
- Investigate the two log home construction sites for potential contamination reaching Kleinschmidt Creek from arsenic based wood preservative products.
- Establish sample sites bracketing the quarry to determine potential contributions of arsenic to Kleinschmidt Creek from the weathering of exposed quarry material.
- Conduct an expanded source assessment of metals pollution in the greater Kleinschmidt Creek watershed (i.e., Ward Creek and Rock Creek), including an investigation into the abandoned mines in the Rock Creek basin. This expanded effort should collect additional streambed sediment samples after Kleinschmidt Creek was the only metal TMDL stream in this addendum to exceed sediment chemistry targets.
- Collect additional metals water quality data on streams in the project area to help explain why all arsenic exceedances were collected in 2003 and subsequent field sampling in 2013 failed to capture any exceedances. While DEQ's 2003 sampling met data quality objectives, there may have been a laboratory or field collection error that lead to inaccurate reporting of arsenic concentrations. Additionally, environmental conditions during September and October 2003 may have been abnormal and not representative of the current conditions. A larger dataset could better place the 2003 samples into perspective.
- Collect additional monitoring on upper Nevada Creek after all four streambed sediment samples exceeded sediment chemistry targets but no surface water sample, out of 24 samples, exceeded water quality targets. Monitoring Nevada Creek may help inform DEQ of the causes of arsenic impairment for the streams with arsenic TMDLs developed in this addendum.
- Continue to monitor the active Fork Horn #4 Mine in the upper Douglas Creek basin to ensure it complies with all permit requirements and is not contributing to a water quality impairment.

If abandoned mines are found to be a source of metals loading, the Abandoned Mines Section of DEQ's Remediation Division will lead abandoned mine restoration projects funded by provisions of the Surface Mine Reclamation and Control Act of 1977. Monitoring and restoration conducted by other parties (e.g. BLM, DNRC's Trust Lands Management Division, and MBMG) should be incorporated into the target attainment and review process as well. Cooperation among agency land managers in the adaptive management process for metals TMDLs will help identify further cleanup and load reduction needs, evaluate monitoring results, and identify water quality trends.

Temperature

As part of the adaptive management approach, changes in land and water management that affect temperature should be monitored. As implementation of restoration projects that reduce thermal input or new sources that increase thermal loading arise, monitoring should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

There is uncertainty associated with the Stream Network Temperature Model (SNTEMP) naturally occurring scenario due to the input data. This scenario was run by setting the Nevada Creek discharge to the temperature corresponding to the naturally occurring temperature resulting from the implementation of all reasonable land, soil, and water conservation practices in that watershed. This analysis was not performed for the other main tributaries to the Blackfoot River from Nevada Creek to Belmont Creek (**Table 4-4**), and therefore, their thermal contributions were not fully integrated in the naturally occurring temperature scenario. In addition, numerous other small tributaries discharge to the

Blackfoot River and were not accounted for in the SNTEMP model. Future data collection and analysis should focus on the tributaries to the Blackfoot River that are potential contributors of human-caused thermal loading. These include all of the tributaries with sediment TMDLs (Table 9-6 in Montana Department of Environmental Quality, 2008) and those suspected to have sediment and/or temperature issues.

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

Any factors that increase water temperatures, including global climate change, could impact thermally sensitive fish species in Montana. The assessments and technical analysis for the temperature TMDLs considered a scenario reflective of a hotter than average summer under current weather conditions, which inherently accounts for any global climate change to date. Allocations to future changes in global climate are outside the scope of this project but could be considered during the adaptive management process if necessary. Uncertainties in environmental assessments should not paralyze, but should point to the need for flexibility in our understanding of complex systems and to adjust our current thinking and future analysis.

7.0 Stakeholder and Public Participation

Stakeholder and public involvement is a component of TMDL planning supported by EPA guidelines and required by Montana state law. MCA 75-5-703 and 75-5-704 direct DEQ to consult with watershed advisory groups and local conservation districts during the TMDL development process. For this addendum project, DEQ partnered with the Blackfoot Challenge, a local watershed group representing private landowners, corporate landowners, and various government officials. The Blackfoot Challenge assisted DEQ by soliciting its members for input throughout the TMDL process and hosting advisory group meetings to discuss project progress.

Upon completion of the draft TMDL document, and prior to submittal to EPA, DEQ issues a press release and enters into a public comment period. During this timeframe, the draft TMDL document is made available for general public comment, and DEQ addresses and responds to all formal public comments. The public review period began on August 18, 2014, and ended on September 19, 2014. DEQ made the draft document available to the public through the DEQ website; the Blackfoot Challenge office in Ovando; the Lincoln, Missoula, and Seeley Lake Public Libraries; and the Montana State Library in Helena. The opportunity to comment on the document and attend a public meeting was announced in notices to the Missoulian (Missoula), the Seeley Swan Pathfinder (Seeley Lake), and the Blackfoot Valley Dispatch (Lincoln) newspapers. Outreach efforts also included e-mails to advisory group members and other interested parties. DEQ held a public meeting in Helmville on September 10, 2014 to provide an overview of the project and field questions.

During the public comment period, DEQ received one formal comment from the Montana Department of Natural Resources and Conservation (DNRC). For organizational purposes, the comment was split into paraphrased remarks with DEQ's accompanying responses directly below. The original comments are held on file at DEQ and are available upon request.

Comment 1

Page 6-2 of the addendum states that the "source assessment and resultant loading scenarios could be improved through: [among other things] Confirmation that the dam is being operated reasonably per ARM 17.30.602(17)." DNRC assures DEQ that the Nevada Creek Dam is being operated reasonably. Reservoirs in Montana are operated to meet the beneficial use of the reservoir, which in Nevada Creek Reservoir's case is agricultural. The definition of reasonable operation must take into consideration the many variables that effect the daily and annual operations at these water projects, such as the underlying water rights, drought, irrigation needs, maintenance and/or rehabilitation requirements and public safety. Dam operations vary from year to year to address these issues, however, some requirements (such as minimum and maximum pool levels) are not flexible. These guidelines can be found in the dam's operations and maintenance manual (DNRC, 2001).

While secondary to public safety objectives and the beneficial uses applicable under the Montana Water Use Act, in this case agricultural uses, DNRC water storage projects are also managed for uses in which water rights are not asserted, such as recreation, fish and wildlife, and flood control. Montana Fish, Wildlife and Parks (FWP) is consulted regarding dam management and these recommendations are followed to the greatest extent possible to minimize impacts to the reservoir and downstream environment. DNRC, FWP, and the water users regularly monitor water quality, flow conditions, and reservoir levels to ensure this occurs.

Response 1

DEQ is encouraged by your approach to dam operation and consideration of multiple uses that include both water quantity (Montana Water Use Act) and water quality (Montana Water Quality Act). Under the Montana Water Quality Act, Nevada Lake is classified as a B-1 category water, which is to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply (ARM 17.30.623). Even if the waterbody is not being used for a beneficial use (e.g., drinking water supply), the water quality still must be maintained suitable for that use. Nevada Lake is currently listed as impaired for not supporting the beneficial uses of primary contact recreation and aquatic life. Agricultural uses are deemed fully supported based on water quality considerations.

As DNRC points out, TMDL development cannot divest, impair, or diminish any water right recognized pursuant to the Montana Water Use Act Title 85 (MCA §75-5-705). DEQ believes that water rights can be protected concurrently as efforts to improve water quality in the lake are undertaken so that more sensitive beneficial uses, like primary contact recreation and aquatic life, are also fully supported. The collaboration between DNRC and FWP to set pool elevation limits designed to benefit the fishery is encouraged and recognized in Section 2.3.2 of the addendum. DEQ recognizes that the Nevada Lake Dam was built for irrigation storage purposes and understands dam management must consider multiple factors that vary from year to year.

Even when a dam is being operated reasonably at the present date, operations can and should be reviewed on a regular basis to incorporate new information/data/technologies and to ensure the resource is being managed in a way that optimizes the protection of water rights and minimizes detrimental impacts to other beneficial uses. The cited quote comes from the adaptive management section of the addendum where adaptive management is discussed as a systematic approach for improving resource management by learning from management outcomes. It is through this concept of adaptive management that DEQ encourages continual "confirmation that the dam is being operated reasonably" into the future.

Comment 2

DNRC supports DEQ's effort to promote water conservation and encourage BMPs in the Nevada Creek watershed upstream from the reservoir for grazing, hay production, logging, road crossings and other uses that may negatively affect water quality. DNRC agrees that culvert failures, hillslope erosion, erosion related to old mining activity and naturally occurring conditions are major contributors to high sediment loads. DNRC believes the implementation of related BMPs will greatly help to reduce sediments from entering the reservoir and improve overall downstream water quality.

Response 2

Thank you for your support. DEQ is encouraged to receive agreeable conclusions from the expert hydrologists, engineers, and specialists that represent DNRC. DEQ welcomes the opportunity for continued partnerships with DNRC while working on water quality issues involving state lands and DNRC managed reservoirs in the future.

Comment 3

Please involve the Nevada Creek Water Users Association in all facets of the TMDL planning process. Success for the TMDL program hinges on voluntary local support. The associations that contract with the

State of Montana to provide water and operate the facilities have a significant interest in and influence on the management of water in their basins. Not only do they use contract water from our storage projects, they also usually hold the most senior water rights in the drainage. Voluntary cooperation from the water users is actively encouraged to the greatest extent possible to maintain fisheries and recreational resources.

Response 3

DEQ agrees that successful implementation of nonpoint source controls, and the TMDL process in general, largely depends upon local support and voluntary efforts on private property. The Nevada Creek Water Users Association Board of Directors were made aware of Nevada Lake TMDL development activities as part of the TMDL outreach. Members of the Waters Users Association can certainly influence water quality, whether it be through land management decisions or through irrigation practices. Waterbodies with established TMDLs and Watershed Restoration Plans receive priority funding through some grant programs to implement BMPs and improve water quality. Contact DEQ's Watershed Protection Section or review Section 10.0 of the 2008 document (DEQ, 2008) to learn more about funding opportunities that encourage and support voluntary restoration to addresses nonpoint sources of pollution.

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APPENDIX A– TOTAL MAXIMUM DAILY LOADS

Table A-1. USGS Stream Gage 12335500 (Nevada Creek above Reservoir) – Percent of Mean Annual Discharge Based on Mean of Daily Mean Discharge for each Day of Record (Calculation Period 10/1/1938-9/30/2013)

Day of Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.08%	0.10%	0.15%	0.60%	0.51%	0.99%	0.33%	0.16%	0.08%	0.09%	0.12%	0.10%
2	0.08%	0.09%	0.17%	0.71%	0.51%	1.02%	0.31%	0.15%	0.08%	0.09%	0.12%	0.11%
3	0.08%	0.09%	0.16%	0.58%	0.54%	1.05%	0.29%	0.15%	0.08%	0.09%	0.12%	0.12%
4	0.11%	0.13%	0.17%	0.47%	0.60%	1.02%	0.29%	0.14%	0.07%	0.09%	0.12%	0.11%
5	0.13%	0.12%	0.16%	0.47%	0.61%	0.99%	0.28%	0.13%	0.07%	0.09%	0.12%	0.11%
6	0.09%	0.11%	0.15%	0.56%	0.61%	0.99%	0.25%	0.13%	0.07%	0.09%	0.12%	0.10%
7	0.09%	0.10%	0.16%	0.63%	0.65%	0.97%	0.25%	0.13%	0.07%	0.09%	0.12%	0.10%
8	0.09%	0.12%	0.16%	0.50%	0.68%	0.93%	0.23%	0.13%	0.08%	0.10%	0.12%	0.10%
9	0.09%	0.14%	0.15%	0.49%	0.69%	0.90%	0.22%	0.12%	0.07%	0.10%	0.12%	0.10%
10	0.09%	0.12%	0.16%	0.51%	0.71%	0.89%	0.23%	0.12%	0.07%	0.10%	0.12%	0.10%
11	0.09%	0.12%	0.18%	0.52%	0.74%	0.85%	0.23%	0.12%	0.07%	0.10%	0.12%	0.10%
12	0.09%	0.09%	0.19%	0.52%	0.75%	0.80%	0.23%	0.12%	0.08%	0.11%	0.12%	0.09%
13	0.09%	0.09%	0.20%	0.52%	0.77%	0.80%	0.23%	0.12%	0.08%	0.11%	0.12%	0.09%
14	0.09%	0.09%	0.19%	0.50%	0.81%	0.74%	0.22%	0.12%	0.07%	0.11%	0.12%	0.09%
15	0.13%	0.09%	0.19%	0.49%	0.88%	0.71%	0.20%	0.11%	0.08%	0.11%	0.12%	0.09%
16	0.12%	0.09%	0.23%	0.51%	0.91%	0.69%	0.21%	0.11%	0.08%	0.11%	0.12%	0.09%
17	0.10%	0.10%	0.28%	0.49%	0.93%	0.69%	0.21%	0.11%	0.08%	0.11%	0.11%	0.09%
18	0.09%	0.10%	0.28%	0.47%	0.98%	0.64%	0.20%	0.10%	0.08%	0.11%	0.11%	0.09%
19	0.10%	0.10%	0.29%	0.45%	1.00%	0.63%	0.19%	0.10%	0.08%	0.11%	0.11%	0.09%
20	0.09%	0.12%	0.29%	0.48%	1.01%	0.63%	0.19%	0.10%	0.09%	0.12%	0.11%	0.10%
21	0.09%	0.14%	0.34%	0.48%	1.04%	0.60%	0.18%	0.09%	0.08%	0.12%	0.11%	0.09%
22	0.09%	0.12%	0.38%	0.47%	1.13%	0.54%	0.17%	0.09%	0.09%	0.12%	0.11%	0.09%
23	0.09%	0.12%	0.44%	0.49%	1.08%	0.50%	0.17%	0.10%	0.09%	0.12%	0.11%	0.09%
24	0.09%	0.12%	0.42%	0.51%	1.06%	0.47%	0.16%	0.10%	0.09%	0.12%	0.11%	0.09%
25	0.09%	0.19%	0.39%	0.50%	1.13%	0.43%	0.16%	0.09%	0.09%	0.12%	0.11%	0.09%
26	0.09%	0.19%	0.44%	0.49%	1.09%	0.43%	0.16%	0.09%	0.09%	0.12%	0.11%	0.11%
27	0.09%	0.16%	0.43%	0.49%	1.02%	0.40%	0.16%	0.09%	0.09%	0.12%	0.11%	0.09%
28	0.09%	0.13%	0.38%	0.49%	0.99%	0.37%	0.16%	0.09%	0.09%	0.12%	0.10%	0.09%
29	0.09%	0.12%	0.34%	0.50%	1.00%	0.36%	0.16%	0.09%	0.09%	0.12%	0.10%	0.09%
30	0.09%	--	0.36%	0.51%	1.03%	0.33%	0.16%	0.09%	0.09%	0.12%	0.10%	0.09%
31	0.12%	--	0.43%	--	1.02%	--	0.16%	0.09%	--	0.12%	--	0.10%

Table A-2. Total Allowable Daily Loads (i.e., TMDLs) for Nevada Lake

Day of Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.47	3.09	4.64	18.56	15.77	30.62	10.21	4.95	2.47	2.78	3.71	3.09
2	2.47	2.78	5.26	21.96	15.77	31.55	9.59	4.64	2.47	2.78	3.71	3.40
3	2.47	2.78	4.95	17.94	16.70	32.48	8.97	4.64	2.47	2.78	3.71	3.71
4	3.40	4.02	5.26	14.54	18.56	31.55	8.97	4.33	2.17	2.78	3.71	3.40
5	4.02	3.71	4.95	14.54	18.87	30.62	8.66	4.02	2.17	2.78	3.71	3.40
6	2.78	3.40	4.64	17.32	18.87	30.62	7.73	4.02	2.17	2.78	3.71	3.09
7	2.78	3.09	4.95	19.49	20.10	30.00	7.73	4.02	2.17	2.78	3.71	3.09
8	2.78	3.71	4.95	15.47	21.03	28.76	7.11	4.02	2.47	3.09	3.71	3.09
9	2.78	4.33	4.64	15.16	21.34	27.84	6.80	3.71	2.17	3.09	3.71	3.09
10	2.78	3.71	4.95	15.77	21.96	27.53	7.11	3.71	2.17	3.09	3.71	3.09
11	2.78	3.71	5.57	16.08	22.89	26.29	7.11	3.71	2.17	3.09	3.71	3.09
12	2.78	2.78	5.88	16.08	23.20	24.74	7.11	3.71	2.47	3.40	3.71	2.78
13	2.78	2.78	6.19	16.08	23.82	24.74	7.11	3.71	2.47	3.40	3.71	2.78
14	2.78	2.78	5.88	15.47	25.05	22.89	6.80	3.71	2.17	3.40	3.71	2.78
15	4.02	2.78	5.88	15.16	27.22	21.96	6.19	3.40	2.47	3.40	3.71	2.78
16	3.71	2.78	7.11	15.77	28.15	21.34	6.50	3.40	2.47	3.40	3.71	2.78
17	3.09	3.09	8.66	15.16	28.76	21.34	6.50	3.40	2.47	3.40	3.40	2.78
18	2.78	3.09	8.66	14.54	30.31	19.80	6.19	3.09	2.47	3.40	3.40	2.78
19	3.09	3.09	8.97	13.92	30.93	19.49	5.88	3.09	2.47	3.40	3.40	2.78
20	2.78	3.71	8.97	14.85	31.24	19.49	5.88	3.09	2.78	3.71	3.40	3.09
21	2.78	4.33	10.52	14.85	32.17	18.56	5.57	2.78	2.47	3.71	3.40	2.78
22	2.78	3.71	11.75	14.54	34.95	16.70	5.26	2.78	2.78	3.71	3.40	2.78
23	2.78	3.71	13.61	15.16	33.40	15.47	5.26	3.09	2.78	3.71	3.40	2.78
24	2.78	3.71	12.99	15.77	32.79	14.54	4.95	3.09	2.78	3.71	3.40	2.78
25	2.78	5.88	12.06	15.47	34.95	13.30	4.95	2.78	2.78	3.71	3.40	2.78
26	2.78	5.88	13.61	15.16	33.71	13.30	4.95	2.78	2.78	3.71	3.40	3.40
27	2.78	4.95	13.30	15.16	31.55	12.37	4.95	2.78	2.78	3.71	3.40	2.78
28	2.78	4.02	11.75	15.16	30.62	11.44	4.95	2.78	2.78	3.71	3.09	2.78
29	2.78	3.71	10.52	15.47	30.93	11.13	4.95	2.78	2.78	3.71	3.09	2.78
30	2.78	--	11.13	15.77	31.86	10.21	4.95	2.78	2.78	3.71	3.09	2.78
31	3.71	--	13.30	--	31.55	--	4.95	2.78	--	3.71	--	3.09

APPENDIX B– METALS DATA

Table B-1. Metals water quality data (TR = total recoverable, T = total, D = dissolved)

Org.	Station Name	Site ID	Assessment Unit ID	Date*	Hardness (mg/L)	Flow (cfs)	pH	Ag (µg/L) TR	Al (µg/L) D	As (µg/L) TR	Cd (µg/L) TR	Cr (µg/L) TR	Cu (µg/L) TR	Fe (µg/L) TR	Hg (µg/L) T	Pb (µg/L) TR	Zn (µg/L) TR	SSC (µg/L)	TSS (µg/L)
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/16/2003		8.4													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/14/2003		236													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/17/2003		100													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***4/17/2003***		53													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/1/2003***		66													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/14/2003***	127	52	8.5			3	< 0.2	< 0.8	1.9	300		0.23	10	11000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/29/2003***		189													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/3/2003***		126													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/6/2003***	105	81	8.2			3	< 0.2	< 0.8	1.6	366		0.31	2	16000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/11/2003		19													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/23/2003	141	11	8.2			5	< 0.035	< 0.8	1.2	180		0.09	< 2	5000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/13/2003	123	11	8.2			5	< 0.035	< 0.8	1.2	45		0.18	1	5000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/27/2003		8													
DEQ	Nevada Creek upstream of Hwy 141 bridge	C03NVDAC02	MT76F003_011	10/1/2003	120			< 1	< 10	10	< 0.1	< 1	< 1	340		< 1	< 1		7000
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/6/2003		7.8													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	11/20/2003		18													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	12/2/2003		11	7.7											9000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/12/2004		11													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	2/20/2004		13													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/10/2004	37.5	146	7.4		7.9	5	0.024		2.8	773		0.69	5	44000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/31/2004		26													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***4/13/2004***	105	28	8.3		1.3	4	< 0.04		1.1	311		0.12	< 2	7000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/5/2004***		38													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/19/2004***		31													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/27/2004***	122	51	8.4		2.2	4	< 0.04		1.9	275		0.18	< 2	8000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/1/2004		20													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/14/2004	142	13	8.5		1.3	5	< 0.04		1.1	294		0.13	1	7000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/27/2004		13													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/25/2004	142	8.4	8.5		0.9	6	< 0.04		1	259		0.07	< 2	4000	
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/31/2004		7.7													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	9/30/2004		12													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	11/15/2004		21													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	12/28/2004		8.1													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	2/8/2005		10													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/3/2005		12													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/10/2005		24													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/25/2005		21													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/3/2005***		25													
DEQ	Nevada Creek upstream of reservoir	12335500	MT76F003_011	***5/11/2005***	84	142	8.22		< 50				10	7270	< 0.1	6			304000
DEQ	Nevada Creek upstream of Hwy 141 crossing	NCSW-1	MT76F003_011	***5/11/2005***	65	103	8.13		< 50					2620	< 0.1				97000
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/12/2005***		121													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/2/2005***		187													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/12/2005		30													
DEQ	Nevada Creek upstream of reservoir	12335500	MT76F003_011	8/25/2005	129	7.79	8						< 1	270		< 3			< 10000
DEQ	Nevada Creek Upper between Gallagher and	NCSW-2	MT76F003_011	8/25/2005	131	8.21	8.01			< 5			4	290		< 3			< 10000

Table B-1. Metals water quality data (TR = total recoverable, T = total, D = dissolved)

Org.	Station Name	Site ID	Assessment Unit ID	Date*	Hardness (mg/L)	Flow (cfs)	pH	Ag (µg/L) TR	Al (µg/L) D	As (µg/L) TR	Cd (µg/L) TR	Cr (µg/L) TR	Cu (µg/L) TR	Fe (µg/L) TR	Hg (µg/L) T	Pb (µg/L) TR	Zn (µg/L) TR	SSC (µg/L)	TSS (µg/L)
	Jefferson Creeks																		
DEQ	Nevada Creek upstream of Hwy 141 crossing	NCSW-1	MT76F003_011	8/25/2005	109	3.61	8.13			< 5			< 1	290		< 3			< 10000
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	9/20/2005		9.1													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/12/2005		13													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	12/6/2005		11													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/11/2006		21													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/30/2006		67													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	4/6/2006		264													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***4/19/2006***		59													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/30/2006***		65													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/10/2006		17													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/15/2006		6													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/4/2006		8													
DEQ	Nevada Creek upstream of proposed restoration area	NCQR-NCWQ-1	MT76F003_011	10/6/2006		5.93	8.19			4			1	150		< .5			< 10000
DEQ	Nevada Creek downstream of proposed restoration area	NCQR-NCWQ-2	MT76F003_011	10/6/2006		7.42	7.96			5			1	440		< .5			12000
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	4/2/2007		25													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/16/2007***		62													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/8/2007***		63													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/5/2007		14													
DEQ	Nevada Creek about 1/2 mile upstream of Shingle Mill Cr	C03NVDAC01	MT76F003_011	7/13/2007			7.8												
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/16/2007		7.2													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/2/2007		7.2													
DEQ	Nevada Creek upstream of proposed restoration area	NCQR-NCWQ-1	MT76F003_011	10/30/2007		8.1	7.83			3			< 1	200		< .5			< 10000
DEQ	Nevada Creek downstream of proposed restoration area	NCQR-NCWQ-2	MT76F003_011	10/30/2007		6.18	8			4			< 1	230		< .5			< 10000
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	11/15/2007		11													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	12/26/2007		7.6													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	2/15/2008		8.1													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/11/2008		12													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/27/2008		12													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/19/2008***		160													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/1/2008		45													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	9/3/2008		17													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/1/2008		8.8													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	11/14/2008		37													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	12/11/2008		19													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/1/2009		11													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/4/2009		18													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	4/8/2009		119													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***4/13/2009***		290													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/21/2009***		301													

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Org.	Station Name	Site ID	Assessment Unit ID	Date*	Hardness (mg/L)	Flow (cfs)	pH	Ag (µg/L) TR	Al (µg/L) D	As (µg/L) TR	Cd (µg/L) TR	Cr (µg/L) TR	Cu (µg/L) TR	Fe (µg/L) TR	Hg (µg/L) T	Pb (µg/L) TR	Zn (µg/L) TR	SSC (µg/L)	TSS (µg/L)
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/12/2009***		66													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/28/2009		32													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	9/9/2009		12													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/14/2010		18													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/14/2010		18													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/7/2011		21													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	2/16/2011		8.6													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/30/2011		48													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	3/31/2011		294													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***5/24/2011***		427													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/12/2011		60													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	8/24/2011		20													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/4/2011		14													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	11/15/2011		31													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	1/6/2012		16													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	2/7/2012		15													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	4/4/2012		92													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***4/24/2012***		217													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	***6/15/2012***		94													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	7/27/2012		25													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	9/12/2012		4.9													
USGS	Nevada Cr ab reservoir, nr Helmville, MT	12335500	MT76F003_011	10/17/2012		15													
DEQ	Nevada Creek upstream of Nevada Lake and Indian Creek Road crossing	C03NVDAC03	MT76F003_011	***5/21/2013***	122	40.2	8.23	< 0.2		4	< 0.03	< 1	2	330	< 0.005	< .3	< 8		10000
DEQ	Nevada Creek upstream of Hwy 141 bridge	C03NVDAC02	MT76F003_011	***5/21/2013***	81	16.56	7.88	< 0.2		3	< 0.03	< 1	1	240	< 0.005	< .3	< 8		7000
DEQ	Nevada Creek between Jefferson Creek and Washington Creek	C03NVDAC04	MT76F003_011	***5/21/2013***	105	30.85	7.99	< 0.2		4	< 0.03	< 1	2	310	< 0.005	< .3	< 8		< 4000
DEQ	Nevada Creek upstream Huckleberry Creek at end of FR 296	C03NVDAC05	MT76F003_011	***5/21/2013***	61	26	8.11	< 0.2		3	< 0.03	< 1	< 1	30	< 0.005	< .3	< 8		< 4000
DEQ	Nevada Creek upstream of Nevada Lake and Indian Creek Road crossing	C03NVDAC03	MT76F003_011	8/14/2013	119	9.14	8.57	< 0.2		5	< 0.03	< 1	< 1	220	< 0.005	< .3	< 8		4000
DEQ	Nevada Creek between Jefferson Creek and Washington Creek	C03NVDAC04	MT76F003_011	8/14/2013	122	8.54	8.49	< 0.2		6	< 0.03	< 1	< 1	240	< 0.005	< .3	< 8		< 4000
DEQ	Nevada Creek upstream of Hwy 141 bridge	C03NVDAC02	MT76F003_011	8/14/2013	109	4.59	8.27	< 0.2		6	< 0.03	< 1	< 1	320	< 0.005	< .3	< 8		< 4000
DEQ	Nevada Creek upstream Huckleberry Creek at end of FR 296	C03NVDAC05	MT76F003_011	8/14/2013	95	4.15	8.22	< 0.2		3	< 0.03	< 1	4	< 20	< 0.005	< .3	< 8		< 4000
DEQ	Douglas Creek 150 yards upstream from second reservoir	C03DOUGC10	MT76F003_081	9/27/2003	150	9	7.82	< 1		11	< 0.1	< 1	< 1	180		< 1	< 1		7800
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	C03DOUGC20	MT76F003_081	9/27/2003	312	1	7.67	< 1		25	< 0.1	< 1	1	480		< 1	< 1		16200
DEQ	Douglas Creek Middle upstream of confluence with Sturgeon Cr	DCSW-2	MT76F003_081	***5/11/2005***	232	4.38	7.64		< 50	< 5			1	250		< 3			< 10000
DEQ	Douglas Creek Middle upstream of confluence with Sturgeon Cr	DCSW-2	MT76F003_081	8/25/2005	181	3.42	8.17			< 3			< 1	370		< 3			11000

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Org.	Station Name	Site ID	Assessment Unit ID	Date*	Hardness (mg/L)	Flow (cfs)	pH	Ag (µg/L) TR	Al (µg/L) D	As (µg/L) TR	Cd (µg/L) TR	Cr (µg/L) TR	Cu (µg/L) TR	Fe (µg/L) TR	Hg (µg/L) T	Pb (µg/L) TR	Zn (µg/L) TR	SSC (µg/L)	TSS (µg/L)
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	C03DOUGC20	MT76F003_081	7/10/2008			8.28												
DEQ	Douglas Creek 150 yards upstream from second reservoir	C03DOUGC10	MT76F003_081	7/10/2008			9.3												
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	C03DOUGC20	MT76F003_081	***5/22/2013***	262	1.51	8.47	< 0.2		7	< 0.03	< 1	1	350		< .3	< 8		5000
DEQ	Douglas Creek 150 yards upstream from second reservoir	C03DOUGC10	MT76F003_081	***5/22/2013***	135	1.11	8.65	< 0.2		1	< 0.03	< 1	< 1	250		< .3	< 8		6000
DEQ	Douglas Creek downstream Upper Douglas Creek Rd crossing	C03DOUGC04	MT76F003_081	***5/22/2013***	134	3.84	8.35	0.4		2	< 0.03	< 1	< 1	180		< .3	< 8		< 4000
DEQ	Douglas Creek upstream Upper Douglas Creek Rd crossing	C03DOUGC05	MT76F003_081	***5/22/2013***	67	0.48	8	< 0.3		2	< 0.04	5	3	3080		1.3	12		58000
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	C03DOUGC20	MT76F003_081	8/15/2013	161	1.28	8.56	< 0.2		6	< 0.03	< 1	1	730		0.4	< 8		18000
DEQ	Douglas Creek 150 yards upstream from second reservoir	C03DOUGC10	MT76F003_081	8/15/2013	119	0.28	8.72	< 0.2		1	< 0.03	< 1	< 1	170		< .3	< 8		6000
DEQ	Douglas Creek downstream Upper Douglas Creek Rd crossing	C03DOUGC04	MT76F003_081	8/15/2013	154	3.32	8.44	< 0.2		1	< 0.03	< 1	< 1	30		< .3	< 8		< 4000
DEQ	Douglas Creek at second road crossing below mine	C03DOUGC07	MT76F003_081	8/15/2013	155	2.65	8.12	< 0.2		1	< 0.03	< 1	< 1	< 20		< .3	< 8		< 4000
DEQ	Douglas Creek 1.25 miles upstream from mouth	C03DOUGC30	MT76F003_082	9/27/2003		0.3	7.41												
DEQ	Douglas Creek at road crossing 2 miles west of Helmville	C03DOUGC01/DCS W-1	MT76F003_082	10/1/2003	294			< 1	< 10	21	< 0.1	< 1	< 1	130		< 1	< 1		13600
DEQ	Douglas Creek upstream of road crossing	C03DOUGC01/DCS W-1	MT76F003_082	***5/11/2005***	183	15.9	7.51		< 50	< 5			2	1410		< 3			43000
DEQ	Douglas Creek upstream of road crossing	C03DOUGC01/DCS W-1	MT76F003_082	8/25/2005	169	2.69	7.3			< 5			< 1	580		< 3			11000
DEQ	Douglas Creek 1.25 miles upstream from mouth	C03DOUGC30	MT76F003_082	7/9/2008			8.38												
DEQ	Douglas Creek about 0.5 mile upstream from mouth	C03DOUGC06	MT76F003_082	***5/22/2013***		0													
DEQ	Douglas Creek at road crossing 2 miles west of Helmville	C03DOUGC01/DCS W-1	MT76F003_082	***5/22/2013***	157	3.13	8.26	< 0.2		4	< 0.03	1	2	670		0.4	< 8		18000
DEQ	Douglas Creek off Hwy 271 on BLM property	C03DOUGC02	MT76F003_082	***5/22/2013***	196	3.01	8.23	< 0.2		5	< 0.03	1	2	870		0.5	< 8		25000
DEQ	Douglas Creek below Murray Creek off Hwy 271	C03DOUGC03	MT76F003_082	***5/22/2013***	232	2.42	8.28	< 0.2		5	< 0.03	< 1	1	370		< .3	< 8		6000
DEQ	Douglas Creek at road crossing 2 miles west of Helmville	C03DOUGC01/DCS W-1	MT76F003_082	8/15/2013	146	2.41	8.24	< 0.2		7	< 0.03	< 1	1	550		0.3	< 8		13000
DEQ	Douglas Creek off Hwy 271 on BLM property	C03DOUGC02	MT76F003_082	8/15/2013	180	1.5	8.47	< 0.2		5	< 0.03	2	2	990		0.6	< 8		26000
DEQ	Douglas Creek below Murray Creek off Hwy 271	C03DOUGC03	MT76F003_082	8/15/2013	187	1.45	8.36	< 0.2		5	< 0.03	< 1	1	470		< .3	< 8		10000
DEQ	Murray Creek 100 yards upstream of lowest road crossing	C03MURYC20	MT76F003_120	9/26/2003	238	0.2	7.49	< 1		16	< 0.1	< 1	< 1	250		< 1	< 1		13300
DEQ	Murray Creek 100 yards upstream from highest road crossing	C03MURYC10	MT76F003_120	9/26/2003	80.7	4	6.91	< 1		5	< 0.1	1	< 1	90		< 1	< 1		5000

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Org.	Station Name	Site ID	Assessment Unit ID	Date*	Hardness (mg/L)	Flow (cfs)	pH	Ag (µg/L) TR	Al (µg/L) D	As (µg/L) TR	Cd (µg/L) TR	Cr (µg/L) TR	Cu (µg/L) TR	Fe (µg/L) TR	Hg (µg/L) T	Pb (µg/L) TR	Zn (µg/L) TR	SSC (µg/L)	TSS (µg/L)
DEQ	Murray Creek	C03MURYC01	MT76F003_120	6/28/2008			7.6												
DEQ	Murray Creek 100 yards upstream from highest road crossing	C03MURYC10	MT76F003_120	6/28/2008			8.29												
DEQ	Murray Creek 100 yards upstream of lowest road crossing	C03MURYC20	MT76F003_120	***5/23/2013***	161	0.29	7.62	< 0.3		2	< 0.04	2	2	710		0.5	< 8		17000
DEQ	Murray Creek near mouth	C03MURYC02	MT76F003_120	***5/23/2013***	212	2.02	7.81	< 0.3		3	< 0.04	2	3	1010		0.5	< 8		23000
DEQ	Murray Creek 100 yards upstream from highest road crossing	C03MURYC10	MT76F003_120	***6/20/2013***	64	3.55	8.13	< 0.2		1	0.04	2	< 1	380		< .3	< 8		6000
DEQ	Murray Creek on BLM property off service road	C03MURYC03	MT76F003_120	***6/20/2013***	64	2.49	8.06	< 0.2		2	< 0.03	1	< 1	250		< .3	< 8		4000
DEQ	Murray Creek near mouth	C03MURYC02	MT76F003_120	8/19/2013	197	0.11	8.24	< 0.2		4	< 0.03	1	1	870		0.4	< 8		18000
DEQ	Murray Creek 100 yards upstream of lowest road crossing	C03MURYC20	MT76F003_120	8/19/2013	196	0.002785	8.19	< 0.2		2	< 0.03	< 1	< 1	130		< .3	< 8		< 4000
DEQ	Murray Creek 100 yards upstream from highest road crossing	C03MURYC10	MT76F003_120	8/19/2013	75	1.69	8.25	< 0.2		< 1	< 0.03	1	< 1	150		< .3	< 8		< 4000
DEQ	Murray Creek on BLM property off service road	C03MURYC03	MT76F003_120	8/19/2013	70	1.58	8.23	< 0.2		< 1	< 0.03	1	< 1	90		< .3	< 8		< 4000
DEQ	Kleinschmidt Creek 200 yards upstream of mouth Rock Creek	C03KLSMC01	MT76F004_110	9/11/2003		16.322	7.46	< 1		22	< 0.1	< 1	< 1	30		< 1	< 1		
DEQ	Kleinschmidt Creek near mouth	C03KLSMC01	MT76F004_110	***5/12/2005***	140	8.62	7.18		< 50	< 5			< 1	40					< 10000
DEQ	Kleinschmidt Creek near mouth	C03KLSMC01	MT76F004_110	8/24/2005	138	11.2	7.02			< 5			< 1	20					< 10000
DEQ	Kleinschmidt Creek 200 yards upstream of mouth Rock Creek	C03KLSMC01	MT76F004_110	***5/21/2013***	142	7.14	8.25	< 0.2		2	< 0.03	< 1	< 1	60		< .3	< 8		< 4000
DEQ	Kleinschmidt Creek about 50 ft downstream Hwy 200 crossing	C03KLSMC02	MT76F004_110	***5/21/2013***	215	0.32	8.24	< 0.2		5	< 0.03	< 1	1	360		< .3	< 8		< 4000
DEQ	Kleinschmidt Creek at first Hwy 200 crossing	C03KLSMC03	MT76F004_110	***5/21/2013***	191	0.28	8.18	< 0.2		3	< 0.03	< 1	1	240		< .3	< 8		8000
DEQ	Kleinschmidt Creek 200 yards upstream of mouth Rock Creek	C03KLSMC01	MT76F004_110	8/14/2013	138	13.6	8.23	< 0.2		1	< 0.03	< 1	< 1	30		< .3	< 8		< 4000
DEQ	Kleinschmidt Creek about 50 ft downstream Hwy 200 crossing	C03KLSMC02	MT76F004_110	8/14/2013	194	0.24	8.32	< 0.2		6	< 0.03	< 1	1	490		0.3	< 8		7000
DEQ	Kleinschmidt Creek at first Hwy 200 crossing	C03KLSMC03	MT76F004_110	8/14/2013	186	0.23	8.38	< 0.2		3	< 0.03	< 1	< 1	190		< .3	< 8		< 4000
DEQ	Coopers Lake at mid-lake	C03COPRL01	NA	7/15/2006	85.6	NA		< 1		< 1	< 0.08	< 1	< 1	10	< 0.05	< .5	2.5		< 1000

****Bold italicized*** dates are considered high flow conditions

Note: this table may not capture all parameters collected

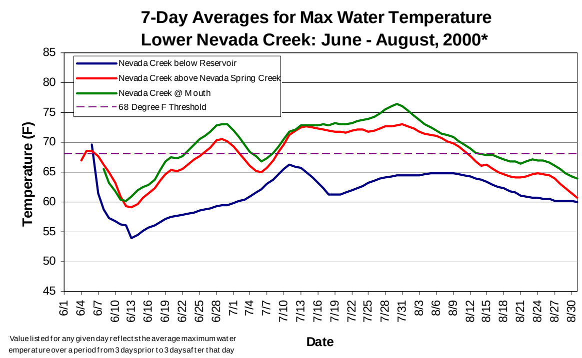
Table B-2. Metals streambed sediment data (T = total, R = recoverable)

Org ID	Station (Site) Name	Assessment Unit ID	Site ID	Activity Date	Al (ug/g) R	As (ug/g) T	As (ug/g) R	Cd (ug/g) T	Cd (ug/g) R	Cr (ug/g) R	Cu (ug/g) T	Cu (ug/g) R	Fe (ug/g) R	Pb (ug/g) T	Pb (ug/g) R	Hg (ug/g) T	Ni (ug/g) R	Se (ug/g) R	Zn (ug/g) T	Zn (ug/g) R
DEQ	Douglas Creek at road crossing 2 miles west of Helmville	MT76F003_082	C03DOUGC01	8/15/2013		8		< 0.2			26			28		< 0.05			61	
DEQ	Douglas Creek off Hwy 271 on BLM property	MT76F003_082	C03DOUGC02	8/15/2013		4		< 0.2			21			42		< 0.05			57	
DEQ	Douglas Creek below Murray Creek off Hwy 271	MT76F003_082	C03DOUGC03	8/15/2013		5		< 0.2			17			33		< 0.05			46	
DEQ	Douglas Creek at road crossing 2 miles west of Helmville	MT76F003_082	C03DOUGC01	10/1/2003	9740		13.1		< 0.5	17.9		22.5	13400		10.7		25.9	< 1		42.4
DEQ	Douglas Creek 150 yards upstream from second reservoir	MT76F003_081	C03DOUGC10	9/27/2003	9870		6.6		< 0.5	27.7		14.1	9470		7.7		26.6	< 1		34.3
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	MT76F003_081	C03DOUGC20	9/27/2003	9550		9.5		< 0.5	13.3		20.6	11500		9.1		21.7	< 1		43.2
DEQ	Douglas Creek downstream Upper Douglas Creek Rd crossing	MT76F003_081	C03DOUGC04	8/15/2013		2		< 0.2			< 20			24		0.054			64	
DEQ	Douglas Creek at second road crossing below mine	MT76F003_081	C03DOUGC07	8/15/2013		3		0.2			23			99		0.15			61	
DEQ	Douglas Creek 150 yards upstream from second reservoir	MT76F003_081	C03DOUGC10	8/15/2013		2		< 0.2			17			32		< 0.05			55	
DEQ	Douglas Creek 1/4 mile upstream of Murray Creek confluence	MT76F003_081	C03DOUGC20	8/15/2013		5		< 0.2			22			23		< 0.05			54	
DEQ	Kleinschmidt Creek 200 yards upstream of mouth Rock Creek	MT76F004_110	C03KLSMC01	9/11/2003	11400		19.6		< 0.5	13.2		59.1	16000		18		9.5	1.3		84.1
DEQ	Kleinschmidt Creek 200 yards upstream of mouth Rock Creek	MT76F004_110	C03KLSMC01	8/14/2013		18		< 0.2			68			35		< 0.05			63	
DEQ	Kleinschmidt Creek about 50 ft downstream Hwy 200 crossing	MT76F004_110	C03KLSMC02	8/14/2013		35		0.2			45			21		< 0.05			69	
DEQ	Kleinschmidt Creek at first Hwy 200 crossing	MT76F004_110	C03KLSMC03	8/14/2013		26		0.3			50			177		0.056			72	
DEQ	Murray Creek near mouth	MT76F003_120	C03MURYC02	8/19/2013		5		< 0.2			19			20		< 0.05			80	
DEQ	Murray Creek on BLM property off service road	MT76F003_120	C03MURYC03	8/19/2013		3		< 0.2			16			59		< 0.05			73	
DEQ	Murray Creek 100 yards upstream from highest road crossing	MT76F003_120	C03MURYC10	8/19/2013		1		< 0.2			< 20			23		< 0.05			57	
DEQ	Murray Creek 100 yards upstream of lowest road crossing	MT76F003_120	C03MURYC20	8/19/2013		2		< 0.2			< 20			46		< 0.05			59	
DEQ	Nevada Creek upstream of Hwy 141 bridge	MT76F003_011	C03NVDAC02	10/1/2003	11200		30.7		< 0.5	10.7		26.1	17400		15.9		18.9	< 1		47
DEQ	Nevada Creek upstream of Hwy 141 bridge	MT76F003_011	C03NVDAC02	8/14/2013		46		0.2			32			38		0.065			62	
DEQ	Nevada Creek upstream of Nevada Lake and Indian Creek Road crossing	MT76F003_011	C03NVDAC03	8/14/2013		23		0.3			27			35		< 0.05			68	
DEQ	Nevada Creek between Jefferson Creek and Washington Creek	MT76F003_011	C03NVDAC04	8/14/2013		22		< 0.2			24			31		< 0.05			55	
DEQ	Nevada Creek upstream Huckleberry Creek at end of FR 296	MT76F003_011	C03NVDAC05	8/14/2013		50		0.3			46			84		0.12			62	

Note: this table may not capture all parameters collected

ATTACHMENT A – TEMPERATURE ANALYSIS AND MODELING OF 303(D) LIST STREAMS IN THE BLACKFOOT RIVER WATERSHED, MONTANA

Temperature Analysis and Modeling of 303(d) List Streams in the Blackfoot River Watershed, Montana



July 31, 2006

Prepared for:
Blackfoot Challenge
Montana Department of Environmental Quality

Prepared by:

DTM Consulting, Inc.
Applied Geomorphology, Inc.
211 N. Grand Ave., Suite J
Bozeman, MT 59715

Table of Contents

1. Introduction

This document presents the results of an assessment of thermal conditions on 303(d) temperature listed streams of the Nevada Creek and Middle Blackfoot TMDL Planning Areas. This includes analysis of temperature data, methods and results of shade data development, and temperature model results for the Nevada Creek and Middle Blackfoot TMDL Planning Areas. Analysis of water temperature data identified reaches with high water temperatures and allowed selection of data from the warmest summer periods for temperature modeling. Shade data development provided critical temperature modeling input and identifies areas where reduced shade may cause high stream temperatures. Finally, results of SNTEMP, a stream network model that simulates water temperatures, indicates the amount of improvement in shade required to meet temperature targets for TMDLs.

This project departs from typical methods for temperature TMDLs utilized in other Montana watersheds. Typically, developing temperature TMDLs for streams in Montana using a numeric model requires collecting the necessary stream temperature, flow, and shade data during a typically warm summer period. In the Blackfoot River watershed, Montana FWP maintains a database of stream temperature data collected from numerous sites between 1994 and 2004. In addition, stream condition (base parameter) data collected in 2004 (DTM and AGI, 2005) includes detailed vegetation transects that can be used as a surrogate for shade measurements. Finally, stream gage data collected by the USGS and Montana DNRC, augmented by instantaneous flow measurements and visual flow estimates from July 2004 provide stream flow data. These datasets allowed development of numeric temperature models using SNTEMP and SSTEMP. In addition, since temperature data collected by Montana FWP span several years, it was possible to identify and analyze data from the warmest periods for this analysis.

1.1. Goals and Objectives

The primary goals of this project are to provide Montana DEQ and the Blackfoot Challenge an assessment of summer stream temperature conditions, develop additional datasets necessary to construct and utilize a numeric temperature models (SNTEMP and SSTEMP), construct and calibrate the temperature models, and run a series of simulations ranging from current conditions to natural conditions. The results will allow development of temperature TMDLs for the eight temperature listed streams. The following tasks define the scope of this project:

- compile, analyze, and summarize existing temperature data to determine locations and magnitudes of temperature;
- develop shade parameter data from existing base parameter data collected in 2004 (DTM and AGI, 2005);
- construct and calibrate a series of SNTEMP and SSTEMP models;
- run model simulations assessing stream temperature changes under various scenarios; and,
- report results.

1.2. Background Information

The Blackfoot River watershed covers 1,479,071 acres (2,311 square miles) and is broken into four TMDL planning areas: the Upper Blackfoot, Nevada Creek, Middle Blackfoot, and Lower Blackfoot planning areas. These areas contain over 50 rivers and streams on Montana's 303(d) list, compiled by the Montana DEQ. Eight streams in the in the Blackfoot River watershed are listed for temperature impairments (Figure 1-1, Table 1-1), and have a total length of 179 miles. Waters identified on the 303(d) list require development of water quality restoration plans and TMDLs to address the causes of impairment.

Stream	***TMDL Planning Area***	***Length (miles)***
Cottonwood Creek	Nevada Creek	7. 45
Murray Creek	Nevada Creek	8.6
Douglas Creek	Nevada Creek	26. 91
Nevada Creek	Nevada Creek	55
Kleinschmidt Creek	Middle Blackfoot	5. 13
Elk Creek	Lower Blackfoot	15. 5
Union Creek	Lower Blackfoot	24. 2
Blackfoot River	Middle and Lower Blackfoot	44. 78

Table 1-1. Streams listed for temperature in the Blackfoot River Watershed.

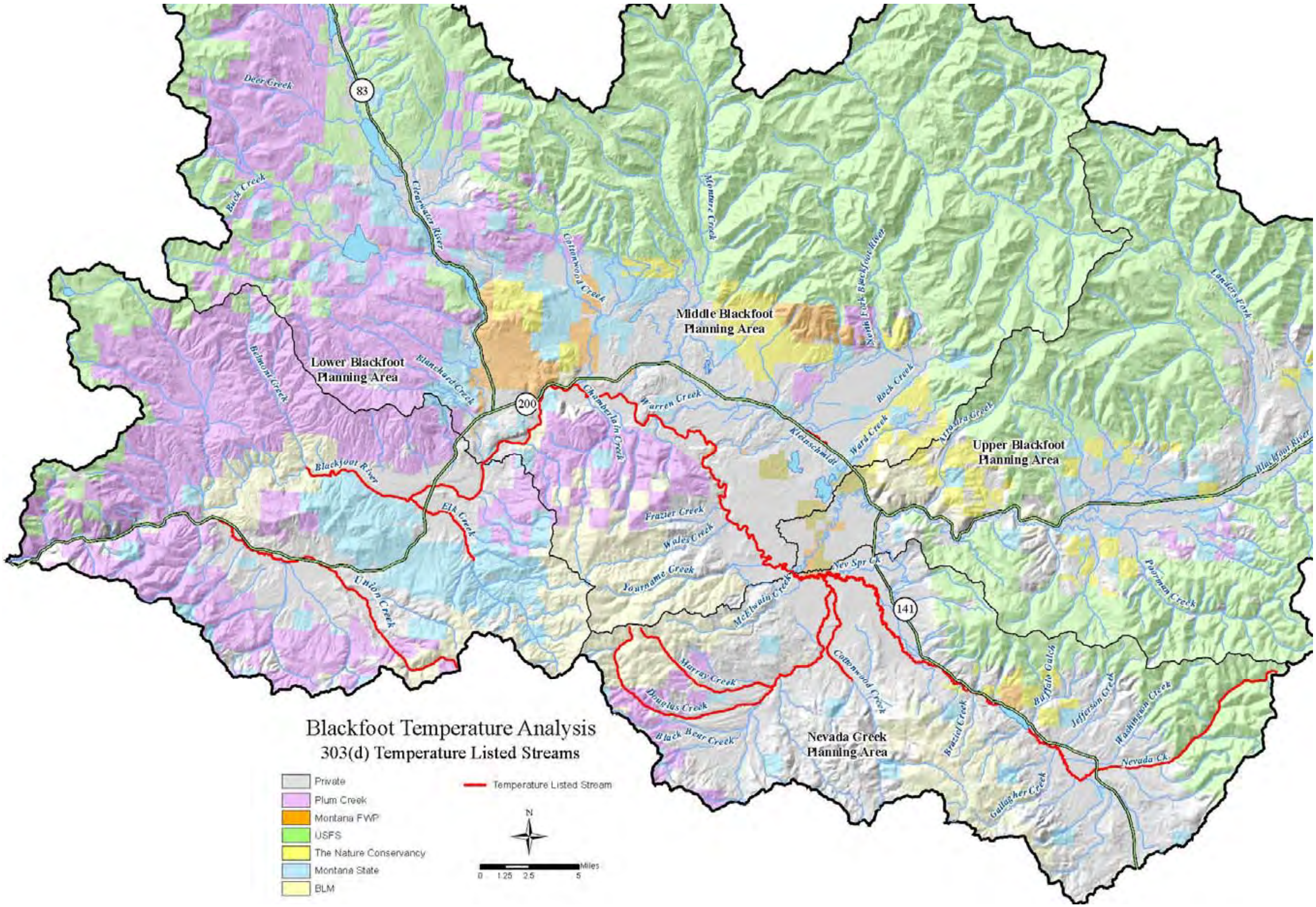


Figure 1-1. The Blackfoot River watershed and streams on the 303(d) list for temperature.

2. Methods

The following sections describe methods used for analysis of existing temperature data, development of input data sets, and construction of SNTEMP and SSTEMP models.

2.1. Temperature Data Analysis

The following sections describe existing temperature data sets and analysis of these data. The results of the data analysis allowed the identification of the locations and magnitudes of high summer water temperatures on 303(d) listed streams and several key tributaries. These results also guided selection of data for use in four SNTEMP models and one SSTEMP model that simulate existing conditions and restoration scenarios.

2.1.1. Available Temperature Data

Available sources of water temperature data for streams in the Blackfoot River watershed include the following:

- A Montana FWP database of continuous summer temperature data from numerous sites from 1994-2004,
- USGS instantaneous temperature measurements from several sites at irregular intervals,
- USFS continuous summer temperature data from the Clearwater River and tributaries (2004),
- DNRC summary temperature data for Blanchard Creek and tributaries (2004), and
- Instantaneous sampling of Nevada Creek and tributaries, and Kleinschmidt Creek in 2003 and 2005 by Hydrometrics, Inc.

The Montana FWP database is the most complete in terms of spatial and temporal coverage, and provides sufficient data for the temperature assessment. One USGS site, located at the mouth of Nevada Creek, does have relevant data, including 3348 records of maximum, minimum and average daily temperatures between 2001 and 2004. All of the other datasets lack sufficient data during critical warm periods.

2.1.2. Montana FWP Temperature Database

The Montana FWP temperature database consists of stream temperature measurements collected continuously every one to two hours over various summer seasons at 122 sites throughout the Blackfoot River watershed. Through 2004, this database contained nearly one million temperature records.

Only a portion of the FWP temperature data is relevant to peak summer temperatures. Of the 122 sites in the database, 49 are located on temperature listed 303(d) streams or important tributary streams (Table 2-1). At several of these sites, temperature records are not available for every summer. Comparison of data between sites required grouping sites by year and area. Table 2-1 lists site names, sites chosen for analysis, and available data by year.

Table 2-1. Montana FWP temperature data analyzed for this project, from upstream to downstream. Sites in bold are on 303(d) streams, others are tributaries. X indicates data chosen for analysis.

303(d) Stream	*Site*	*Sampling Year*										
		1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Upper Nevada Creek	**Nevada Creek above Shingle Mill Creek**								X			
	Mitchell Creek	√							X			
	Halfway Creek near mouth								X			
	Nevada Creek below Halfway Creek								X			
	Washington Creek at Hwy 141	√							X			
	Jefferson Creek at HWY 141								X			
	Nevada Creek above Reservoir	√						√	X			
	Buffalo Creek near Mouth								X			
Cottonwood Creek	**Cottonwood Creek above Pole Creek**	√						X				
	Cottonwood Creek above Douglas Creek	√						X				
Douglas Creek	**Douglas Creek Upstream Reservoirs**					X[3]						
	Douglas Creek Downstream Reservoirs	√				X[3]						
	Douglas Creek at Mouth of Chimney Creek	√						X				
	Douglas Creek above Cottonwood Creek	√						X				
Lower Nevada Creek	**Nevada Creek below Reservoir**	√	√	√		X	√	X				
	Nevada Creek near Helmville, MT					X						
	Wasson Creek near Mouth										X[2]	√
	Nevada Creek above Nevada Spring Creek	√						X			√	X
	Nevada Spring Creek at Mouth	√	√					X	√		√	X
	Cottonwood Creek above Douglas Creek	√						X				
	Douglas Creek above Cottonwood Creek	√						X				
	Nevada Creek below Nevada Spring Creek	X[2]	√									X
	McElwaine Creek at Ovando-Helmville Road							X	√	√		
	Nevada Creek at Mouth	√						X	√	√	√	
Kleinschmidt Creek	**Kleinschmidt Creek**	√				√	√		√	√	√	√
Union Creek	**Union Creek (Upper)**									X		
	Washoe Creek at Mouth									X		

303(d) Stream	***Site***	***Sampling Year***										
		1994	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***
	Union Creek at HWY 200 Potomac									**X**		
	Camas Creek									**X**		
	Ashby Creek									**X**		
	Union Creek at Morrison Lane									**X**		
	Union Creek at Mouth								√	**X**		
Elk Creek	**Elk Creek at Cap Wallace**									**X**	√	
	Elk Creek at Sunset Hill Road	√	√	√	√			√		**X**	√	
	Elk Creek at HWY 200	√	√	√	√		√	√	√	**X**		
	Elk Creek at Mouth	√	√	√				√			**X** [4]	
Blackfoot River	Blackfoot River at Cutoff Bridge	√	√			√	√	**X**	√	√	√	√
	Nevada Creek at Mouth	√						**X**	√	√	√	
	Yourname Creek at Wales Creek Road	√						**X**	√	√	√	√
	Wales Creek at Mouth	√						**X**	√		√	
	Blackfoot River at Raymond Bridge	√				√	√	**X**	√	√	√	√
	Frazier Creek									√	**X** [1]	
	North Fork Blackfoot River at Ovando-HelmvilleRoad	√				√	√	**X**	√	√	√	√
	Warren Creek near Mouth	√						**X**	√	√	√	√
	Monture Creek at Mouth						**X** [1]					
	Blackfoot River at Scotty Brown Bridge	√				√	√	**X**	√	√	√	√
	Chamberlain Creek near Mouth	√					√	**X**				
	Cottonwood Creek at HWY 200				√		√		√	√	√	√
	Clearwater River at Mouth					√				√	**X** [1]	√
	Elk Creek at Mouth	√	√	√				**X**			√	
	Blackfoot River at Corrick River Bend	√					√	**X**				
	Blackfoot River above Belmont Creek				√		√		√	√	√	√
	Belmont Creek at Mouth	√	√	√	√	√	√		√	√	√	√

Bold X (**X**) indicates data chosen for analysis. **X** [1] indicates substitute data used for year 2000 Blackfoot River analysis. **X**[2] indicates substitute data used in analysis of 2000 Lower Nevada Creek temperature data. **X** [3] indicates substitute data used in analysis of 2000 Douglas Creek temperature data. **X** [4] indicates data used in analysis of 2002 Elk Creek temperature data.

Air temperature and precipitation data also helped with the selection of Montana FWP temperature data for analysis. The ideal temperature data for this analysis is a continuous dataset through the summer months from a warm, dry summer (Figure 2-1 and Figure 2-2).

For example, on Lower Nevada Creek, Montana FWP stream temperature measurements are sporadic, with incomplete data from three years. Analysis of these data covers all three years (1998, 2000, and 2004). However, for modeling purposes, data from 2000 provided a reasonably complete dataset.

In some cases, modeling required using temperature data from two different years. This was possible only if the two years were similar climatically. Analysis of temperature data on lower Nevada Creek, Douglas Creek, the mainstem Blackfoot River, and Elk Creek all include some data from an alternate year (Table 2-1). Table 2-2 summarizes the data analyzed for each stream and the climatic conditions for those years.

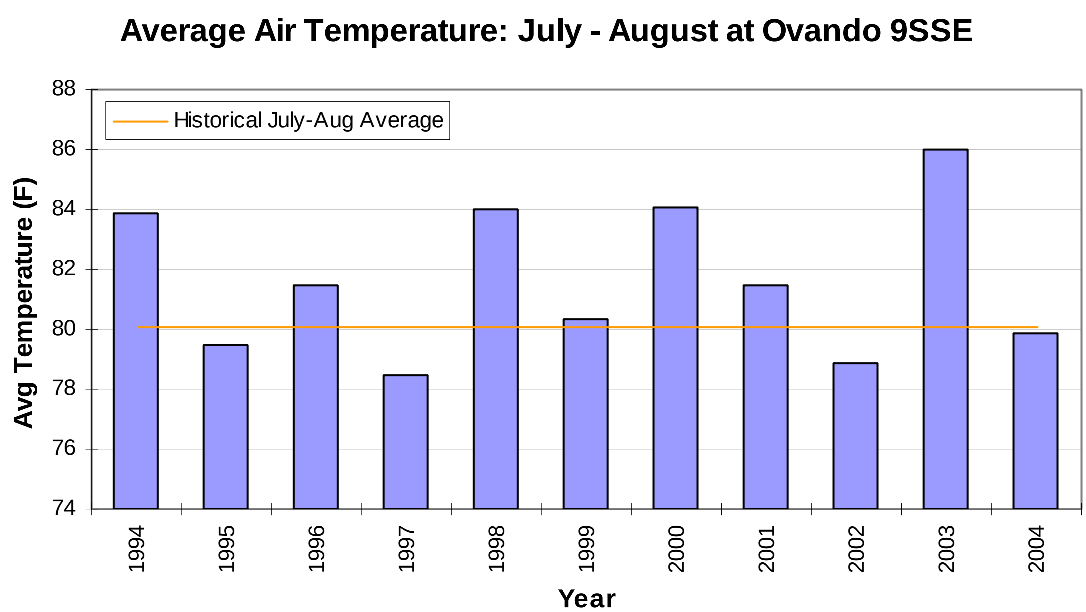


Figure 2-1. Average air temperature for July–August, 1994–2004.

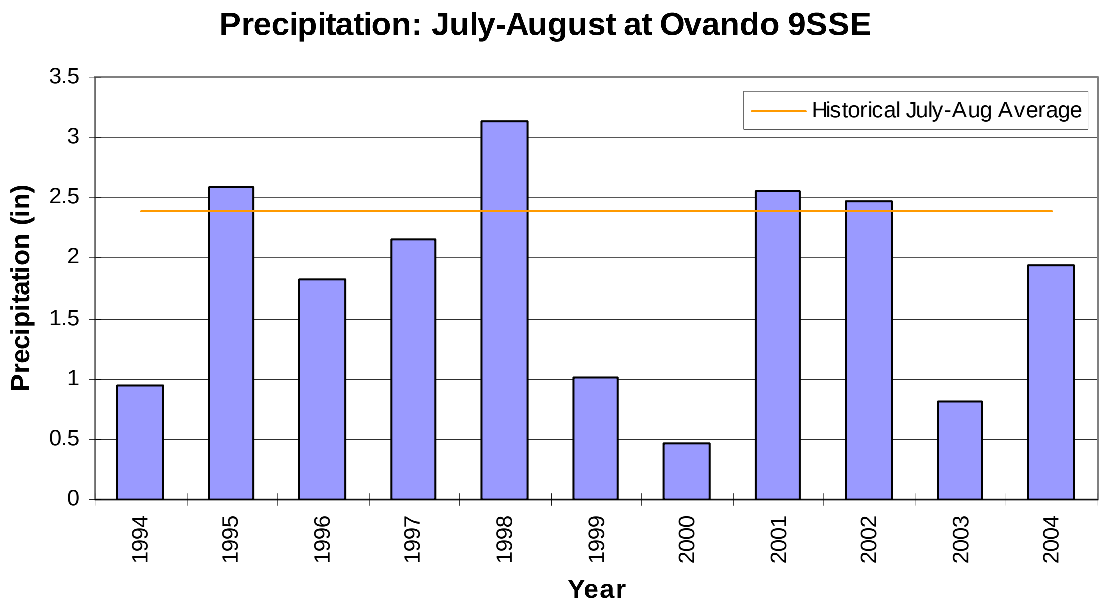


Figure 2-2. Precipitation for July–August, 1994–2004.

Stream	***TMDL Planning Area***	***Model***	***Analysis Year***	***Temperature***	***Precip***
Upper Nevada Creek	Nevada Creek	Upper Nevada	**2001**	Average	Average
Lower Nevada Creek	Nevada Creek	Lower Nevada	1998	Warm	Wet
			2000	Warm	Dry
			2004	Average	Dry
Lower Douglas Creek	Nevada Creek	Lower Nevada	**2000**	Warm	Dry
Cottonwood Creek	Nevada Creek		2000	Warm	Dry
Upper Douglas Creek	Nevada Creek	Upper Douglas	**1998**	Warm	Wet
Kleinschmidt Creek	Middle Blackfoot	Kleinschmidt	2004	Warm	Dry
Blackfoot River	Middle, Lower Blackfoot	Blackfoot	**2000**	Warm	Dry
Elk Creek	Lower Blackfoot		**2002**	Average	Average
Union Creek	Lower Blackfoot		**2002**	Average	Average

Table 2-2. Summary of data selected for analysis and modeling. Primary modeling data year is bold.

2.1.3. Temperature Data Trends

Analysis of temperature data consisted of displaying hourly temperature data, the range of temperature measurements, and seven-day average maximum water temperatures in a series of graphs and box and whisker plots. The hourly temperature data throughout the summer illustrates the timing of temperature increases as well as the diurnal fluctuation in temperature. The box and whisker plots illustrate changes in temperature between sites, and the seven-day average maximum temperature graphs show which sites have the highest temperatures and their duration. Maps showing the seven-day average maximum at each temperature monitoring location helped visualize the spatial distribution of high water temperatures. Together, these figures provide temporal, statistical, and spatial descriptions of summer water temperatures in the Blackfoot River watershed.

Sections three and four contain graphs of hourly summer water temperature for the 24 selected sites on 303(d) streams and important tributaries. Each graph represents one year of data for one site. The continuous temperature graphs also show the effect of weather patterns on stream temperature. For example, the drop in water temperature beginning around July 29th 2001 seen in the upper Nevada Creek graphs corresponds to a cool and rainy storm cycle. Comparison of these graphs illustrates the stream segments that have relatively high temperatures, as well as tributaries that contribute warm or cool water.

Box and whisker plots and seven-day average maximum graphs are also included in sections three and four. Box and whisker plots show the statistical distribution of summer temperatures for sites on 303(d) streams and their tributaries. These plots display the sites from upstream to downstream, and allow comparison of temperature between sites and identify sites with the highest temperatures. Seven-day average maximum graphs plot maximum temperatures over the summer months to illustrate the timing and duration of high temperatures.

Analysis of these graphs and plots allows an upstream to downstream assessment of temperature variability for each stream. Together with information from prior studies on these streams, these data also allow determination of potential sources of temperature gains such as:

- Increased solar input due to lack of shade from degradation or removal of riparian vegetation,
- Reduced stream flow from diversion of water, or
- Increased stream width from channel modifications

2.2. Shade Parameter Development

The quantitative assessment of 303(d) listed thermal impairments in the Nevada Creek and Middle Blackfoot planning areas using the SNTEMP model requires several input datasets. One of the required datasets describes the total amount of shade on a channel cross section on a given day. This section provides a summary of the methods used to quantify shading influences for stream segments included in the models.

The SNTEMP model requires a total shade value for each reach of interest. Model construction requires either entering a total shade parameter or the individual components comprising total shade. If the components are entered individually, the model will calculate the total shade value (Table 2-3, Figure 2-3). This series of shade components describe vegetation character and extent, stream width, stream orientation, and local topography. Calculating total shade based on each of these contributing factors provides a more accurate estimate of overall shade than a total shade input value (Bartholow, 2004).

For this effort, quantification of the individual shade components for each modeled stream segment allowed calculation of a single total shade value (Table 2-3). The data used to derive the shading estimates include aerial photography, digital elevation data, base parameter assessment data, field photos, aerial assessment results, and existing literature. In addition to the parameters shown in Figure 2-3, low flow channel width, stream azimuth, and topographic shade values were developed for each reach using available data.

Table 2-3. Data sources utilized to define topographic, morphologic, and riparian shading parameters.

Type of Shade	***Parameter***	***Definition***	***Data Source***
Topographic	Stream Reach Azimuth	The average departure angle of the stream reach from a north-south reference line when looking south.	Calculated in the GIS
	Topographic Altitude Angle	The vertical angle from a level line at the streambank to the general top of the local terrain when looking at a right angle to the reach azimuth.	Calculated from a Digital Elevation Model (DEM)
Riparian	Height of Vegetation (Vh)	The average maximum height of the overstory riparian vegetation above the water surface.	Base Parameter Assessment Data, Field Photos
	Crown Measurement (Vc)	The average maximum diameter of the riparian vegetation immediately adjacent to the stream.	Base Parameter Assessment Data, Field Photos
	Crown Offset (Vo)	The average distance of the tree trunks from the water's edge.	Base Parameter Assessment Data, Field Photos
	Vegetation Density (Vd)	Measure of sunlight screening. Equal to percent bank length of vegetation times percent of sunlight screened by shading vegetation. (***Pct bank length multiplied by filter factor***)	Base Parameter Assessment Data, Field Photos, Aerial Assessment Results, Literature
Channel Morphology	Low Flow Channel Width	Topwidth of wetted channel under low flow modeled conditions	Base Parameter Assessment Data, Field Photos, Aerial Photographs

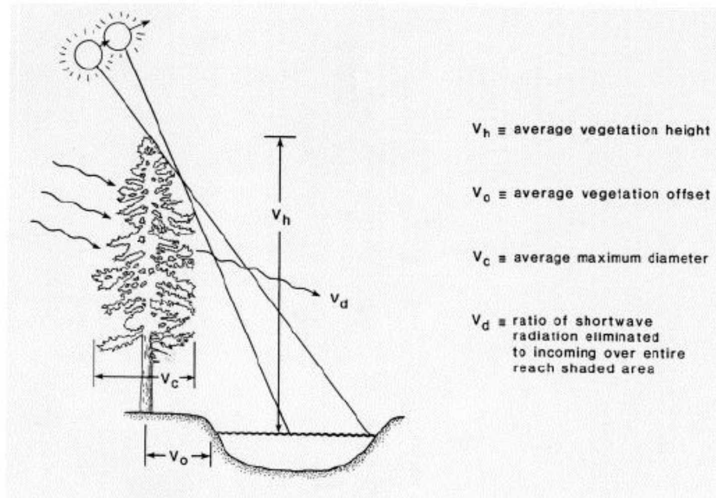


Figure 2-3. Schematic diagram of riparian shading components (Theurer et al, 1984).

2.2.1. Topographic Shade

The two components of topographic shade include stream reach azimuth and topographic altitude angle. The project GIS provided a tool for measuring these parameters for each of the reaches located within the modeling network.

The general stream reach azimuth is a measure of the average departure angle of the reach from a North-South reference line looking south. The direction of flow has no effect on determining the azimuth. The average reach azimuth was calculated in the GIS using a straight line between reach boundaries.

Topographic altitude angle is the angle from the stream bottom to the nearest topographic feature that forms the highest point perpendicular to the stream corridor. In general, this reflects the valley wall of the stream corridor. Points on each valley wall that reflect the topographic shape of the valley wall, and corresponding points on the stream bottom define topographic angle lines perpendicular to the direction of stream flow. Elevations of the two points and the distance between them allowed calculation of the topographic altitude angles (rise over run) for both left and right banks of the channel.

2.2.2. Channel Width

Stream topwidth is a required input parameter in the temperature models. In assessed reaches, the base parameter data includes measurements of bankfull channel width. These widths reflect channel topwidth dimensions at relatively high flows, and likely overestimate the channel width during low flow model conditions. Viewing field photographs helped estimate the ratio of low flow to bankfull width. Channels that are symmetrical and U shaped tend to have similar topwidths under both bankfull and low flow conditions. However, channels that are asymmetric, such as those with point bars tend to have low flow widths that are significantly less than bankfull.

On several reaches in the Nevada Creek planning area and for all of the mainstem Blackfoot River reaches, measuring the visible channel width from aerial photos allowed determination of the low flow channel width. In some areas of the Nevada Creek planning area where the channel is obscured or too small to measure, width information from adjacent assessed reaches and field photos helped refine the air photo estimates. Width measurements developed from the air photos reflect an average of multiple random measurements from each reach.

2.2.3. Riparian Vegetation

Within the modeled stream networks of the Nevada Creek planning area, numerous reaches have base parameter field assessment data that include measurements of vegetation type, extent, and channel cross section. For each of these reaches, queries of the base parameter database extracted the necessary riparian vegetation mapping and cross section data. For reaches without base parameter data, examination field photos helped define a series of vegetation types, with each type assigned an average vegetation height (Vh), canopy diameter (Vc), and offset (Vo). Filtering values were also developed for each vegetation category based on field photos and available literature. Bankline vegetation was then digitized in the GIS for the entire reach extent. This allowed calculation of a weighted average for each reach of the shade parameters based on the relative extent of the various vegetation types. These results combined with channel width and topographic shade measurements allowed calculation of a single shade value for each reach.

2.3. Pilot SSTEMP Modeling

Prior to construction of the SNTEMP models for this project, a pilot modeling effort using SSTEMP, the Stream Segment Temperature Model, was undertaken. The purpose of the pilot model was to determine if the developed input data would yield results requiring reasonable parameter adjustment for calibration. The results were favorable allowing the project to proceed with development of SNTEMP models.

2.4. SNTEMP Modeling

The utilization of a temperature model allowed simulation of stream temperatures under varying conditions. Simulations included current conditions, natural conditions based on higher levels of streambank vegetation, and vegetation conditions between current and natural conditions. In addition, preliminary simulations of increased flow or decreased channel width demonstrated the changes in temperature associated with these scenarios (Appendix C).

SNTEMP, the Stream Network Temperature Model, is a mechanistic heat transport model that predicts daily mean and maximum water temperatures at the end of a stream network (Theurer et al., 1984, Bartholow, 2004). Model simulations occur over a single time step, such as a day, and evaluate the effects of changing shade, stream geometry, and flow on instream temperature. The model requires inputs describing stream geometry, hydrology, meteorology, and stream shading.

SNTEMP expands upon SSTEMP by modeling multiple, linked stream segments to predict water temperature at the end of the network and at points within the network. Because SNTEMP models multiple stream segments, it allows for variability in flow, shade, and other factors at multiple locations within the modeled stream. Effects on stream temperature from one set of stream conditions can then propagate downstream to a stream segment with different conditions. This allows for more comprehensive modeling of stream temperatures than SSTEMP.

2.4.1. Model Construction

Analysis of the temperature data allowed assessment of the distribution of temperature monitoring sites and the periods of data collection. From this, it was apparent that five models were necessary to address temperature impairments on the 303(d) listed streams (Figure 2-4). The models are:

- Upper Nevada Creek,
- Lower Nevada Creek (includes Douglas Creek and Cottonwood Creek),
- The Blackfoot River
- Kleinschmidt Creek, and
- Upper Douglas Creek.

The Upper Nevada Creek, lower Nevada Creek, and Blackfoot River models are large, multi-segment, SNTEMP models. The lower Nevada Creek model simulates temperatures in three 303(d) listed streams: lower Nevada Creek, Douglas Creek, and Cottonwood Creek. Kleinschmidt Creek is a smaller SNTEMP model. The Upper Douglas Creek model uses SSTEMP and simulates temperatures for a section of Douglas Creek consisting of two short stream segments between irrigation reservoirs. The three reservoirs themselves were addressed through a simple surface area approach.

Input Data

A basic suite of input data describing stream conditions and other factors during the modeling period is required. Three broad categories of input data are required in SNTEMP: meteorology, stream geometry, and hydrology.

Local weather stations at Ovando and Helmville supplied the meteorological data. Meteorologic data are mean values for the modeling period, and consists of:

- Air temperature
- Relative humidity
- Wind speed
- Cloud cover, presented as a percent of possible sunshine
- Solar Radiation

Values for solar radiation were not available for the modeling periods from the local weather stations. In lieu of solar radiation values, the model calculates solar radiation if values for dust coefficient and ground reflectivity are available. Dust coefficient and ground reflectivity values representative of the season and ground cover for the modeling period were used (Tennessee Valley Authority, 1972).

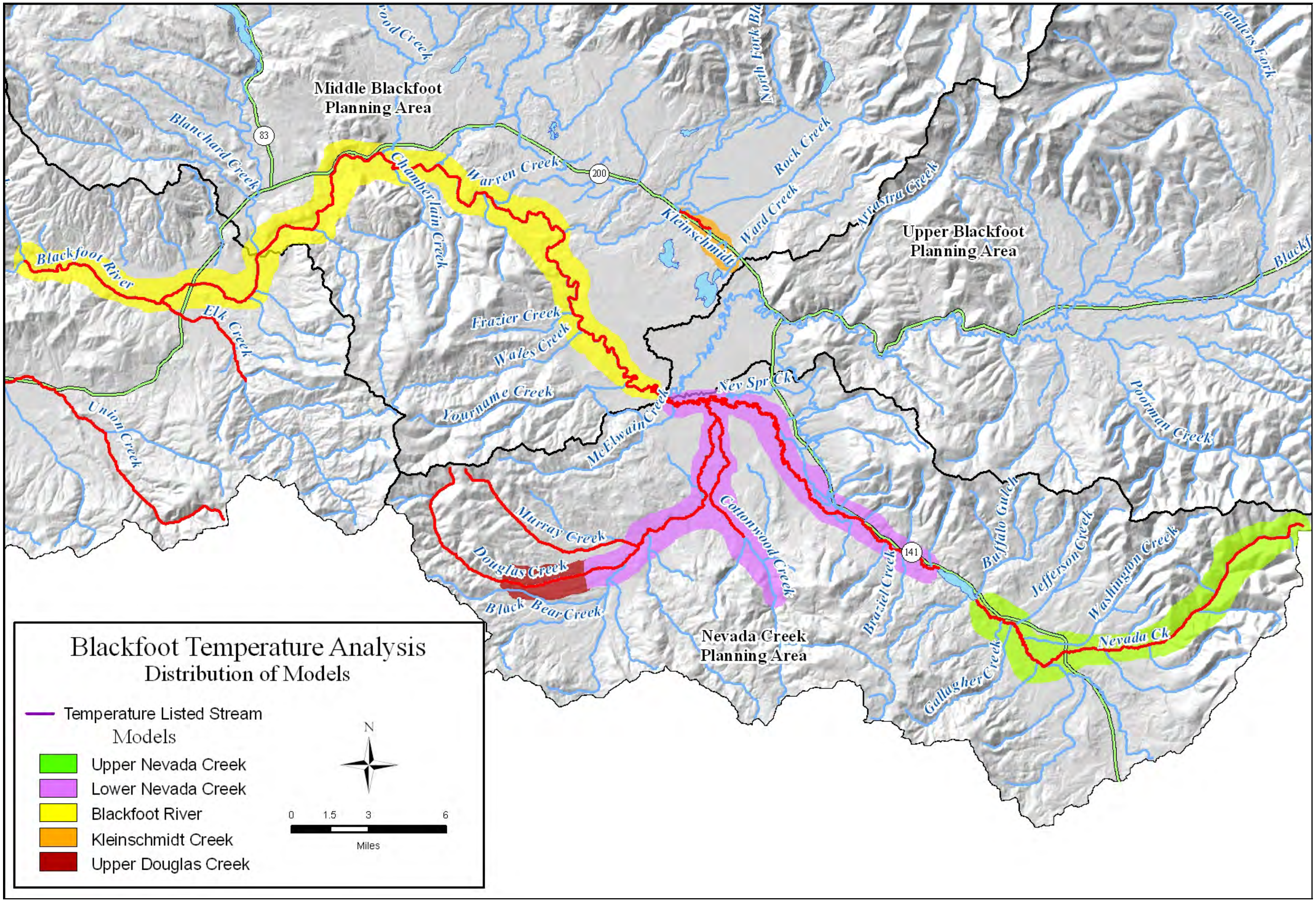


Figure 2-4. Distribution of temperature models in the Blackfoot River and Nevada Creek planning areas.

Hydrologic data are mean values for the modeling period, and include stream discharge throughout the system and water temperature. USGS gages, instantaneous flow measurements associated with water quality sampling, and visual flow estimates from July 2004 supplied flow data, while the FWP database supplied the temperature data. Initial flow at the beginning of the modeled stream, surface and ground water flow, point sources into the stream, and any flow diversions characterize flow throughout the system. Water temperature is input into the model at the beginning of the network, at any locations where additional flow enters the network, and at calibration points.

Other input data includes:

- shade,
- stream width,
- site elevations, and
- Manning's n.

Sections three and four contain tables specifying input data for each of the five models These sections describe meteorological, hydrological, and stream geometry input data for each model. Conditions represent the modeling period.

Model Networks

Each model required development of a spatial model network consisting of multiple stream segments. Each stream segment is unique and has homogenous characteristics such as length, stream width, slope, channel roughness (Manning's n), shade, and flow. Delineation of each segment occurs through identification of a series of nodes along the model network, and these nodes specify values for some or all of the segment characteristics (Table 2-4).

Node Type	***Input Stream Characteristics***
Headwater	Latitude, elevation, stream distance, water temperature, flow, stream width, Manning's n, shade
Segment	Latitude, elevation, stream distance, stream width, flow, Manning's n, shade
Point	Stream distance, water temperature, flow
Diversion	Stream distance, flow
Calibration	Stream distance, water temperature
Temperature Output	Stream distance
Flow	Stream distance, flow
End	Stream distance, flow

Table 2-4. SNEMP model network nodes and stream characteristics described with each node.

Headwater and segment nodes define the upstream point at which a stream segment begins, and that segment's stream characteristics. Segment nodes also define the downstream extent of a stream segment, but not its characteristics. Point nodes are additions of flow to the modeled stream, and can define the location and flow of important tributaries. Diversion nodes specify flow removed from the network. Flow nodes redefine the quantity of instream flow, and account for lateral flow such as groundwater. The Kleinschmidt model employed flow nodes to account for significant groundwater input to the stream. End nodes define the downstream extent of a stream or the network. Temperature predictions occur at these nodes. Additionally, temperature predictions occur at any point in the network where a temperature output node exists.

Sections three and four contain figures illustrating the model network for each of the models. These figures, and the input data, describe the distribution of model nodes and stream segments within each model network and allow spatial identification of characteristics such as shade, flow, and temperature.

2.4.2. Model Calibration

After model construction, calibration of simulated water temperatures with observed water temperature data is necessary. The goal of calibration is to ensure that the temperatures simulated with SNTEMP match well with observed conditions. The model is then suitable for assessing potential restoration efforts and conditions related to TMDLs.

To calibrate each model, observed daily mean and maximum water temperatures are assigned to calibration nodes at the end of each network and at various points within the network. A comparison of observed temperatures with simulated daily mean and maximum water temperatures at those points allows for an assessment of how well the model is simulating temperatures. For SNTEMP, a model is accurate if the difference between observed and simulated temperatures is no greater than 0.5^{o} C (0.9^{o} F) (Bartholow, 1989).

Calibration of simulated to observed water temperatures is accomplished by changing model input parameters in successive calibration iterations until simulated temperatures match observed temperatures. Parameters can be modified singly or in combination. Parameters modified include those described in SNTEMP literature (Bartholow, 1989, Bartholow, 2004) and fit with the project team's knowledge of the modeled streams. The parameters considered for modification during calibration were:

- relative humidity,
- cloud Cover,
- wind,
- dust coefficient,
- ground reflectivity,
- thermal gradient, and
- Manning's n (for maximum temperatures only).

Sections three and four contain tables specifying the parameters modified and the simulated temperatures for each calibration run. These sections also describe the rationale for each change in parameters. Calibration results at multiple nodes in a model network illustrate the accuracy of the model at multiple locations within each network.

2.4.3. Model Simulation

Once calibrated, the models can simulate resultant changes in water temperature from varying shade, flow, or channel width. Since lack of riparian shade is a large contributor to high temperatures in the modeled streams most simulations focused on this parameter.

Predicted temperatures from multiple simulations for each model determined the amount of shade required to meet temperature targets. Simulations typically include:

- current stream conditions,
- natural stream conditions (defined by Montana DEQ, usually 95% streambank vegetation and corresponding increase in shade),
- several simulations between current and natural conditions, and
- one simulation of the target values for shade.

The temperature targets are for mean daily temperatures due to uncertainty in the model's ability to simulate maximum daily temperatures. The target simulation simulates a mean temperature that is no more than one degree Fahrenheit warmer than the simulated mean temperature under the defined natural conditions. However, simulation results for maximum temperatures are reported as well. Sections three and four contain tables and graphs listing which parameters were changed in each simulation, the degree of change, and the resulting temperatures for each simulation.

3. Results: Nevada Creek Planning Area

The following sections describe the results of temperature data analysis, shade parameter development, and temperature modeling for the 303(d) temperature impaired streams in the Nevada Creek Planning Area. The results are presented by stream although in some cases multiple streams are part of a temperature model.

3.1. Shade

The following section presents the results of the shade parameter development for modeled reaches on the Nevada Creek Planning Area. These values are a function of shading vegetation type and extent, topographic conditions, and channel width. Section 2.2 describes the methods used to calculate each of these parameters.

3.1.1. Riparian Vegetation

For the modeled segments of the Nevada Creek Planning area, base parameter assessment data (DTM and AGI, 2005) and field photos allowed definition of the vegetation categories along the streams of interest. For each of these categories, field photos and notes provided the data for estimates of vegetation offset (Vo), diameter (Vd), and height (Vh). The median values of these estimates define typical conditions for each vegetation type. The greatest range in estimated values of height, crown diameter, and offset is the conifer or deciduous/conifer vegetation type (Figure 3-1 through Figure 3-3). However, in all modeled reach segments, this vegetation type occupied less than 10 percent of the total bank length. In general, the most extensive vegetation type mapped is willows/shrubs, which has a relatively small range in Vo, Vh, and Vc values. A summary of the median values measured for height, crown diameter, and offset are in Table 3-1.

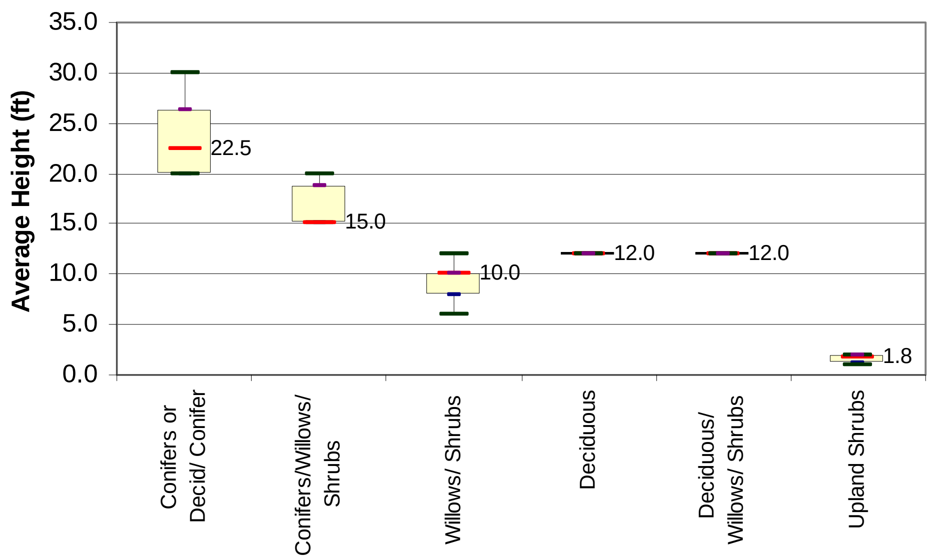


Figure 3-1. Estimated average heights for each vegetation type with median values labeled.

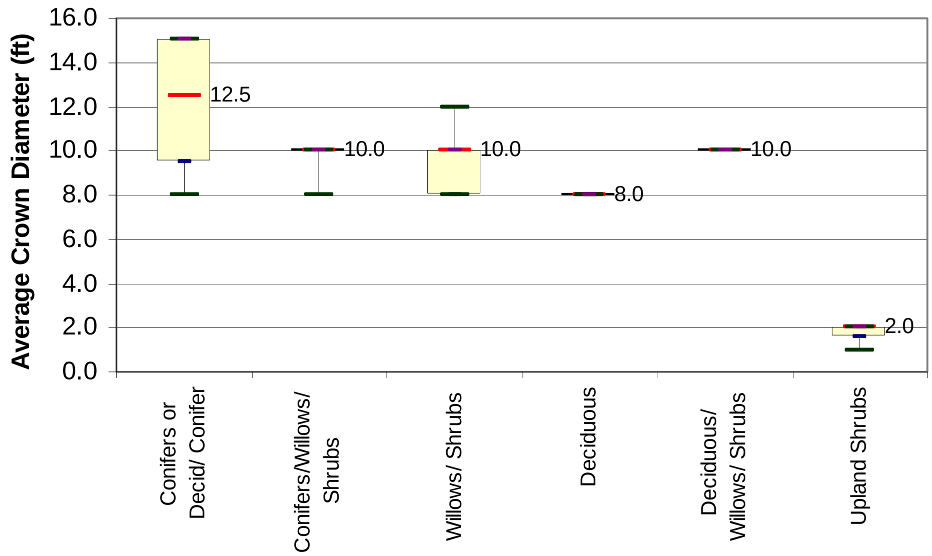


Figure 3-2: Estimated average crown diameter for each vegetation type with median values labeled.

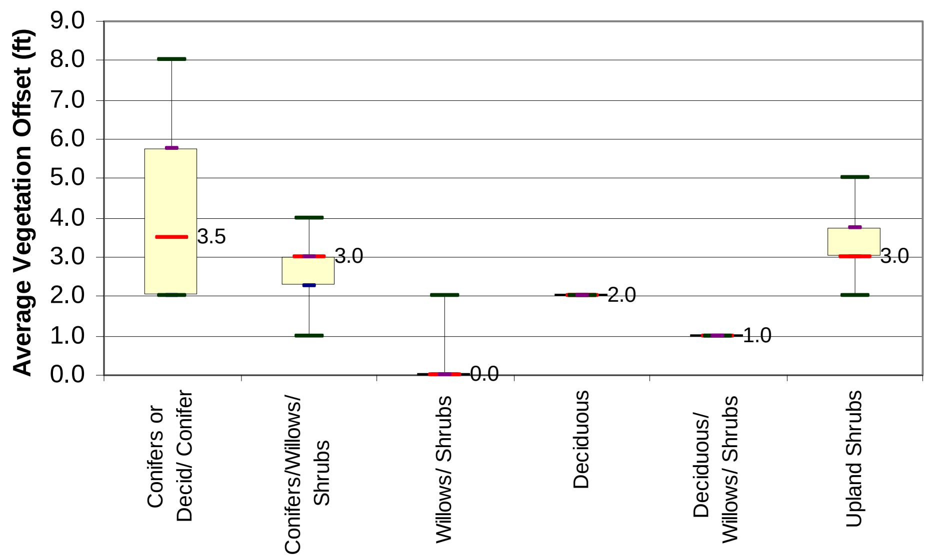


Figure 3-3: Estimated average offset for each vegetation type with median values labeled.

Table 3-1. Shade parameter values utilized for each vegetation category.

Vegetation Type	*Filtering*	*Vh: Crown Height (ft)*	*Vd: Crown Diameter (ft)*	*Vo: Offset (ft)*
Conifer or Deciduous/Conifer	0.6	22.5	12.5	3.5
Conifer/Willow/ Shrub	0.7	15.0	10.0	3.0
Willow/Shrub	0.7	10.0	10.0	0.0
Deciduous	0.6	12.0	8.0	2.0
Deciduous/Willow/ Shrub	0.7	12.0	10.0	1.0
Upland Shrub	0.2	1.8	2.0	3.0

Vegetation density (Vd) is a key input parameter into SSTEMP, for running both existing conditions and potential restoration scenarios. This parameter is the product of the vegetation's sunlight filtering capacity (filtering value) and its extent (percent coverage). Filtering values depend on the structure of the vegetation type. Available literature guided the selection of appropriate values for the vegetation categories mapped in the area (Manoukian and Marlow, 2002; Risley, 1997; Bartholow, 2004). The filtering values range in value from 0.2 to 0.7 (Table 3-1).

The shading parameter value developed for reaches without base parameter data reflects woody vegetation in each reach as measured on 1995 DOQQ and 2005 NAIP imagery. Within the GIS, line segments representing topbank vegetation were digitized and attributed with bank (right or left) and vegetation type. Summarizing the line segment attributes allow calculation of the total length of each vegetation type within each reach. From the extent of the various vegetation types, weighted averages of vegetation height, offset, crown diameter, and filtering value were calculated. Within the reach segments of the modeling network that do not have base parameter data, virtually all of the vegetation mapped was willow/shrub communities in the open valley bottoms.

3.1.2. Topographic Shade

In general, most of the modeled stream segments of the Nevada Creek Planning Area flow through open valleys that provide little topographic shade during summer months. However, some headwater areas, as well as entrenched stream segments, do receive significant shading from local topography. Table 3-2 presents topographic shade values for each reach.

3.1.3. Channel Width

Measured cross section data, air photos, and field photos provided the data to estimate channel width under low flow conditions for each modeled reach segment. Measured cross section data and field photos were available for all of the reach segments with base parameter data. These values, in combination with measurements from air photos helped estimate low flow widths in reaches without field data. Table 3-2 lists the estimated low flow width values for each reach.

3.1.4. Total Shade Calculations

The total shade value is the sum of the topographic and vegetation shade. Using the input parameters described above, a total shade value was calculated for each reach located within a modeling network (Table 3-2, Figure 3-4). Figure 3-5 shows the spatial distribution of shading values by reach and highest 7-day average maximum water temperature by site. These total shade values are a sum of the shade contributions from topography and vegetation typical of the reach during the modeling period. Total shade values range from less than one percent to 58 percent.

Table 3-2. Calculated topographic, vegetation, and total shading parameter for August 15, Nevada Creek Planning Area assessment reaches.

Model	Stream	Reach	B.P. Data	Reach Length (ft)	Pct Shaded Bank	Low Flow Width (ft)	Stream Azimuth (deg)	Crown Diam (ft)	Tree Height (ft)	Offset (ft)	Shade Density Decimal	% SHADE		
												Topo-graphic %	Vege-tation %	Total %
Upper Nevada Creek	Nevada Creek	Nev1		23018	83	5.0	57.4	10.0	14.5	2.7	0.6	1.64	55.23	56.87
		Nev2	√	10108	86	16.6	37.3	10.0	10.0	0.0	0.60	9.07	38.11	47.18
		Nev2b	√	10108	89	16.4	37.3	10.3	12.4	1.0	0.61	9.74	39.44	49.18
		Nev3	√	9666	81	16.0	46.5	8.9	8.9	0.5	0.51	8.60	29.17	37.78
		Nev4		12061	97	16.0	79.6	10.0	10.0	0.0	0.7	0.19	44.77	44.95
		Nev5b	√	33181	30	13.1	-86.3	10.0	10.0	0.0	0.21	0.01	11.13	11.15
		Nev5c	√	33181	0	13.4	-86.3	0.0	0.0	0.0	0.00	0.01	0.00	0.01
		Nev6	√	22204	20	14.2	-50.2	10.0	10.0	0.0	0.14	0.62	11.11	11.74
		Nev6b	√	22204	0	10.8	-50.2	0.0	0.0	0.0	0.00	0.62	0.00	0.62
	Washington Creek	Wash3b		11365	3	5.5	75.9	10	10	0.0	0.02	.02	1.98	2.00
Lower Nevada Creek	Nevada Creek	Nev7	√	22749	0	26.0	-65	0.0	0.0	0.0	0.00	0.72	0.00	0.72
		Nev8	√	18867	42	19.1	-53.8	10.0	10.0	0.0	0.29	0.80	18.40	19.20
		Nev9	√	18803	98	18.4	-48.9	9.1	9.1	0.3	0.63	0.07	38.52	38.59
		Nev10		21720	58	18.0	-31.8	10.0	10.0	0.0	0.4	0.10	28.06	28.15
		Nev11		8048	28	18.0	-26.8	10.0	10.0	0.0	0.2	0.00	13.88	13.88
		Nev12	√	18971	57	14.9	-26.7	10.0	10.0	0.0	0.40	0.00	31.19	31.19
		Nev12b	√	18971	62	9.2	-26.7	10.0	10.0	0.0	0.43	0.00	40.21	40.21
		Nev13	√	22779	34	34.1	-26.7	10.0	10.0	0.0	0.24	0.00	10.20	10.20
		Nev14	√	38527	35	39.2	-85.8	10.0	10.0	0.0	0.25	0.00	6.66	6.66
		Nev14		38527	27	39	-85.8	10	10	0.0	0.19	0.00	5.19	5.19
	Cottonwood Creek	CttnNev1		10201	45	8.0	-42.5	10.0	10.3	0.1	0.3	0.57	29.71	30.29
		CttnNev2	√	16331	25	7.3	10.2	9.5	9.5	0.2	0.17	0.07	15.93	16.00
		CttnNev2b	√	16331	21	9.3	10.2	10.0	10.0	0.0	0.15	0.07	13.53	13.60
		CttnNev3		15317	31	8.0	-14.6	10.0	10.0	0.0	0.2	0.07	20.68	20.75
	Douglas Creek	Doug3g		8896	9	5.9	75.5	10.0	10.0	0.0	0.06	0.11	6.23	6.34
		Doug5	√	17447	32	10.8	62.7	9.5	9.5	0.2	0.21	0.62	18.48	19.10
		Doug6		14486	80	10.0	17.3	10.0	10.0	0.0	0.6	0.55	50.43	50.98
		Doug7	√	10705	44	8.7	10.9	9.8	9.8	0.1	0.30	0.02	28.12	28.13
		Doug7		10705	38	8.7	10.9	10.0	10.0	0.0	0.27	0.02	25.22	25.24

Model	Stream	Reach	B.P. Data	Reach Length (ft)	Pct Shaded Bank	Low Flow Width (ft)	Stream Azimuth (deg)	Crown Diam (ft)	Tree Height (ft)	Offset (ft)	Shade Density Decimal	% SHADE		
												Topo-graphic %	Vege-tation %	Total %
		Doug8		15002	4	10	12.3	10.0	10.0	0.0	0.0	0.00	2.78	2.78
		Doug9		7933	32	12	-23	10.0	10.0	0.0	0.2	0.00	18.86	18.86
Upper Douglas Creek	Douglas Creek	Doug3a		1891	45	5.9	75.5	10.0	10.0	0.0	0.31	0.11	31.26	31.37
		Doug3c		2840	54	5.9	75.5	10.0	10.0	0.0	0.38	0.11	37.92	38.03
		Doug3e		6783	34	5.9	75.5	10.0	10.0	0.0	0.24	0.11	23.55	23.67
		Doug3g		8896	9	5.9	75.5	10.0	10.0	0.0	0.06	0.11	6.23	6.34
None	Murray Creek	Murr1		18108	88	7	-46.5	10.0	15.0	3.0	0.6	4.69	53.44	58.13
		Murr2		10937	60	7	-55.2	10.0	15.0	3.0	0.4	0.44	38.43	38.87
		Murr3		20299	39	6	85.7	10.0	10.7	0.4	0.3	0.10	27.43	27.53

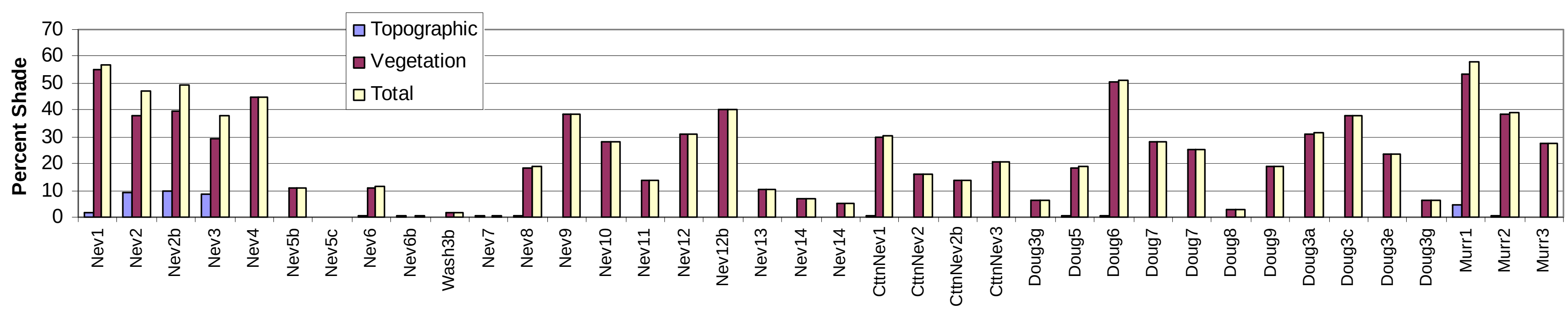
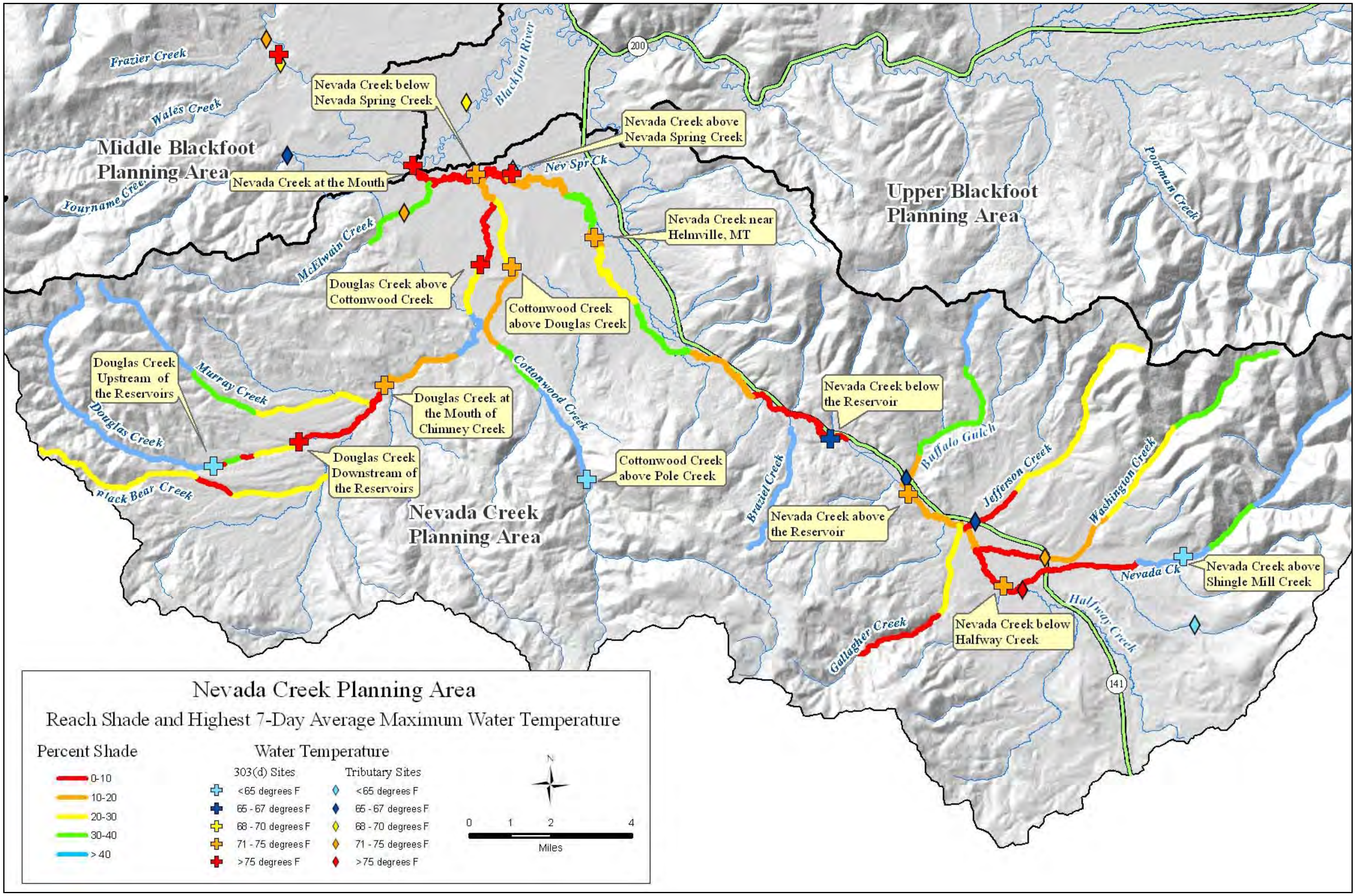


Figure 3-4. Total shade values calculated for modeled reaches, Nevada Creek Planning Area

Figure 3-5: Nevada Creek planning area map showing vegetation shade by reach and temperature at monitoring sites.



3.2. Temperature Conditions

The following sections describe the stream temperature conditions for each 303(d) listed stream in the Nevada Creek Planning Area. This includes important tributaries to these streams.

3.2.1. Upper Nevada Creek

Above Nevada Reservoir, the only stream on the 303(d) list for temperature impairments is Nevada Creek. However, tributary streams also contribute warm water. The Montana FWP temperature database contains data collected in 2001 for three sites on upper Nevada Creek and for four sites on tributary streams. Figure 3-6 through Figure 3-12 (upstream to downstream) display continuous water temperature readings collected at the seven monitoring sites during the summer of 2001. These figures illustrate that the daily range in water temperatures (diurnal fluctuation) is around 10- 15 ^{o} F. The drop in temperature around July 30 at all sites corresponds with a cool and rainy period (Figure 3-14).

Figure 3-13 shows the distribution of summer temperatures during 2001 at the seven monitoring sites. This figure allows comparison of temperature between sites. For example, Nevada Creek temperatures increase significantly between the site above Shingle Mill Creek and the site below Halfway Creek, with Halfway Creek itself having the highest temperatures of all the sites.

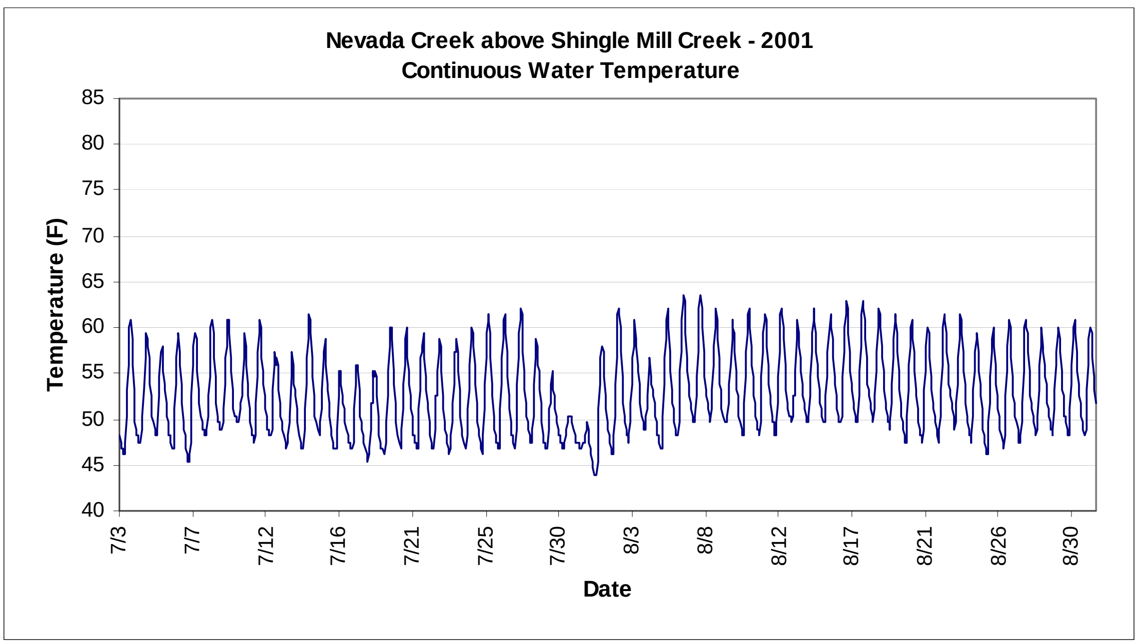


Figure 3-6: Continuous water temperature, Nevada Creek above Shingle Mill Creek, 2001.

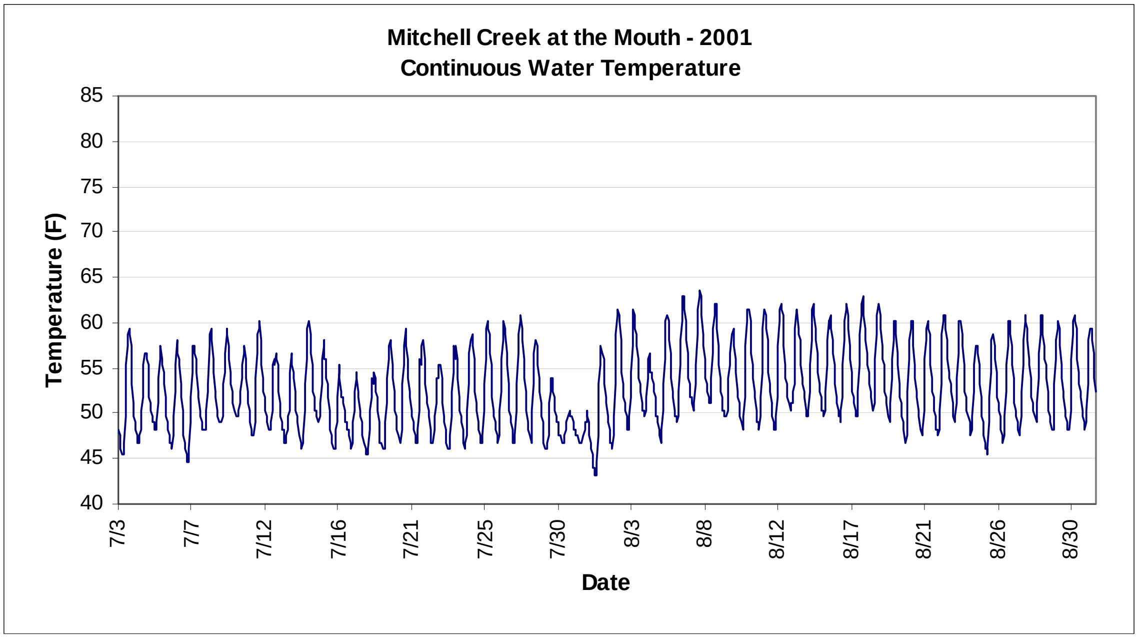


Figure 3-7: Continuous water temperature, Mitchell Creek at the mouth, 2001.

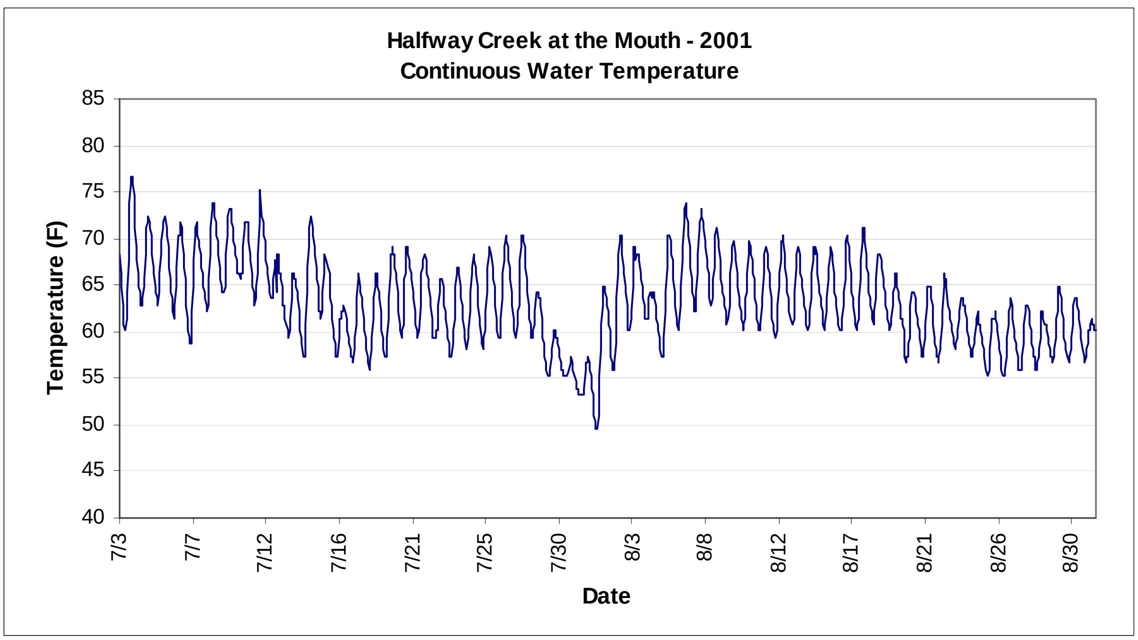


Figure 3-8: Continuous water temperature, Halfway Creek at the mouth, 2001.

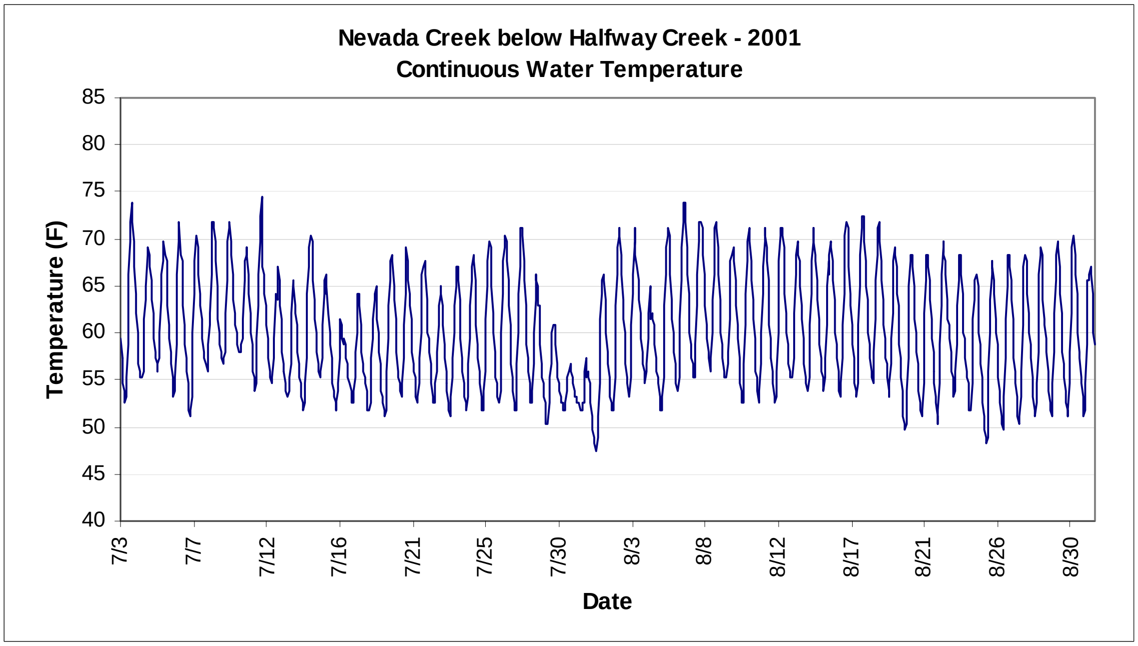


Figure 3-9. Continuous water temperature, Nevada Creek below Halfway Creek, 2001.

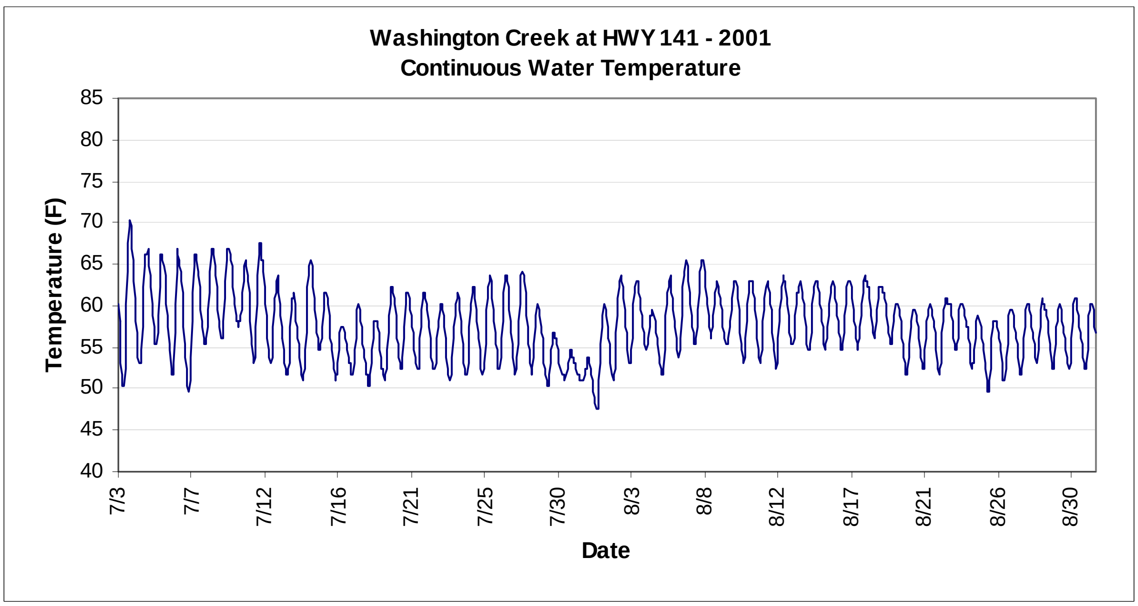


Figure 3-10. Continuous water temperature, Washington Creek at Highway 141, 2001.

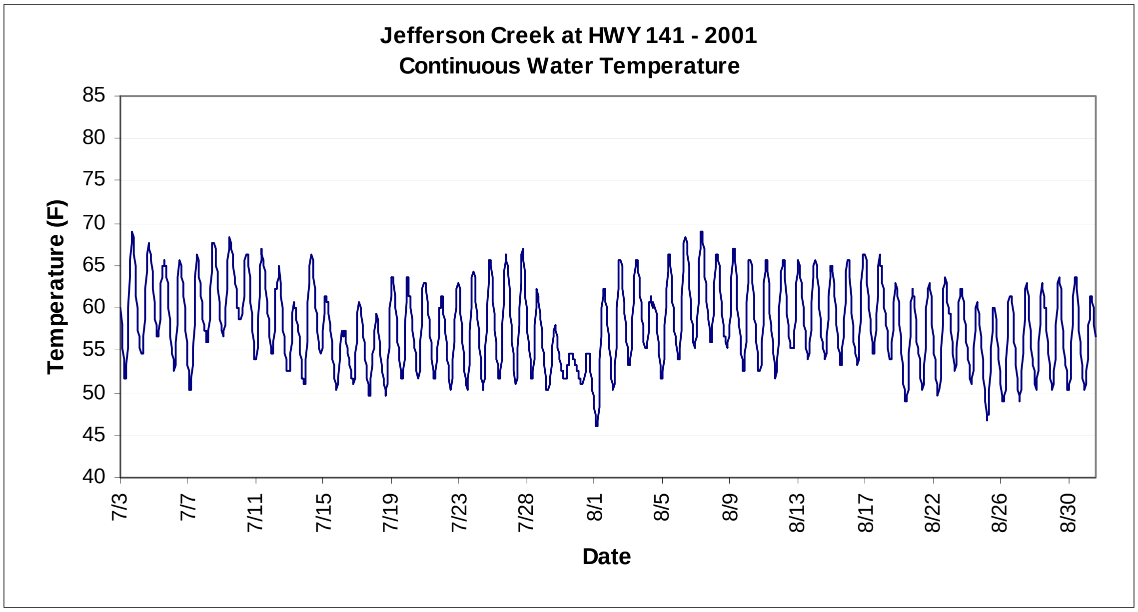


Figure 3-11. Continuous water temperature, Jefferson Creek at Highway 141, 2001.

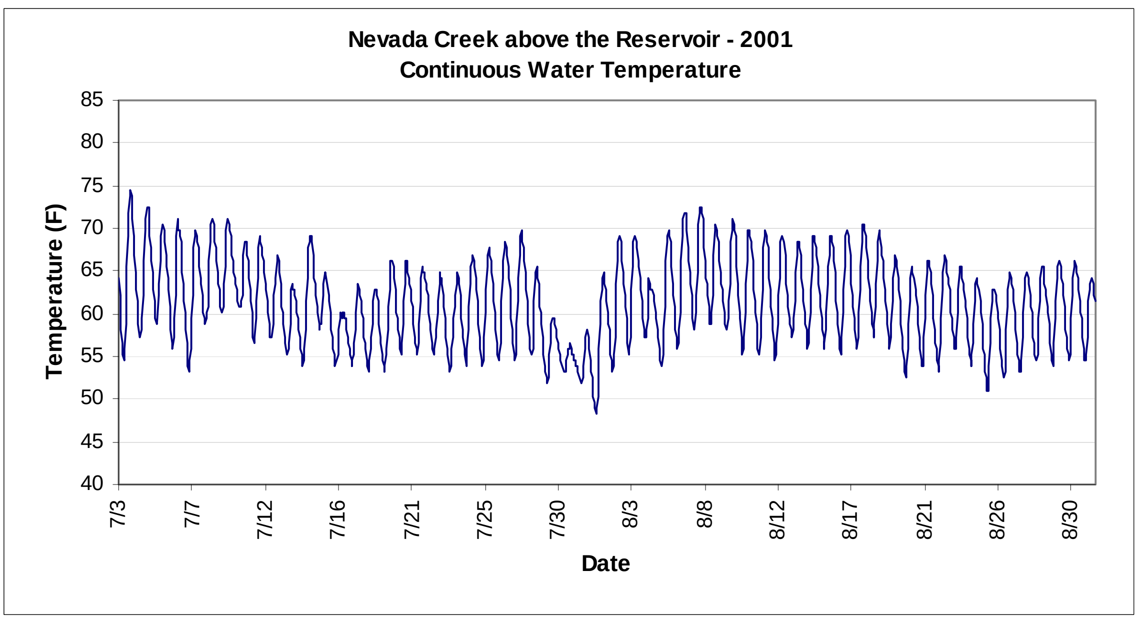


Figure 3-12: Continuous water temperature, Nevada Creek above the reservoir, 2001.

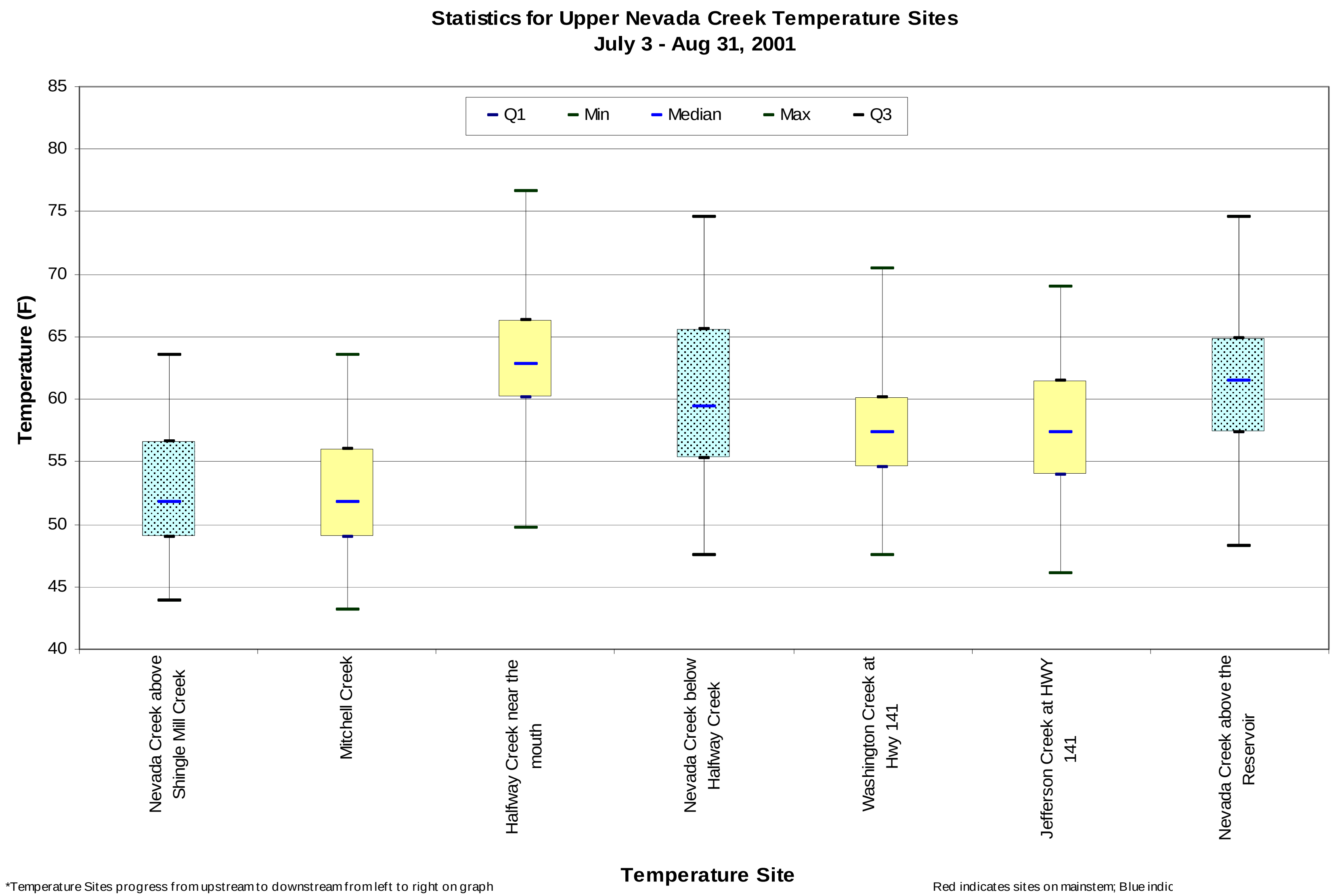


Figure 3-13. Upstream to downstream temperature variation, upper Nevada Creek, 2001.

Figure 3-14 and Figure 3-15 display the daily maximum and seven-day average maximum temperatures, respectively, at the three monitoring sites on upper Nevada Creek during the summer of 2001. Precipitation and air temperature plotted on the maximum daily water temperature graph illustrates that these factors strongly influence water temperature, as water temperatures fluctuate with changes in air temperature. The seven-day average maximum temperature graph shows that high temperatures occur at the two downstream monitoring sites in early July and for an extended period during the first three weeks in August.

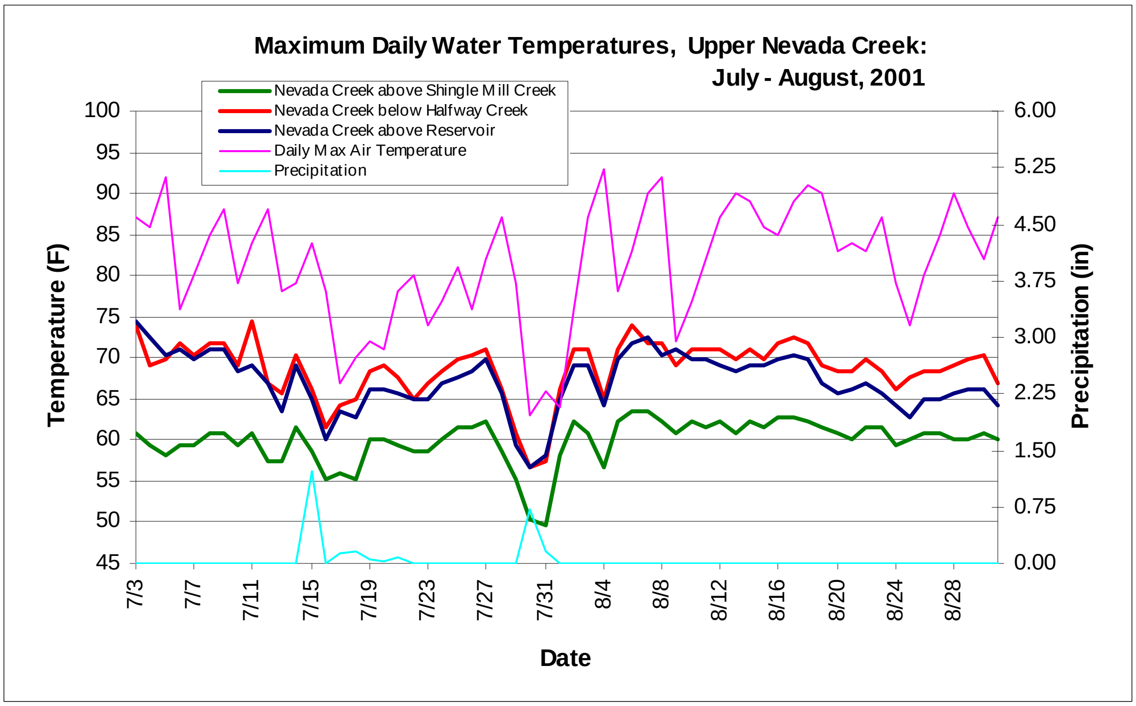


Figure 3-14: Maximum daily water temperature, air temperature, and precipitation, upper Nevada Creek, 2001.

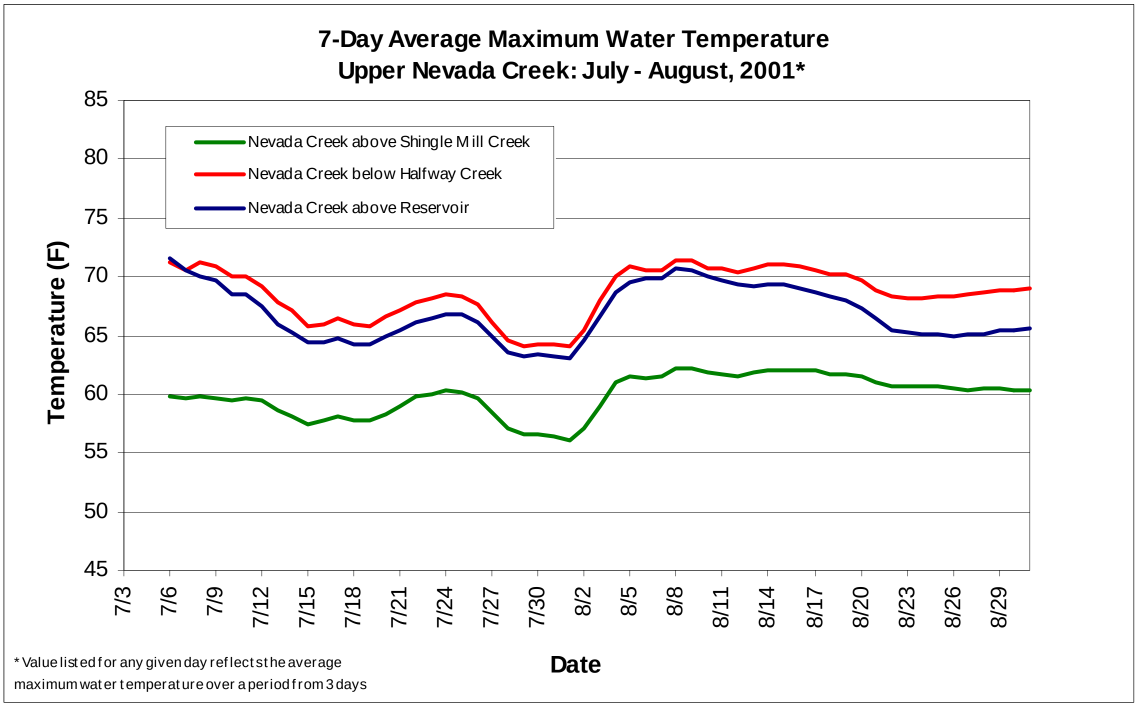


Figure 3-15: 7-day average maximum daily temperatures, Upper Nevada Creek, 2001.

Together, these graphs and plots assist with an upstream to downstream assessment of temperature variability in upper Nevada Creek. Relatively cool water temperatures measured at Nevada Creek above Shingle Mill Creek and Mitchell Creek reflect cold inflows from the headwater areas of Nevada Creek (Figure 3-6). Nevada Creek temperatures increase below the confluence of Halfway Creek, indicating a contribution of relatively warm water from that tributary. Air photos and base parameter assessment data (DTM and AGI, 2005) depict a lack of riparian shading on much of Halfway Creek, as well as on Nevada Creek above Halfway Creek. Both of these reaches likely experience large thermal gains during hot summer days, which results in warm stream temperatures in Nevada Creek below Halfway Creek. Farther downstream, Washington Creek is slightly warm at the Highway 141 crossing, which is approximately two miles upstream of its confluence with Nevada Creek. Between the measuring site and the confluence, the stream temperatures on Washington Creek likely experience substantial gains due to a lack of riparian vegetation on lower Washington Creek. Jefferson Creek contributes water slightly cooler than Washington Creek, and this may in part be due to groundwater inputs. Between the Halfway Creek confluence and Nevada Reservoir, the Nevada Creek corridor is also sparsely vegetated and significant solar warming of water is likely in the reach, as indicated by warm temperatures measured just above the reservoir.

Diversion of water for irrigation occurs in the early summer in upper Nevada Creek since water rights in this area allow diversion until late June. Note that the water temperatures at the start of the monitoring period (July 3) are relatively warm, and may reflect warm return flows from the early summer flood irrigation.

3.2.2. Lower Nevada Creek

The year chosen for temperature analysis and modeling for lower Nevada Creek is 2000. This year had the most consistent temperature dataset for the largest group of sites in the area. This section also includes temperature data for Nevada Spring Creek collected in 2004. Nevada Spring Creek underwent significant restoration in 2001, resulting in significantly reduced channel width. Comparison of the 2000 with 2004 continuous temperature graphs for Nevada Spring Creek indicates a significant improvement in stream temperatures since restoration (Figure 3-19 and Figure 3-20).

Figure 3-16, Figure 3-18 through Figure 3-19, and Figure 3-21 (upstream to downstream) display continuous water temperature readings collected for lower Nevada Creek during the summer of 2000. Figure 3-17 displays water release dat from Nevada Reservoir. Note that dam releases drop significantly around the July 4th first cutting of hay and the corresponding increase in diurnal fluctuation in water temperature. Figure 3-22 displays temperature statistics for lower Nevada Creek and tributary sites. Note that the temperature data from Douglas and Cottonwood creeks is from significantly upstream of their confluence with Nevada Creek. Therefore, the actual contribution from these tributaries is likely warmer.

The range in diurnal temperature is low immediately below Nevada Reservoir, but increases downstream above Nevada Spring Creek and more so at the mouth of Nevada Creek. Temperatures also increase from upstream to downstream in Nevada Creek.

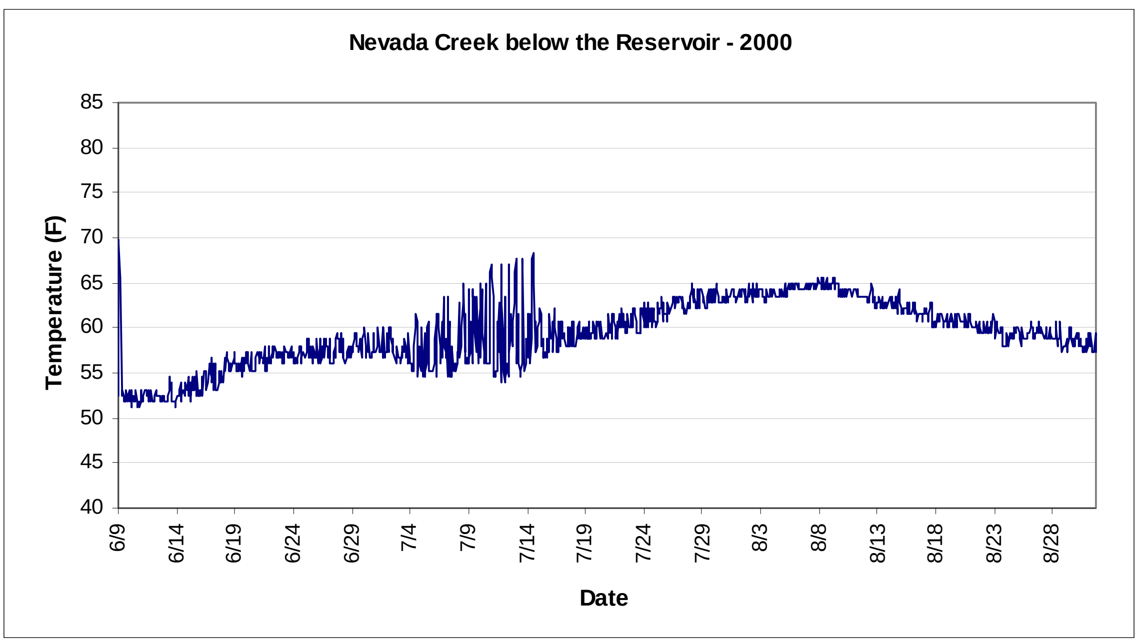


Figure 3-16. Continuous water temperature, Nevada Creek below the reservoir, 2000.

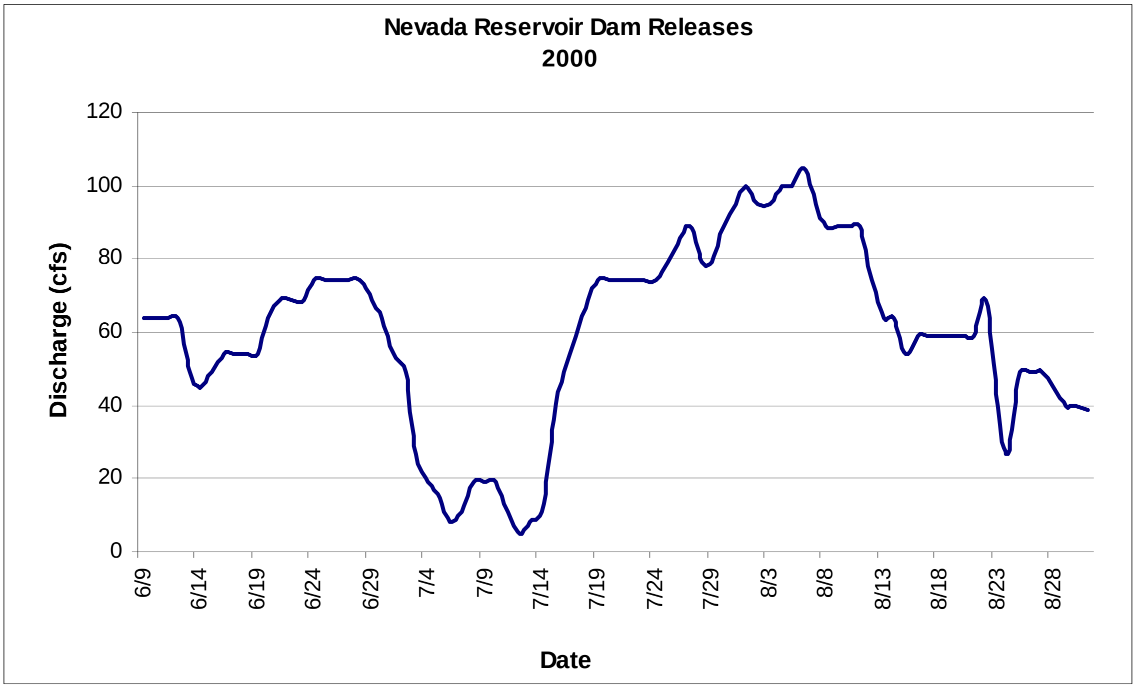


Figure 3-17. Flow below Nevada Reservoir, 2000.

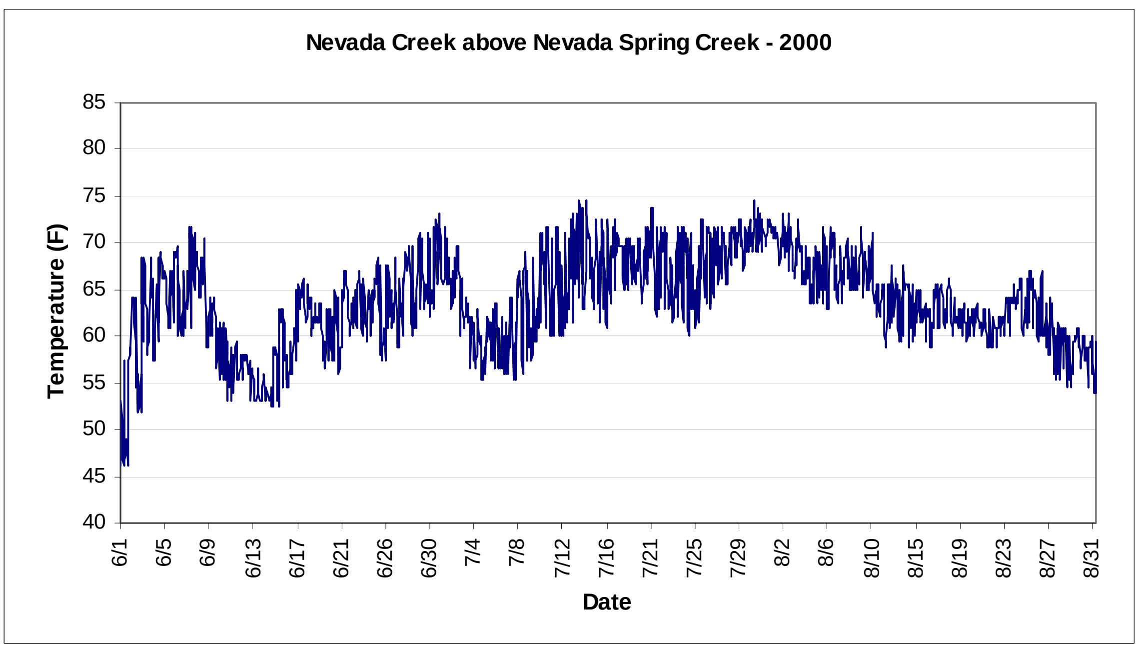


Figure 3-18. Continuous water temperature, Nevada Creek above Nevada Spring Creek, 2000.

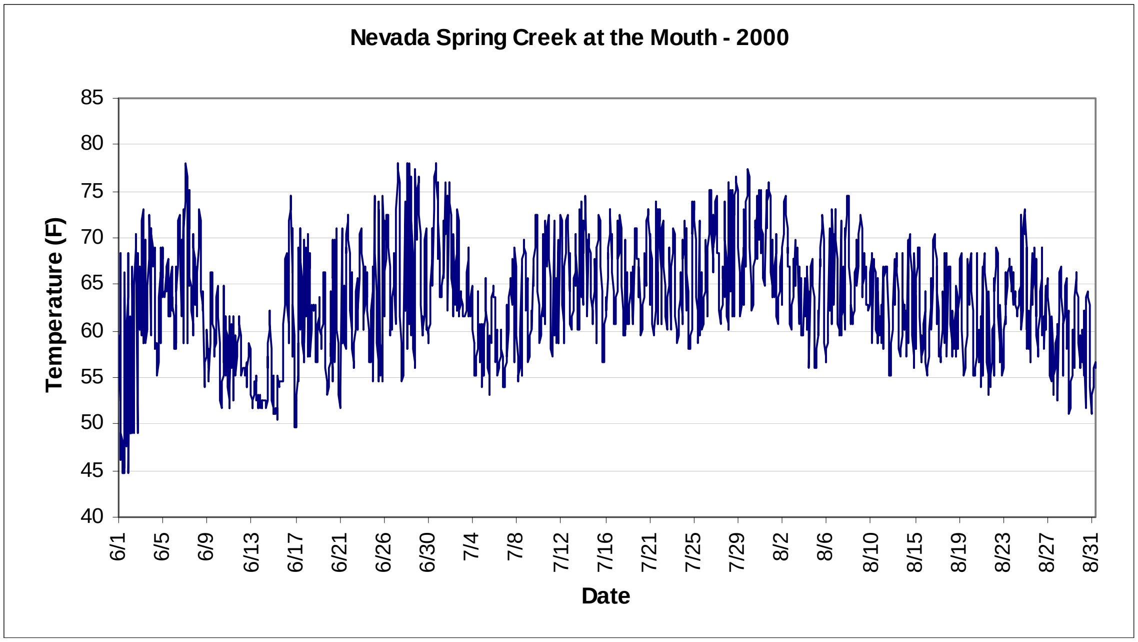


Figure 3-19. Continuous water temperature, Nevada Spring Creek, 2000.

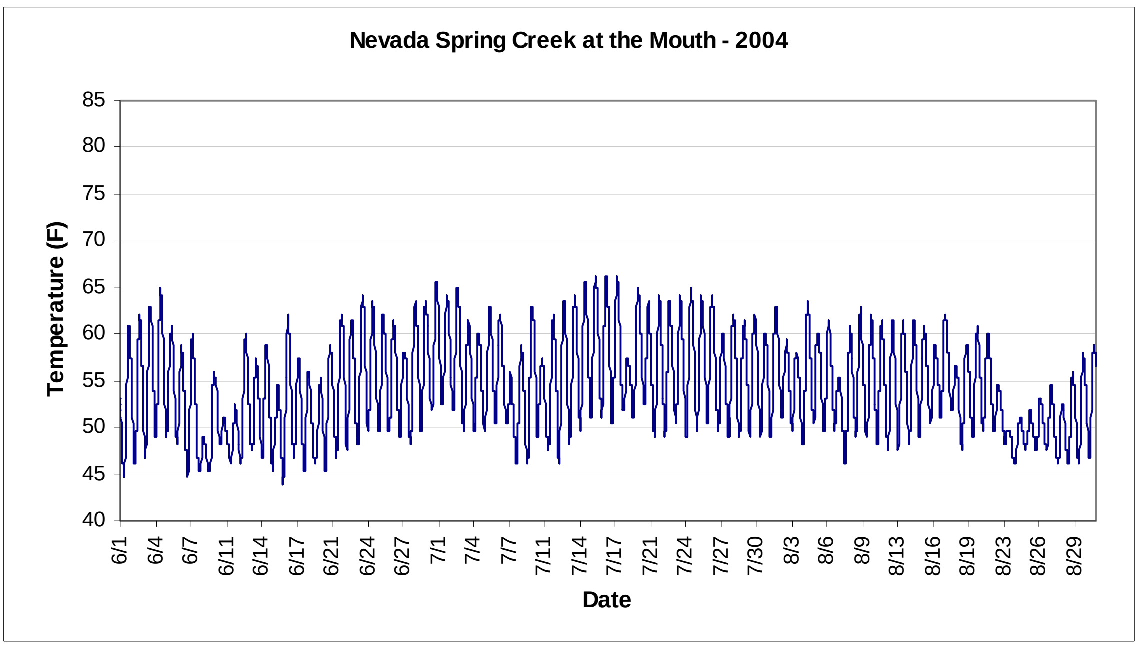


Figure 3-20: Continuous water temperature, Nevada Spring Creek at the mouth, 2004.

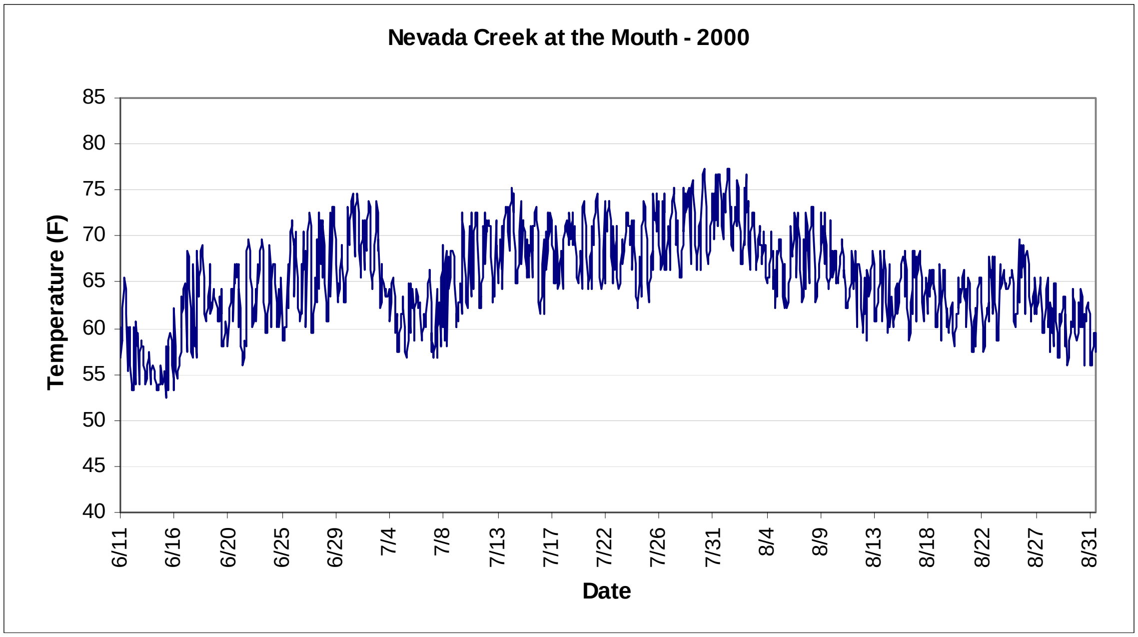


Figure 3-21: Continuous water temperature, Nevada Creek at the mouth, 2000.

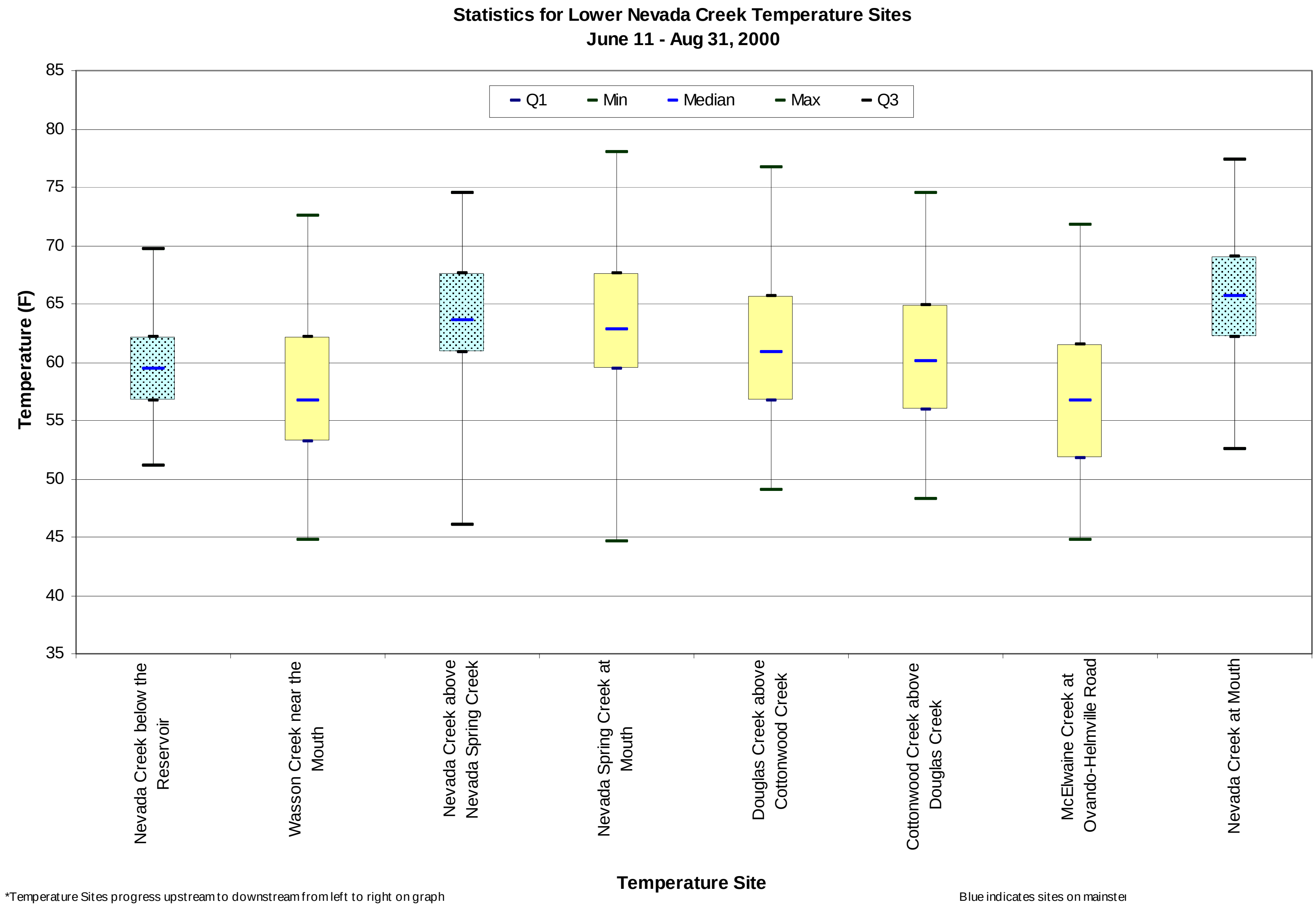


Figure 3-22. Upstream to downstream temperature variation, lower Nevada Creek, 2000.

Figure 3-23 and Figure 3-24 display the daily maximum and seven-day average maximum temperatures, respectively, at three monitoring sites on lower Nevada Creek during the summer of 2000. Precipitation and air temperature plotted on the maximum daily water temperature graph illustrates that these factors strongly influence water temperature. The seven-day average maximum temperature graph shows that maximum temperatures increase from upstream to downstream, with the highest temperatures occurring from mid July through early August before dropping off steadily in late August.

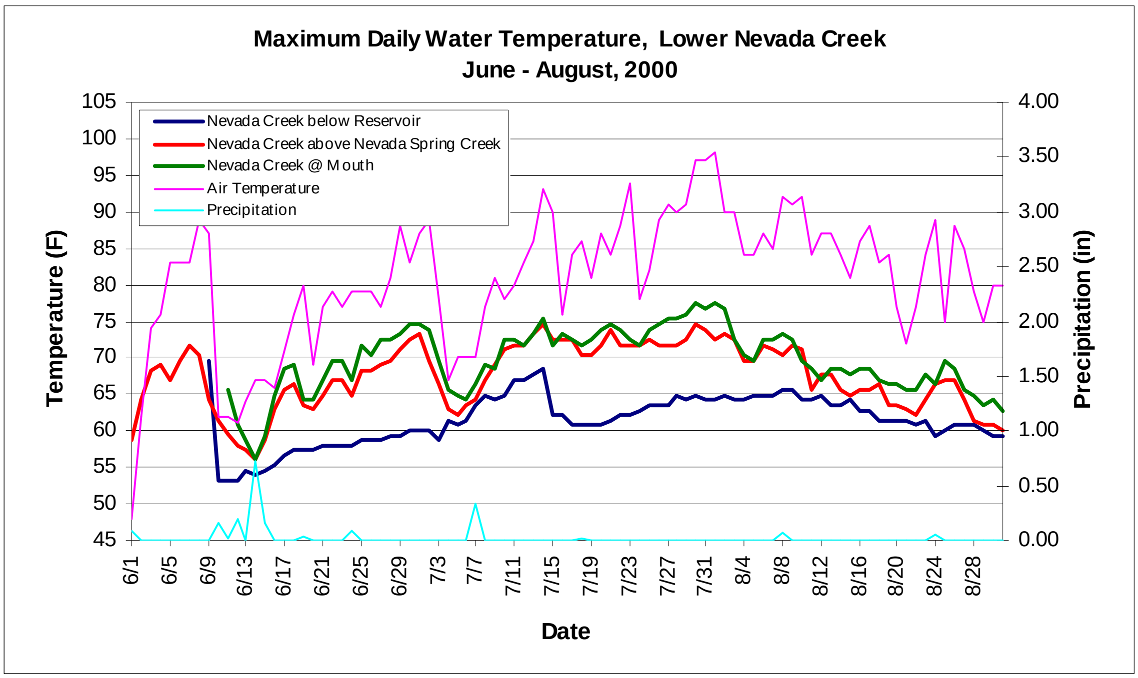


Figure 3-23. Maximum daily water temperature, air temperature, and precipitation, lower Nevada Creek, 2000.

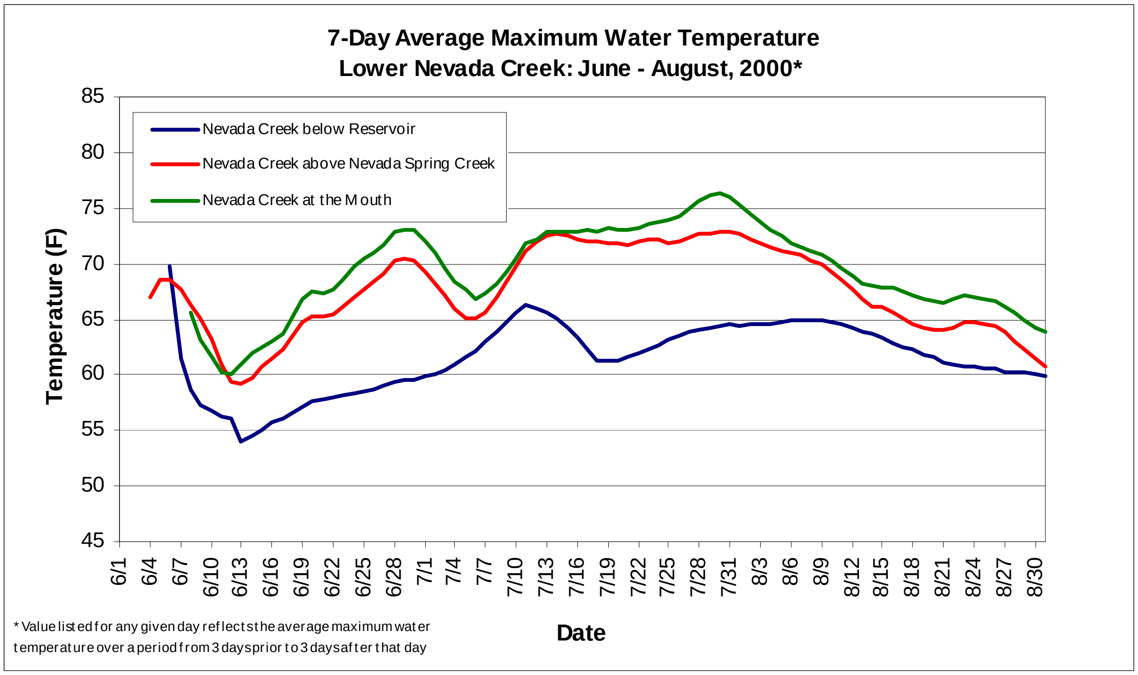


Figure 3-24. 7-day average maximum daily temperatures, lower Nevada Creek, 2000.

Lower Nevada Creek begins at the outlet of Nevada Reservoir. Here, cool water from the bottom of Nevada Reservoir is released (Figure 3-16). Between July 4 and July 15, temperatures increase below the reservoir. This reflects reduced water releases from Nevada Reservoir (Figure 3-17). Downstream, measured temperatures above Nevada Spring Creek reflect a significant temperature increase in Nevada Creek between the reservoir and Nevada Spring Creek. This reach of Nevada Creek notably lacks riparian shading and contains two major irrigation diversions. These conditions all contribute to the large thermal gains during hot summer days on this reach. Downstream, at the mouth of Nevada Creek, temperature readings indicate that Nevada Creek experiences thermal gains from Nevada Spring Creek to its confluence with the Blackfoot River. Several factors contributed to significant warming of streamflow in this reach in 2000 including warm water from Nevada Spring Creek prior to restoration, warm water from Douglas Creek, and a lack of shade and high channel width between Nevada Spring Creek and the mouth.

3.2.3. Cottonwood Creek

Temperature data for Cottonwood Creek is available for two years, 1994 and 2000. Temperature analysis and modeling for Cottonwood Creek is for the year 2000, as this is the most complete dataset. In addition, using the 2000 data allows including Cottonwood Creek in the lower Nevada Creek temperature model. Figure 3-25 and Figure 3-26 (upstream and downstream) display continuous water temperature readings collected at the two monitoring sites on Cottonwood Creek during the summer of 2000. Figure 3-27 shows the statistical distribution of summer temperatures at the two monitoring sites. The continuous temperature graphs show that temperatures fluctuate around 10-15^{o} F each day. The drop in temperatures around July 3rd indicates a cooler weather period and coincides with the drop in temperatures on lower Nevada Creek during the same period (Figure 3-16 through Figure 3-21). This may also be partly due to reduced irrigation withdrawals during hay cutting. The plots shows that temperatures are much higher downstream, although the range between maximum and minimum temperatures is similar.

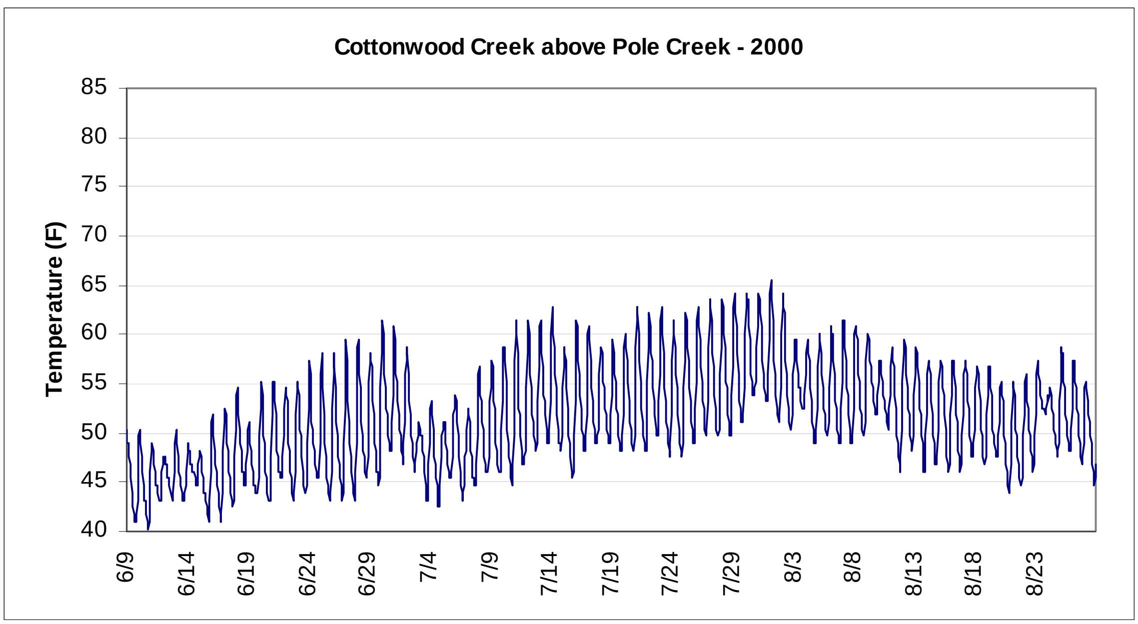


Figure 3-25: Continuous water temperature, Cottonwood Creek above Pole Creek, 2000.

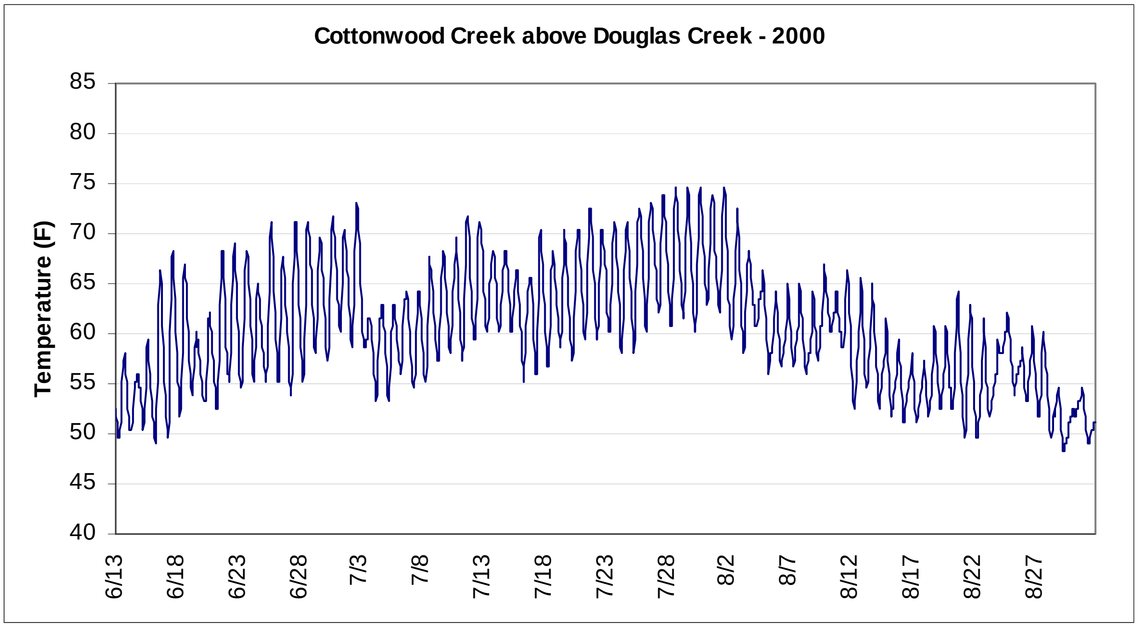


Figure 3-26: Continuous water temperature, Cottonwood Creek above Douglas Creek (Ovando-Helmville Road), 2000.

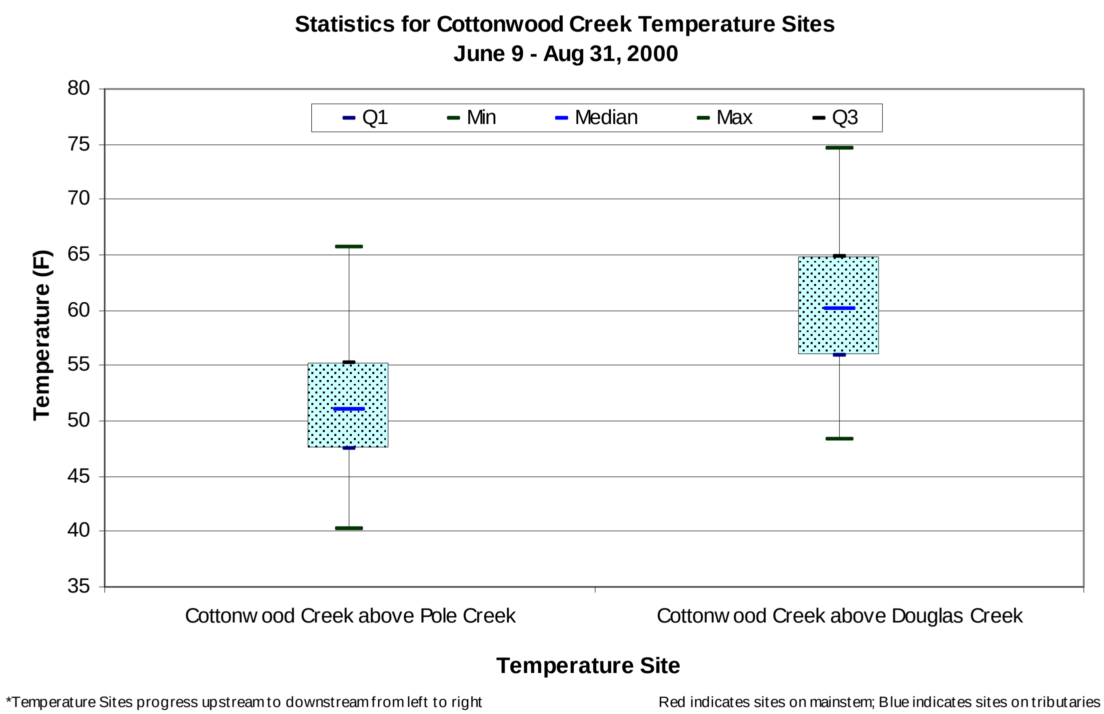


Figure 3-27. Upstream to downstream temperature variation, Cottonwood Creek, 2000.

Figure 3-28 and Figure 3-29 display the daily maximum and seven-day average maximum temperatures, respectively, at the two monitoring sites on Cottonwood Creek during the summer of 2000. As seen in other areas, precipitation and air temperature strongly influence water temperature. The seven-day average maximum temperature graph shows that maximum temperatures increase from upstream to downstream, and the highest temperatures occur in late July before dropping off steadily through August.

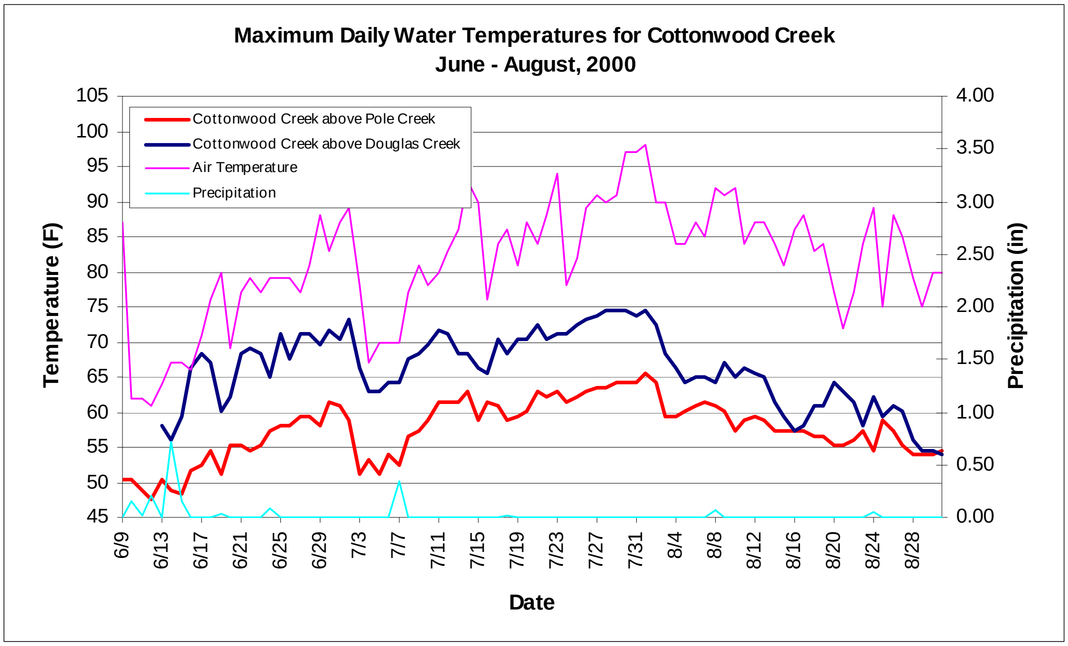


Figure 3-28. Maximum daily water temperature and climate Cottonwood Creek, 2000.

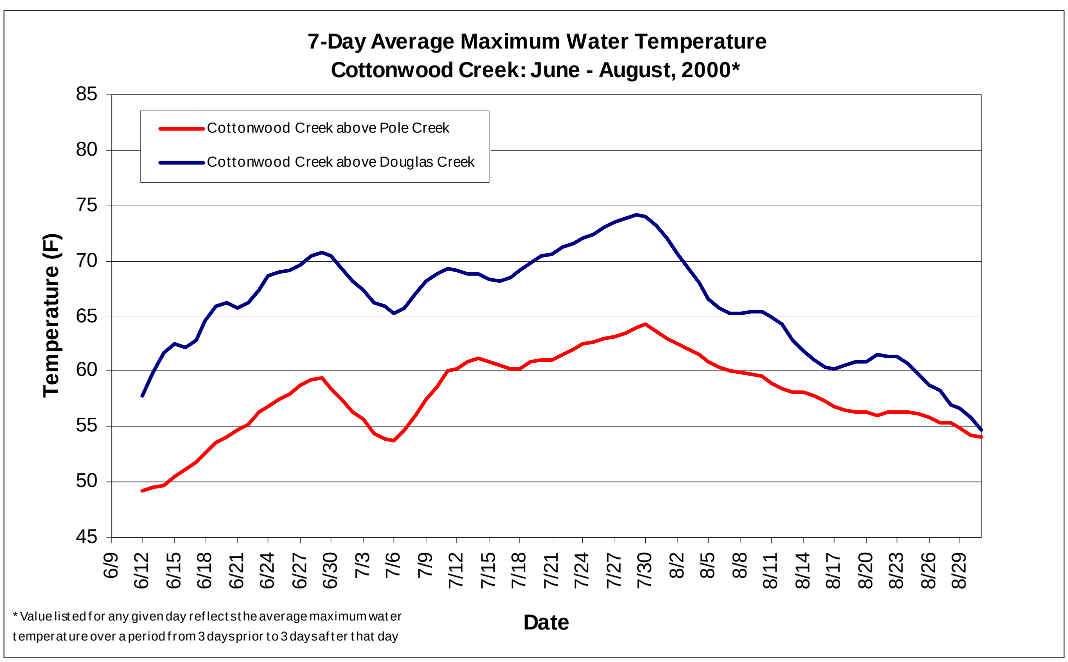


Figure 3-29. 7-day average maximum daily temperatures, Cottonwood Creek, 2000.

Cottonwood Creek above Pole Creek has cool water throughout the summer. However, Cottonwood Creek temperatures increase significantly by the time Cottonwood Creek reaches Ovando-Helmville Road, suggesting large thermal gains in the reach between these two sites. Air photos and water rights data show that below the South Fork of Cottonwood Creek, irrigation diversions reduce flow in Cottonwood Creek. About halfway between the South Fork Cottonwood Creek and Ovando-Helmville Road, riparian vegetation is sparse. Much of the thermal gain realized on hot summer days in Cottonwood Creek is attributable to these factors.

3.2.4. Douglas Creek

The Montana FWP temperature database contains temperature data collected at four sites on Douglas Creek, but not for all four sites in any year. The two upstream sites have data from 1998, while for the two sites downstream have data from 2000. However, similarities in climate (Figure 2-1 and Figure 2-2) between these two years allowed comparison of temperature data between all four sites. The 2000 data also allows inclusion of Douglas Creek in the temperature model for lower Nevada Creek.

Figure 3-30 through Figure 3-33 (upstream to downstream) display continuous water temperature readings collected at the four monitoring sites during the summers of 1998 and 2000. The lower temperatures in Douglas Creek above the reservoirs is due to much of this water sourcing from springs in Madison limestone in the Douglas Creek headwaters. The wide range in daily temperatures at the sites below the reservoirs indicates large thermal gain from both the reservoirs and stream segments separating the reservoirs.

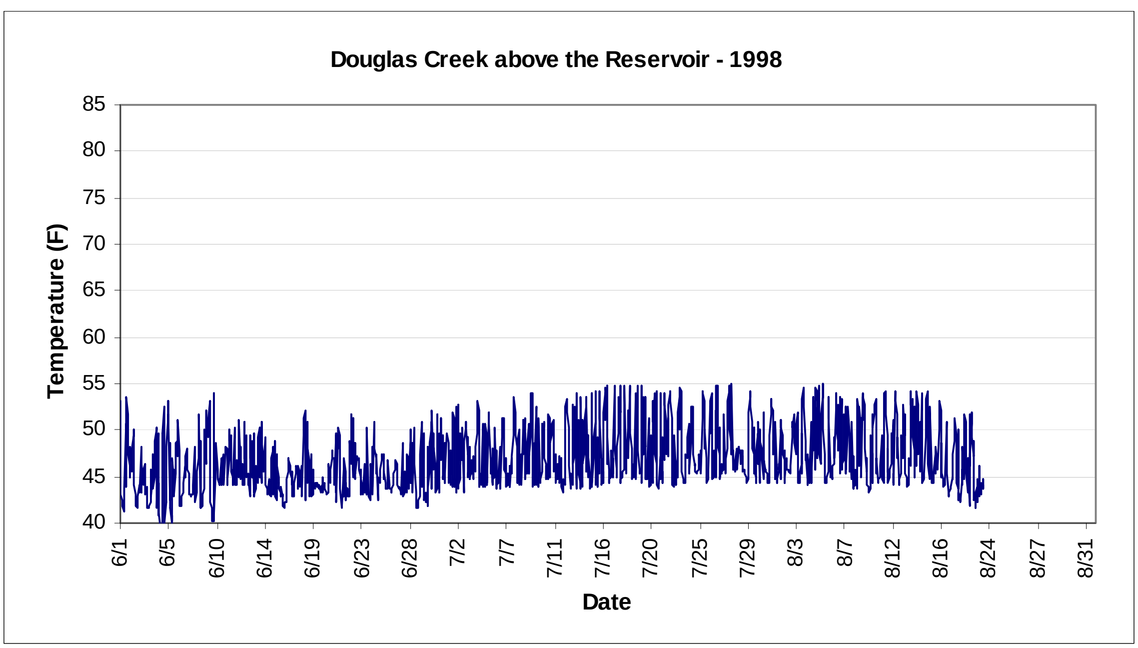


Figure 3-30: Continuous water temperature, Douglas Creek above the reservoirs, 1998.

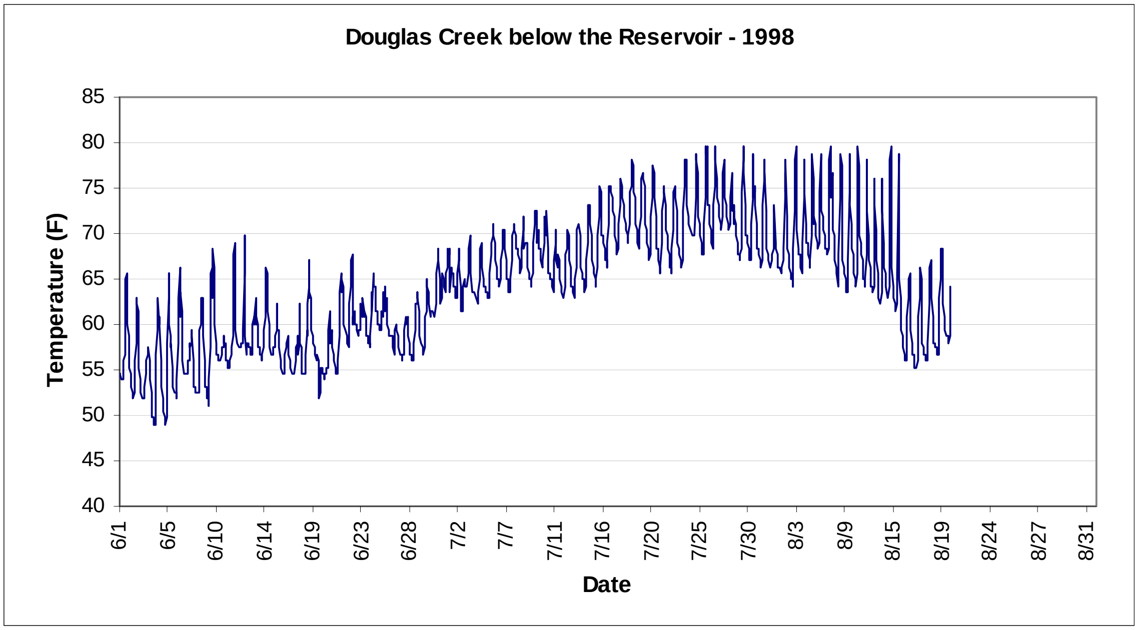


Figure 3-31: Continuous water temperature, Douglas Creek below the reservoirs, 1998.

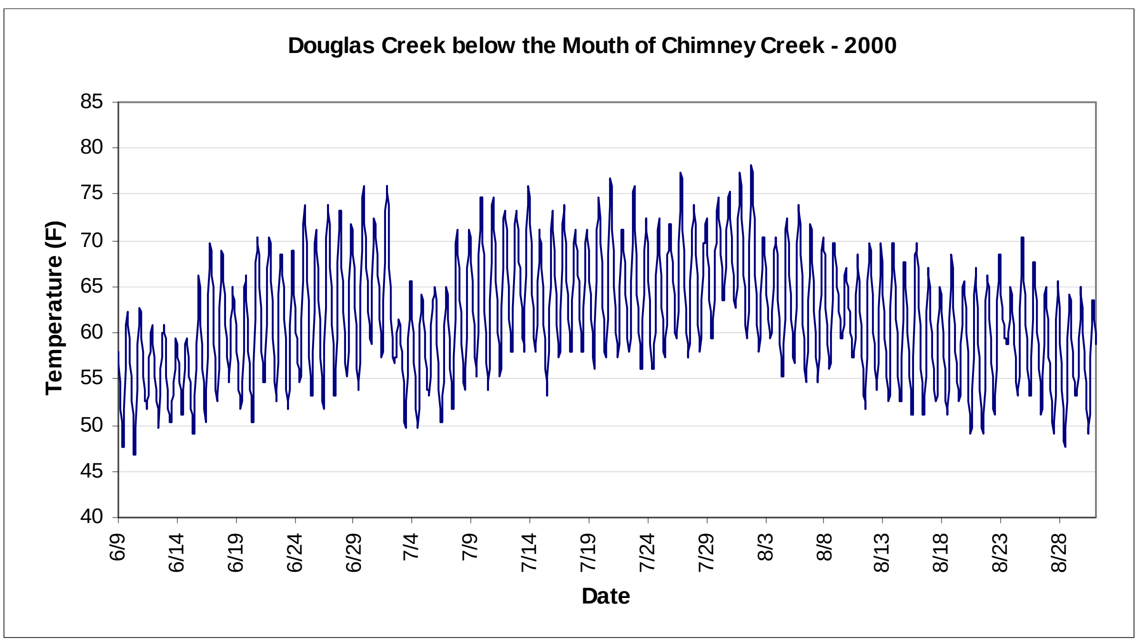


Figure 3-32: Continuous water temperature, Douglas Creek below Chimney Creek, 2000.

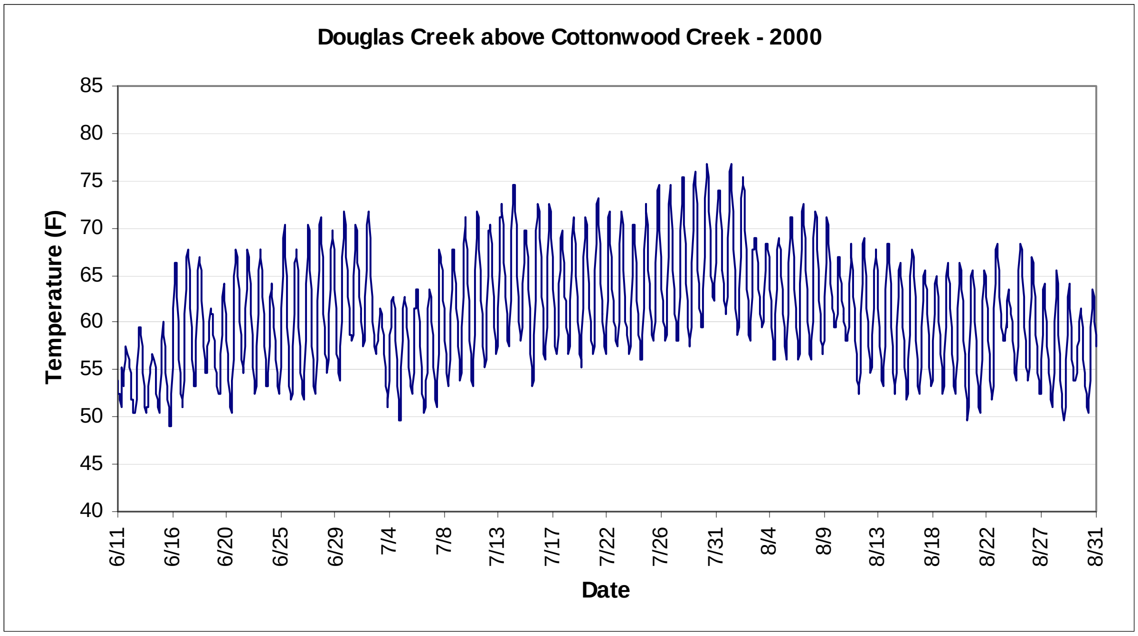


Figure 3-33: Continuous water temperature, Douglas Creek above Cottonwood Creek (Ovando-Helmville Road), 2000.

Figure 3-34 shows the statistical distribution of summer temperatures at the four monitoring sites. This figure illustrates the low temperatures at the site above the reservoir and high range in temperatures at the sites below the reservoir. Temperatures also decrease slightly downstream from the reservoir to the site above Cottonwood Creek due to cool water inflow from Chimney Creek.

The daily maximum and seven-day average maximum temperature graphs show that the highest maximum temperatures occur at the site below the reservoir. Similar to other areas, the highest temperatures at all sites occur in late July before dropping off steadily through August (Figure 3-35 and Figure 3-36). The increase in maximum temperatures of 20 to 25 ^{o} F between the sites above and below the reservoirs represents a substantial increase in temperature over a very short distance. As is the case for other streams, precipitation and air temperature strongly influence water temperature as illustrated in the daily maximum temperature graph (Figure 3-35).

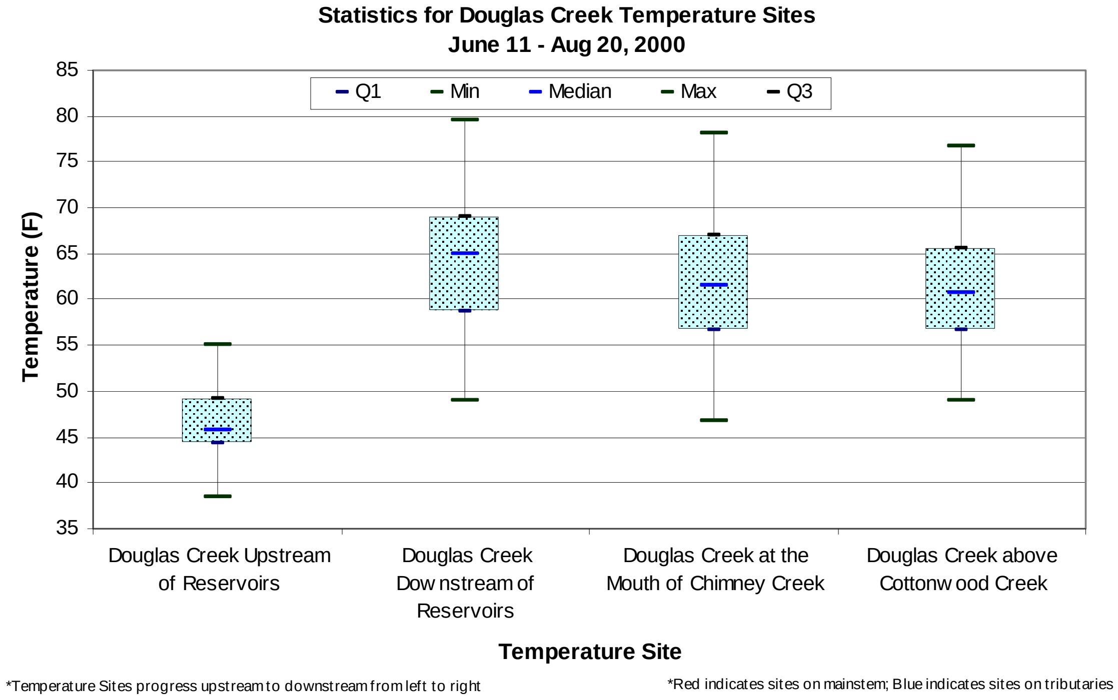


Figure 3-34. Upstream to downstream temperature variation, Douglas Creek, 2000.

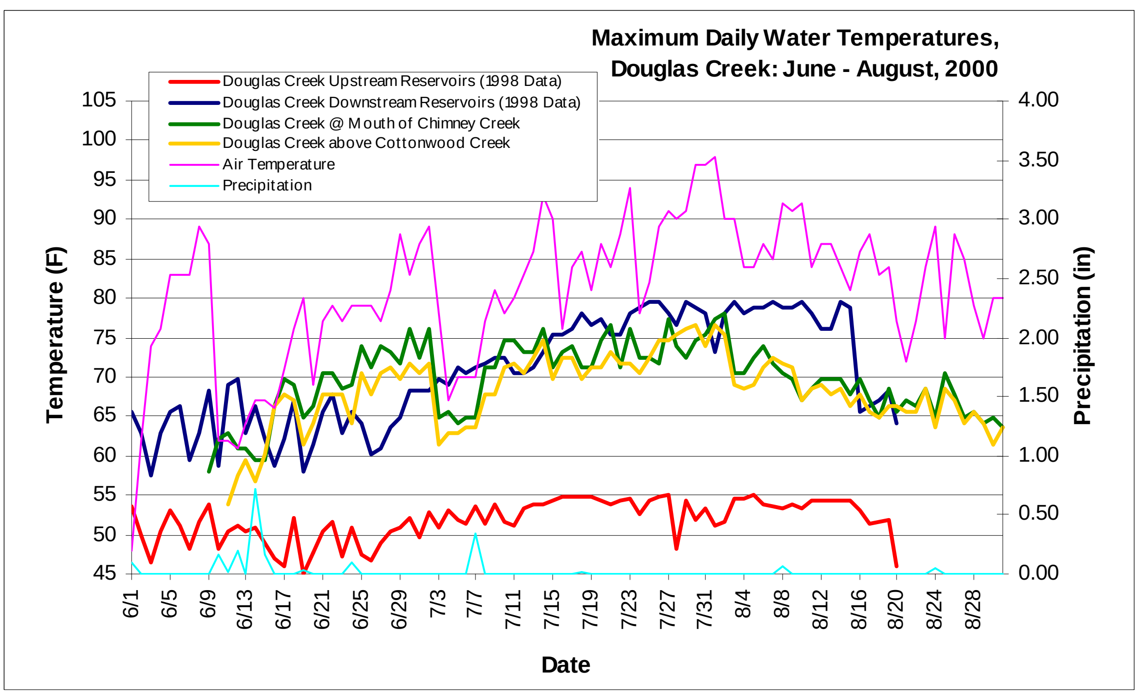


Figure 3-35. Maximum daily water temperature, air temperature, and precipitation, Douglas Creek, 2000.

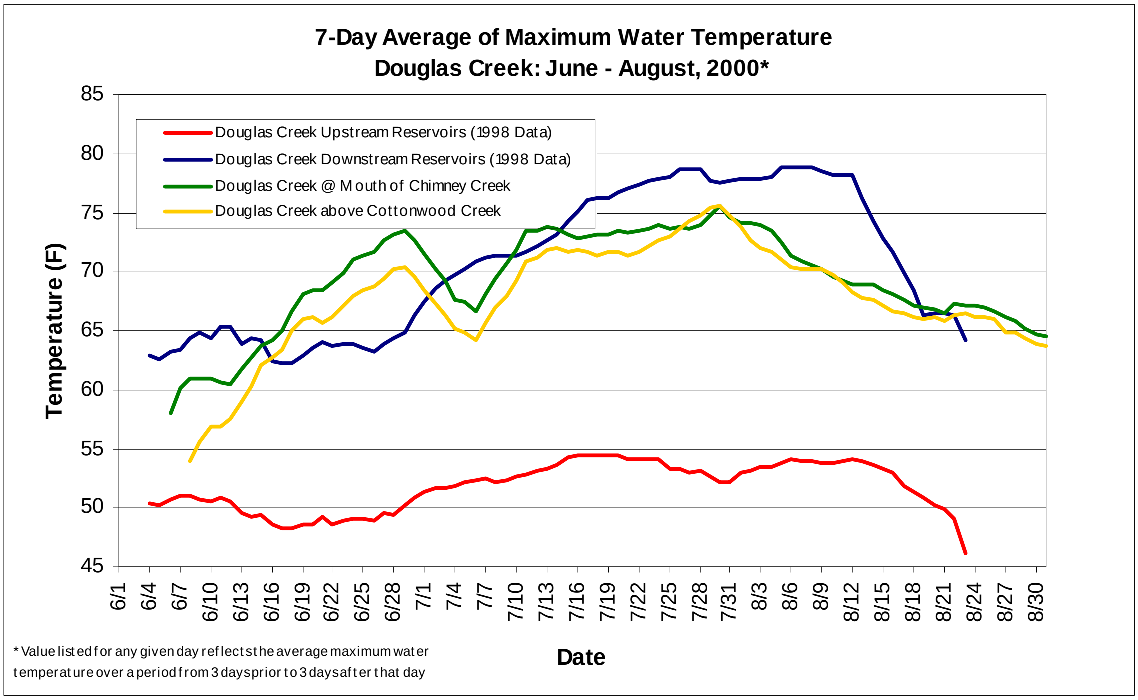


Figure 3-36. 7-day average maximum daily temperatures, Douglas Creek, 2000.

Douglas Creek above the reservoirs has cold headwaters emanating from springs in Madison limestone. The mean summer temperature of 46 ° F is the coldest water measured in the Nevada Creek watershed. Measured Douglas Creek temperatures increase by as much as 25 ° F below the reservoirs, indicating that the reservoirs heat the water significantly. Field observations from the base parameter assessment (DTM and AGI, 2005) suggest that the reservoirs are relatively shallow, resulting in rapid solar heating of reservoir water. Downstream, water temperatures at the monitoring site below Chimney Creek are slightly lower than below the reservoir, indicative of cooler water contributed by Chimney Creek. Temperatures then slightly decrease downstream to the site above Cottonwood Creek at Ovando-Helmville Road. In this reach Douglas Creek and the Douglas Creek Canal are coincident for ¼ mile. In this section, Douglas Creek mixes with cooler canal water, resulting in the observed temperature reduction and dampening of diurnal variation. No temperature data is available below Ovando-Helmville Road. However, a diversion that removes a large proportion of Douglas Creek's flow and the contribution of warm water from Cottonwood Creek suggests that temperatures likely increase in the reach downstream from Ovando-Helmville road to the confluence with Nevada Creek.

3.3. Temperature Modeling

The following sections describe temperature modeling for each of the 303(d) listed streams in the Nevada Creek Planning Area. SNTEMP simulated temperatures for upper and lower Nevada Creek, Douglas Creek, and Cottonwood Creek, while temperatures for the reservoirs section of upper Douglas Creek were simulated with SSTEMP.

3.3.1. Upper Nevada Creek Model

The upper Nevada Creek model simulated temperatures for Nevada Creek above Nevada Reservoir and included sections of two streams, Nevada creek and Washington Creek (Figure 3-37). Nevada Creek extends for 11.7 miles from a point above Shingle Mill Creek downstream to above Nevada Reservoir. Washington Creek is a 2.2-mile long segment extending from Highway 141 to its confluence with Nevada Creek. Modeling of Washington Creek allowed simulation of temperatures in Washington Creek and resulting effects on Nevada Creek.

Construction

Nodes in the model identify where hydrology, stream geometry, and temperature data are input in the stream network. Mitchell Creek, Halfway Creek, and Jefferson Creek are included in the model as point sources to Nevada Creek (Figure 3-37). An additional point source below Jefferson Creek accounted for groundwater flow from the Jefferson Creek drainage. Two calibration points are located in the stream network, below Halfway creek and above the reservoir. No diversion of flow occurred during the modeling period since water rights allow diversion only until late June.

Modeling of upper Nevada Creek is for the period August 5 – 7, 2001. A three-day modeling period ensured that water completed travel from the top to the bottom of the network. Table 3-3 lists stream geometry and general vegetation characteristics for the upper Nevada Creek model. About 25 percent of Nevada Creek has woody streambank vegetation, while Washington Creek is largely absent of woody vegetation.

Stream	***Modeling Period***	***Length (mi)***	***Average Low Flow Width (ft)***	***Streambank Vegetation (%) ****	***Current Shade (%)***
Nevada Creek	Aug 5-7, 2001	11.7	12.5	24.1	13.1
Washington Creek	Aug 5-7, 2001	2.2	5.5	2.6	2.8

*Streambank vegetation is percent of total stream bank in model that consists of vegetation that produces shade. Shade is percent of total stream surface area covered by shade.

Table 3-3. Current stream characteristics for the upper Nevada Creek SNTEMP model.

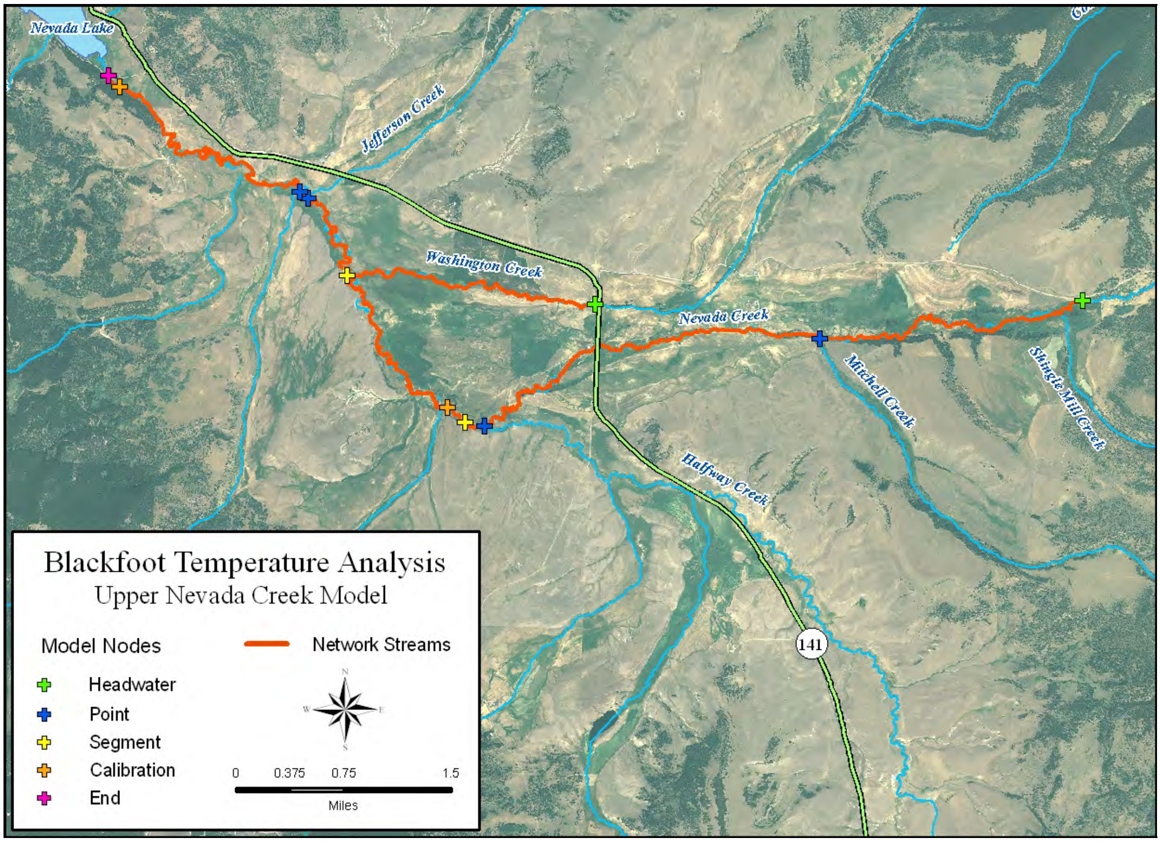


Figure 3-37. Schematic of the Upper Nevada Creek model network and model nodes.

For the modeling period, stream geometry and hydrology data was input into the model for all segments and nodes in the upper Nevada Creek network (Table 3-4). For each segment, flow, width, Manning's-n, and shade are defined. The table illustrates that the segment of Nevada Creek from Shingle Mill Creek to Halfway Creek accounts for most of the streambank vegetation and shade in the model. Woody vegetation is largely absent in Nevada Creek from Halfway Creek to the reservoir, and in Washington Creek. The Manning's n value, (a measure of water friction flowing over a streambed) of 0.062 is representative of the streams substrate, planform, and vegetation. Halfway Creek, with a mean water temperature of 65.9 ^{o} F, has the highest temperature water input in the model. The groundwater temperature of 55 ^{o} F to Nevada Creek below Jefferson Creek reflects historical summertime well and spring temperature measurements from the Nevada Creek watershed. Along with Mitchell Creek at 55.1 ^{o} F, these waters are the lowest temperature contributions to the model.

Table 3-4. Input data for the upper Nevada Creek model.

Stream	*Segment*	*Node*	*Stream Mile*	*Water Temperature Mean (F)*	*Flow (cfs)*	*Stream Width (ft)*	*Manning's n*	*Streambank Veg (%)*	*Shade (%)*	*Comments*
Nevada Creek	**Shingle Mill to Halfway Ck**	Headwater*	46.2	54.5	8.1	13.1	0.062	48.0	25.7	Above Shingle Mill Creek
Nevada Creek	**Shingle Mill to Halfway Ck**	Point	43.8	55.1	1.5	13.1	0.062	48.0	25.7	Mitchell Creek
Nevada Creek	**Shingle Mill to Halfway Ck**	Point	40.6	65.9	1.8	13.1	0.062	48.0	25.7	Halfway Creek
Nevada Creek	**Halfway Ck to Washington Ck**	Segment	40.5		11.4	13.4	0.062	0.0	0.0	Below Halfway Creek
Nevada Creek	**Halfway Ck to Washington Ck**	Calibration	40.2	62.6	11.4	13.4	0.062	0.0	0.0	Temperature site below Halfway Ck
Nevada Creek	**Washington Ck to the Reservoir**	Segment	38.4		15.4	11.3	0.062	3.0	2.1	Confluence with Washington Ck
Nevada Creek	**Washington Ck to the Reservoir**	Point	37.3	60.5	2.3	11.3	0.062	3.0	2.1	Jefferson Ck
Nevada Creek	**Washington Ck to the Reservoir**	Point	37.2	55.0	1.0	11.3	0.062	3.0	2.1	Point source return flow
Nevada Creek	**Washington Ck to the Reservoir**	Calibration	34.6	63.8	18.7	11.3	0.062	3.0	2.1	Temperature site above reservoir
Nevada Creek	**Washington Ck to the Reservoir**	End	34.5		18.7	11.3	0.062	3.0	2.1	Above Nevada Reservoir
Washington Creek	**HWY 200 to Nevada Ck**	Headwater*	40.6	59.0	4.0	5.5	0.062	2.6	2.8	At Highway 141
Washington Creek	**HWY 200 to Nevada Ck**	End	38.4		4.0	5.5	0.062	2.6	2.8	Confluence with Nevada Creek

*Headwater is the starting point of each stream in the model network. Water temperature and flow for point nodes represent temperature of water and amount of water contributed to Nevada Creek from point source. Flow for all other nodes represents flow in the stream.

Meteorological data for the modeling period August 5 - 7, 2001 were summarized and input into the model (Table 3-5). These data are representative of the hot and dry conditions that cause water temperature extremes. The average daily maximum air temperature for this period of 88.3^{o} F represents one of the hotter periods of the summer of 2001.

Modeling Period	*Air Temperature (F)*		*Relative Humidity (%)*	*Wind (mph)*	*Possible Sun (%)*	*Dust Coefficient*	*Ground Reflectivity*
	Daily Mean	*Daily Maximum**					
Aug 5 - 7, 2001	68.0	88.3	57.1	2.4	95	0.05309	0.27086

* Daily maximum temperature is not an input into model but is included for comparison purposes.

Table 3-5. Meteorological input data for the upper Nevada Creek SNTEMP model.

Calibration

Model runs for Nevada Creek required little calibration. The first model run for Nevada Creek simulated temperatures that were too high. Simulated mean daily temperatures were 1.93^{o} and 3.28^{o} F greater than observed mean temperatures at the locations below Halfway Creek and above the reservoir, respectively (Table 3-6 through Table 3-7).

Meteorological data was least reliable in terms of characterizing conditions found on the stream, as the weather stations that provided data are located off the stream. To calibrate the model, wind speed was increased to 6.72 mph. The resulting simulated mean temperatures were still too high. Adjusting relative humidity to 40% lowered temperatures further. This yielded simulated mean daily temperatures lower than observed temperatures by 0.39^{o} F below Halfway Creek and higher by 0.33^{o} F above the reservoir. These values were well within the margin of 0.9^{o} F for calibration.

Calibration Iteration	*Temperature (F)*		*Difference from Observed Temp (F)*		*Parameter Changed / Rational*
	Mean	*Max*	*Mean*	*Max*	
Observed Temperature	62.58	72.23	NA	NA	NA
Initial Model Run	64.51	76.05	1.93	3.82	Default Parameter Values
1	64.00	73.94	1.42	1.71	Wind Speed - increased to 6.72 mph
2	62.19	72.34	-0.39	0.11	Wind Speed - increased to 6.72 mph Relative Humidity - decreased to 40%

Table 3-6: Initial model and calibration results for upper Nevada Creek below Halfway Creek.

Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed / Rational***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	63.82	71.31	NA	NA	NA
Initial Model Run	67.10	75.00	3.28	3.69	Default Parameter Values
1	66.11	73.15	2.29	1.84	Wind Speed - increased to 6.72 mph
2	64.15	71.35	0.33	0.04	Wind Speed - increased to 6.72 mph Relative Humidity - decreased to 40%

Table 3-7: Initial model and calibration results for upper Nevada Creek above the reservoir.

Simulations

After calibration, model simulations evaluated the effect different levels of riparian shade had on stream temperatures. Increased flow and channel width were not relevant for the simulations for upper Nevada Creek. Riparian shade is presented as percent of streambank with woody vegetation.

Five SNTEMP simulations assessed the effect of riparian shade on stream temperatures. One simulation was the calibrated model with current streambank vegetation conditions (19%). A second simulation modeled natural conditions. Montana DEQ defined natural conditions as 95% of streambanks with woody vegetation for this project. Two additional simulations modeled streambank vegetation at levels between current and natural conditions. A final simulation assessed the amount of vegetation required to keep temperatures within one degree Fahrenheit of the natural condition scenario. The one-degree allowable increase is the temperature target established by Montana DEQ (ARM, 2006).

For natural conditions, the model simulated a mean daily temperature of 60.66^{o} F (Table 3-8 and Figure 3-38). This value is lower than temperature simulated with current stream conditions by 3.49^{o} F. A simulation that increases streambank vegetation to 20% reduced mean temperature by 0.14^{o} F, while simulating streambank vegetation increased to 60% reduced mean temperature by 1.94^{o} F. A linear relationship between the results for these three simulations established a target value for streambank vegetation of 73%. Using this target value, the model simulated a mean daily temperature of 61.61^{o} F. This is 2.54^{o} F less than the mean daily temperature with current conditions, and 0.95^{o} F greater than the temperature for natural conditions. This falls within the one-degree allowable increase from with natural conditions.

These results indicate that meeting temperature targets in Nevada Creek above the reservoir requires increasing woody vegetation to 73% along Nevada Creek and Washington Creek modeled streambanks.

Model Run	***Temperature (F)***		***Difference from Calibration (F)***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	63.82	71.31	NA	NA	NA
Calibrated Temperature	64.15	71.35	NA	NA	Simulated temperature above the reservoir with current stream conditions
Simulation 1	64.00	70.59	-0.14	-0.76	20% of bank with woody vegetation cover
Simulation 2	62.24	67.60	-1.91	-3.75	60% of bank with woody vegetation cover
Target Conditions	61.61	66.74	-2.54	-4.61	73% of bank with woody vegetation cover
Natural Conditions	60.66	64.98	-3.49	-6.37	95% of bank with woody vegetation cover

Table 3-8. Simulation results for upper Nevada Creek above the reservoir.

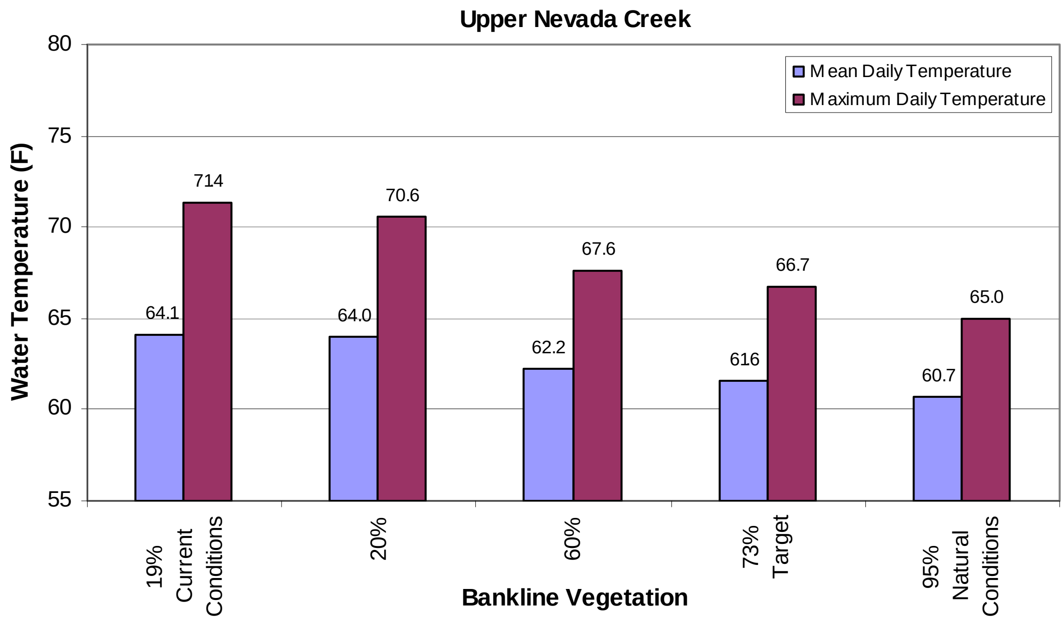


Figure 3-38. Simulated mean and maximum temperature with change in bankline vegetation for Upper Nevada Creek.

3.3.2. Lower Nevada Creek Model

The lower Nevada Creek model simulated temperatures for three connected 303(d) list streams; Cottonwood Creek, Douglas Creek, and lower Nevada Creek (Figure 3-39). Nevada Creek extends for 31.5 miles from below Nevada Reservoir downstream to its confluence with the Blackfoot River. Cottonwood Creek is an 11.1-mile long segment extending from above Pole Creek to its confluence with Douglas Creek. Douglas Creek is a 16 miles long from below the reservoirs to its confluence with Nevada Creek.

Construction

Nodes in the model identify where hydrology, stream geometry, and temperature data are input in the stream network. Point sources from tributary streams in the model include Nevada Spring Creek, Sturgeon Creek, Chimney Creek, and Murray Creek. An additional point source into Douglas Creek below Chimney Creek and subsequent removal downstream accounted for mixing of Douglas Creek canal water with Douglas Creek water. Calibration points for Nevada Creek are above Nevada Spring Creek and at the mouth. Cottonwood Creek and Douglas Creek had calibration points at the Ovando-Helmville Road. An additional calibration point for Douglas Creek is located below Chimney Creek. All streams had water diversion points. For Nevada Creek, four diversion points were located along a nine mile stretch downstream of Braziel Creek. These include the Douglas Creek and North Helmville canals. Cottonwood Creek had two diversion points, below the North Fork Cottonwood Creek and downstream below the Ovando-Helmville Road, while Douglas Creek also had water diverted below the Ovando-Helmville Road.

Modeling of lower Nevada Creek is for the period July 27 – August 2, 2000. A seven-day modeling period ensured that water completed travel from the top to the bottom of the network. Table 3-9 lists stream geometry and general vegetation characteristics for the lower Nevada Creek model. About 44 percent of the Nevada and Cottonwood creek streambanks have woody vegetation, while Douglas Creek has woody vegetation on about 30 percent of its streambanks. Cottonwood Creek is the narrowest stream with an average low flow width of only 5.2 feet.

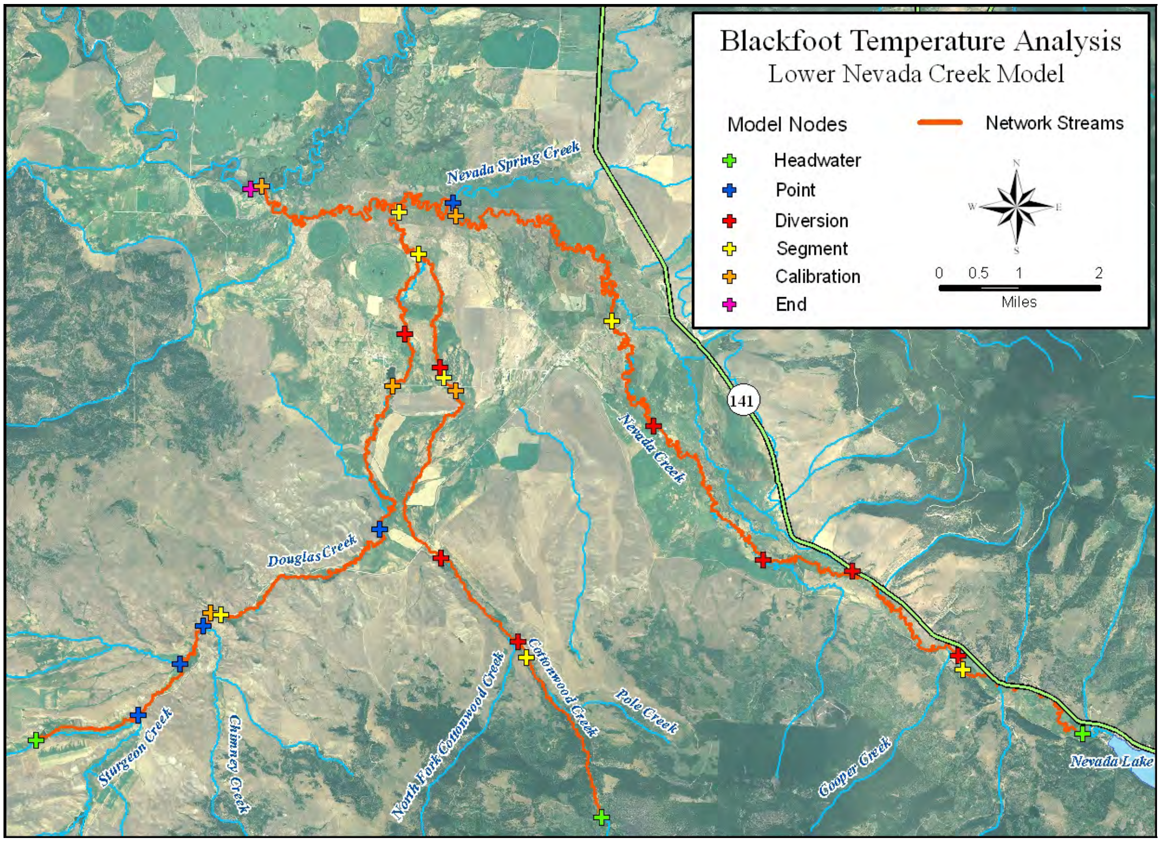


Figure 3-39. Schematic of the Lower Nevada Creek model network and model nodes.

Stream	*Modeling Period*	*Length (mi)*	*Average Low Flow Width (ft)*	*Streambank Vegetation (%)*	*Average Shade (%)*
Cottonwood Creek	July 27 - Aug 2, 2000	11.1	5.2	43.8	30.0
Douglas Creek	July 27 - Aug 2, 2001	16.0	9.1	29.9	18.8
Nevada Creek	July 27 - Aug 2, 2001	31.5	20.1	44.0	12.2

*Streambank vegetation is percent of total stream bank in model that consists of vegetation capable of producing shade. Shade is percent of total stream surface area covered by shade.

Table 3-9. Stream conditions for the lower Nevada Creek SNTEMP model.

Table 3-10 lists data input into the model. For each segment and headwater node, flow, width, Manning's-n, and shade must be designated, while water temperature is required for headwater nodes. All other nodes require only water temperature and/or flow data.

Table 3-10. Input data for the lower Nevada Creek model.

Stream	Segment	Node	Stream Mile	Water Temperature (F)	Flow (cfs)	Stream Width (ft)	Manning's n	Streambank Veg (%)	Shade (%)	Comments
Nevada Creek	Reservoir to above Cooper Ck	Headwater*	31.5	63.3	89.0	26.0	0.062	0.0	0.8	Below the reservoir
	Cooper Ck to Above Nevada Spring Creek	Segment	28.8		89.0	18.9	0.062	57.5	24.5	Above Cooper Creek
		Diversion	28.6		30.0					
		Diversion	25.5		30.0					
		Diversion	23.4		10.0					
		Diversion	19.2		10.0					
	Above Nevada Spring Creek to Douglas Ck	Segment	15.3		9.0	11.3	0.062	42.0	2.1	Above Lincoln Slough
		Calibration	7.3	70.4	9.0					Site above Nev Spg Ck
		Point	7.2	55.7	9.0					Nevada Spring Creek
	Douglas Ck to the Mouth	Segment	4.8		22.0	39.2	0. 062	35.0	6.0	Confluence with Douglas Ck
		Calibration	0.1	71.9	22.0					Site at the mouth of Nevada Ck
		End	0.0		22.0					Confluence with Blackfoot River

Stream	***Segment***	***Node***	***Stream Mile***	***Water Temperature (F)***	***Flow (cfs)***	***Stream Width (ft)***	***Manning's n***	***Bankline Veg (%)***	***Shade (%)***	***Comments***
Douglas Creek	**Below the Reservoir to Chimney Ck**	Headwater*	20.8	70.6	1.0	5.9	0.062	7.1	5.2	Above Shingle Mill Creek
		Point	18.9	66.0	2.0					Sturgeon Creek
		Point	17.7	70.0	1.0					Murray Creek
		Point	16.8	65.0	2.0					Chimney Creek
		Calibration	16.7	67.4	6.0					Site below Chimney Creek
	Chimney Ck to Cottonwood Ck	Segment	16.6		6.0	10.0	0.062	38.9	24.3	Below Halfway Creek
		Point	12.5	64.0	2.0					Canal return
		Calibration	9.2	66.9	8.0					Site at Ovando-Helmville Rd
		Diversion	8.0		5.0					Below Ovando-Helmville Rd
	Cottonwood Ck to Mouth at Nevada Ck	Segment	6.3		3.0	12.0	0.062	32.0	18.7	Confluence with Cottonwood Ck
		End	4.8		2.3					Confluence with Nevada Ck
Cottonwood Creek	**Above Pole Ck to the South Fork**	Headwater*	17.4	56.7	4.0	6.0	0. 062	80.0	56.2	Above Pole Creek
	South Fork to Ovando-Helmville Road	Segment	14.7		4.0	5.0	0.062	32.8	21.5	South Fork Cottonwood Ck
		Diversion	14.4		1.0					Below South Fork
		Diversion	12.6		1.0					
		Calibration	9.3	67.5	2.0					Site at Ovando-Helmville Rd
	Ovando-Helmville Road to Douglas Ck	Segment	9.1		2.0	5.0	0.062	31.0	21.6	Below Ovando-Helmville Rd
		Diversion	8.8		1.0					
		End	6.3		1.0					Confluence with Douglas Ck

*Headwater is the starting point of each stream in the model network

Meteorological data for the modeling period July 27 – August 2, 2000 were summarized and input into the model (Table 3-11). These data are representative of hot and dry conditions that cause water temperature extremes. The average daily maximum temperature, 90.7° F, represents a hot period in the summer of 2000.

Modeling Period	***Air Temperature (F) (mean)***	***Relative Humidity (%) (mean)***	***Wind (mph) (mean)***	***Possible Sun (%)***	***Dust Coefficient***	***Ground Reflectivity***
July 27 - Aug 2, 2000	69	43.2	3.6	94	0.05103	0.27690

Table 3-11. Meteorological input data for the lower Nevada Creek SNTEMP model.

Calibration

Calibration for the lower Nevada Creek model required adjusting parameters sequentially for three streams, Cottonwood Creek, Douglas Creek, and Nevada Creek. Since Cottonwood Creek terminates at and contributes its water to Douglas Creek, temperature at the outlet of Cottonwood Creek influences Douglas Creek. Therefore, calibration on Cottonwood Creek commenced first. Calibration for Douglas Creek occurred next as this stream contributes water to Nevada Creek. Nevada Creek simulated temperatures were the last calibrated.

Cottonwood Creek

Model runs for Cottonwood Creek required little calibration. The first model run simulated a mean and maximum daily temperature of 67.10° and 77.74° F, respectively (Table 3-12). The mean temperature was 0.38° F lower than observed mean temperature at this site, within the requirements for calibration. However, the maximum temperature was 3.7° F warmer than the observed maximum temperature.

To improve the model's performance for maximum temperature, Manning's n was increased from 0.062 to 0.080. Manning's n was adjusted because changes in this parameter only effects maximum temperatures in the model. The SNTEMP model uses the Manning's n parameter to capture the appropriate mixing depth and travel time of the stream. The result of changing Manning's n to 0.080 "speeds up" the stream and lowers simulated maximum temperature by 0.54° F, 3.16° F above the observed maximum temperature. However, higher values for Manning's n are unrealistic. In addition, there is uncertainty in the capability of SNTEMP to predict daily maximum temperatures accurately (Bartholow, 2004).

Location: Cottonwood Creek at Ovando-Helmville Road					
Calibration Iteration	Temperature (F)		Difference from Observed Temp (F)		Parameter Changed
	Mean	Max	Mean	Max	
Observed Temperature	67.48	74.04	NA	NA	NA
Initial Model Run	67.10	77.74	-0.38	3.70	Default Parameter Values
1	67.10	77.20	-0.38	3.16	Manning's n - Increase to 0.080

Table 3-12. Initial model and calibration results for Cottonwood Creek at Ovando-Helmville Road.

Douglas Creek

The Douglas Creek model required little calibration. The initial model run for Douglas Creek simulated mean daily temperatures 0.83^o F and 1.63^o F greater than observed temperatures at the locations below Chimney Creek and below Ovando-Helmville Road, respectively (Table 3-13 through Table 3-14). The difference between simulated and observed mean temperature at the site below Chimney Creek was within the margin for calibration of 0.9^o F and no further calibration was required for the upstream portion of the model. However, additional calibration was necessary for the site below Ovando-Helmville Road.

Since the lower Nevada Creek SNTEMP model includes Douglas Creek and Cottonwood Creek, adjustment of meteorological parameters would also affect results of these streams. The excellent calibration results for Cottonwood Creek would be degraded by adjusting meteorology input. Calibrating temperatures at the node at Ovando-Helmville Road without affecting Cottonwood Creek and Nevada Creek therefore required adjustment of a segment specific parameter.

Field observations suggest that some of the flow in Douglas Creek upstream from the Ovando-Helmville Road is subsurface and interacts with groundwater. A suppressed diurnal temperature variation in the FWP data supports this observation (Figure 3-34). Thermal gradient is a segment specific parameter that is a measure of thermal exchange between the streambed and water in joules/meter^{2}second/^{o}C (Bartholow, 2004). Streams that interact with groundwater typically have a higher thermal gradient and a suppressed diurnal temperature variation. Based on this information, thermal gradient was increased for calibration and yielded satisfactory results (Table 3-13 and Table 3-14).

Location: Douglas Creek below Chimney Creek					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	67.37	75.6	NA	NA	NA
Initial Model Run	68.20	77.22	0.83	1.62	Default Parameter Values Thermal gradient = 1.65 joules/meter^{2}second/^{o}C
1	67.87	76.64	0.50	1.04	Thermal Gradient - Increase to 2.65
2	67.77	76.44	0.40	0.84	Thermal Gradient - Increase to 3.00

Table 3-13. Initial model and calibration results for Douglas Creek below Chimney Creek.

Location: Douglas Creek at Ovando-Helmville Road					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	66.91	75.50	NA	NA	NA
Initial Model Run	68.54	75.90	1.63	0.40	Default Parameter Values
1	67.80	75.04	0.89	-0.46	Thermal Gradient - Increase to 2.65
2	67.55	74.75	0.64	-0.75	Thermal Gradient - Increase to 3.00

Table 3-14. Initial model and calibration results for Douglas Creek at Ovando-Helmville Road.

Lower Nevada Creek

The lower Nevada Creek model required little calibration (Table 3-15 and Table 3-16). The initial model run simulated mean daily temperatures of 70.92^o and 71.74^o F above Nevada Spring Creek and at the mouth, respectively. When compared to observed mean temperatures at these locations, both of these temperatures were within the 0.9^o F requirement for calibration. However, simulated maximum temperatures were 5.5 and 1.43^o F higher than observed temperatures at the two sites. The high, simulated maximum temperatures are explained by proximity to Nevada Reservoir. Water released from the reservoir has minimal diurnal variation in temperature since it is a bottom release dam. The lack of diurnal temperature fluctuation propagates downstream, resulting in over prediction of diurnal variation and maximum temperatures.

Similar to Cottonwood Creek, Manning's n was increased from 0.062 to 0.080 to calibrate for maximum temperature on Nevada Creek. This lowered the simulated maximum temperature to 77.74^o F above Nevada Spring Creek, and to 77.18^o F at the mouth. The simulated temperature above Nevada Spring Creek was still high, while the simulated maximum temperature at the mouth was 0.78^o higher than the observed temperature, within the required range for calibration. Since higher values for Manning's n are unrealistic and the suppressed diurnal variation of reservoir water causes SNTEMP to over-predict temperatures, no addition calibration was necessary.

Location: Nevada Creek Above Nevada Spring Creek					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed / Rational***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	70.36	72.85	BNA	NA	NA
Initial Model Run	70.92	78.35	0.56	5.50	Default Parameter Values
1	70.92	77.74	0.56	4.89	Manning's n - Increase to 0.080

Table 3-15. Initial model and calibration results for lower Nevada Creek above Nevada Spring Creek.

Location: Nevada Creek Above the Confluence with the Blackfoot River					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed / Rational***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	71.91	76.40	NA	NA	NA
Initial Model Run	71.74	77.83	-0.17	1.43	Default Parameter Values
1	71.74	77.18	-0.17	0.78	Manning's n - Increase to 0.080

Table 3-16. Initial model and calibration results for lower Nevada Creek at the mouth.

Simulations

Simulations for Cottonwood Creek, Douglas Creek, and Nevada Creek evaluated the effect different levels of shade have on stream temperatures. Shade is expressed as percent of streambank with woody vegetation.

Five SNTEMP simulations modeled the effect of shade on stream temperatures. One simulation was the calibrated model for current conditions. A second simulation modeled natural conditions, defined by Montana DEQ as 95% of streambank having woody vegetation. Two additional simulations assessed streambank vegetation at levels between current and natural condition. A final simulation determined the one-degree allowable increase from natural conditions as the TMDL target vegetation value.

Since Cottonwood Creek flows into Douglas Creek and Douglas Creek flows into Nevada Creek, the target streambank vegetation simulations proceeded from upstream to downstream. For example, initial simulations defined the vegetation target for Cottonwood Creek at 87% streambank woody vegetation. The water temperature resulting from this simulation served as input to develop the Douglas Creek vegetation target. Douglas Creek water temperature at target vegetation levels then served as input for Nevada Creek.

Initially, simulations for Nevada Creek included channel narrowing in the lower reaches of Nevada Creek and flow augmentation of 15 percent by either reduced irrigation withdrawal or increased reservoir releases. However, results indicated minimal improvements in mean daily water temperature from these scenarios. Requiring a larger amount of flow augmentation could place large burdens on landowners and would be difficult politically. Therefore, all simulations focus on increased shade from increased streambank vegetation. Preliminary simulation results including flow and channel width are in Appendix C.

Cottonwood Creek

Results illustrate that for natural conditions (95% streambank woody vegetation); the model simulated a mean temperature of 62.67^{o} F at the mouth of Cottonwood Creek

(Table 3-17 and Figure 3-40). This value is lower than temperatures simulated with current stream conditions (33% streambank woody vegetation) by 6.88° F. A reduction in streambank vegetation to 20% increases water temperatures. A simulation that increases streambank vegetation to 60% reduces mean temperature by 4.43° F. Simulating 87% of streambank with woody vegetation is within the one-degree allowable increase from natural conditions and is the target condition.

Model Run	***Temperature (F)***		***Difference from Calibration (F)***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Calibrated Model	69.55	79.05	NA	NA	Simulated temperature at output of creek with current stream conditions (33% streambank vegetation)
Simulation 1	70.97	81.03	1.42	1.98	20% of bank with vegetation cover
Simulation 2	66.70	74.62	-2.84	-4.43	60% of bank with vegetation cover
Target Conditions	63.59	69.85	-5.96	-9.20	87% of bank with vegetation cover
Natural Conditions	62.67	68.40	-6.88	-10.66	95% of bank with vegetation cover

Table 3-17. Simulation results for Cottonwood Creek at the confluence with Douglas Creek.

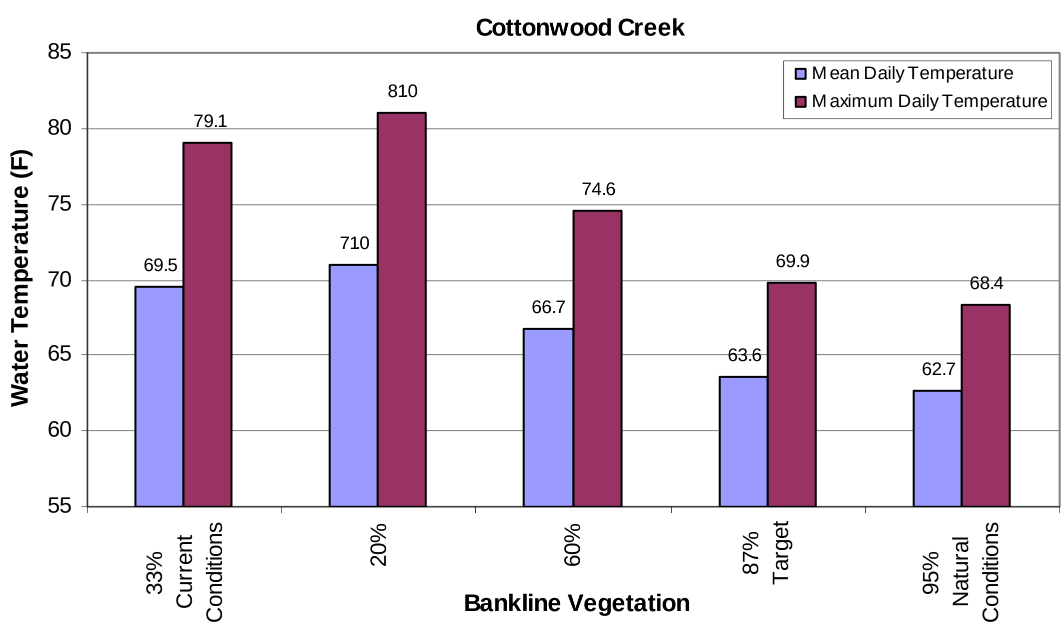


Figure 3-40. Simulated mean and maximum temperature with change in bankline vegation for Cottonwood Creek .

Douglas Creek

The difference in simulated mean temperature in Douglas Creek between current and natural conditions is 5.92° F (Table 3-18 and Figure 3-41). Simulating 84 percent streambank woody vegetation yields the one-degree allowable increase from the natural conditions scenario.

Model Run	*Temperature (F)*		*Difference from Calibration (F)*		*Comments*
	Mean	*Max*	*Mean*	*Max*	
Calibrated Model	69.30	78.22	NA	NA	Simulated temperature at output of creek with current stream conditions (23% bankline woody vegetation)
Simulation 1	69.55	79.23	0.25	1.01	20% of bank with vegetation cover Cottonwood Creek target vegetation
Simulation 2	66.38	74.03	-2.92	-4.19	60% of bank with vegetation cover Cottonwood Creek target vegetation
Target Conditions	64.36	70.74	-4.93	-7.49	84% of bank with vegetation cover Cottonwood Creek target vegetation
Natural Conditions	63.37	69.12	-5.92	-9.11	95% of bank with vegetation cover

Table 3-18. Simulation results for Douglas Creek at the confluence with Nevada Creek.

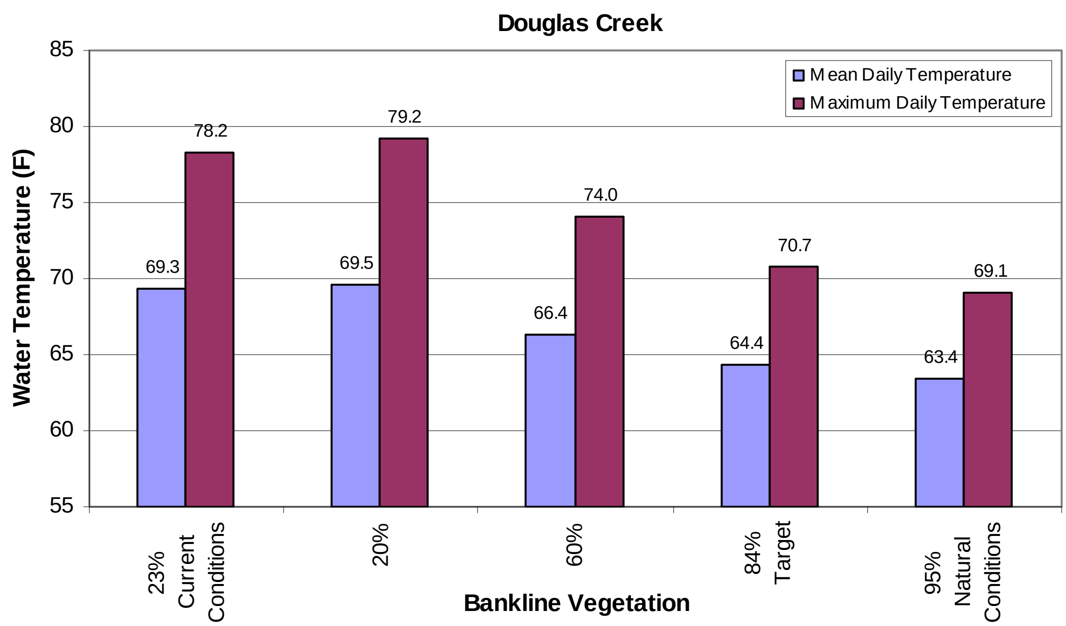


Figure 3-41. Simulated mean and maximum temperature with change in bankline vegetation for Douglas Creek.

Lower Nevada Creek

At the mouth of Nevada Creek, the difference between simulation of current and natural conditions for mean temperature is 2.12° F and 2.57° F for maximum temperature (Table 3-19 and Figure 3-42). Simulating 65 percent streambank woody vegetation along lower Nevada Creek (as well as target vegetation conditions for Cottonwood and Douglas creeks) yields the one-degree allowable increase in mean daily water temperature from natural conditions. The 65 percent value for streambank woody vegetation is therefore the target for lower Nevada Creek.

Note that the model utilized 2004 input water temperatures for Nevada Spring Creek for the 2001 modeling period. This accounts for the improvement in water temperature (1.3° F mean daily) already realized from post 2001 restoration of Nevada Spring Creek.

Model Run	***Temperature (F)***		***Difference from Updated Calibration***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	71.91	76.40	NA	NA	Observed Temperature in 2000 above the confluence with Blackfoot River
Calibrated Temperature	71.71	77.18	1.30	1.13	Simulated temperature with current stream conditions
Updated Calibration	70.41	76.05	NA	NA	Simulated temperature with current stream conditions and 2004 Nevada Spring Creek temperature data
Simulation 1	70.66	76.44	0.25	0.40	20% of bank with woody vegetation cover; Cottonwood and Douglas Creek with target bankline vegetation
Simulation 2	69.44	74.89	-0.97	-1.15	60% of bank with woody vegetation cover; Cottonwood and Douglas Creek with target bankline vegetation
Target Conditions	69.28	74.68	-1.13	-1.37	65% of bank with woody vegetation cover; Cottonwood and Douglas Creek with target bankline vegetation
Natural Conditions	68.29	73.47	-2.12	-2.57	95% of bank with vegetation cover

Table 3-19. Simulation results for lower lower Nevada Creek at the mouth.

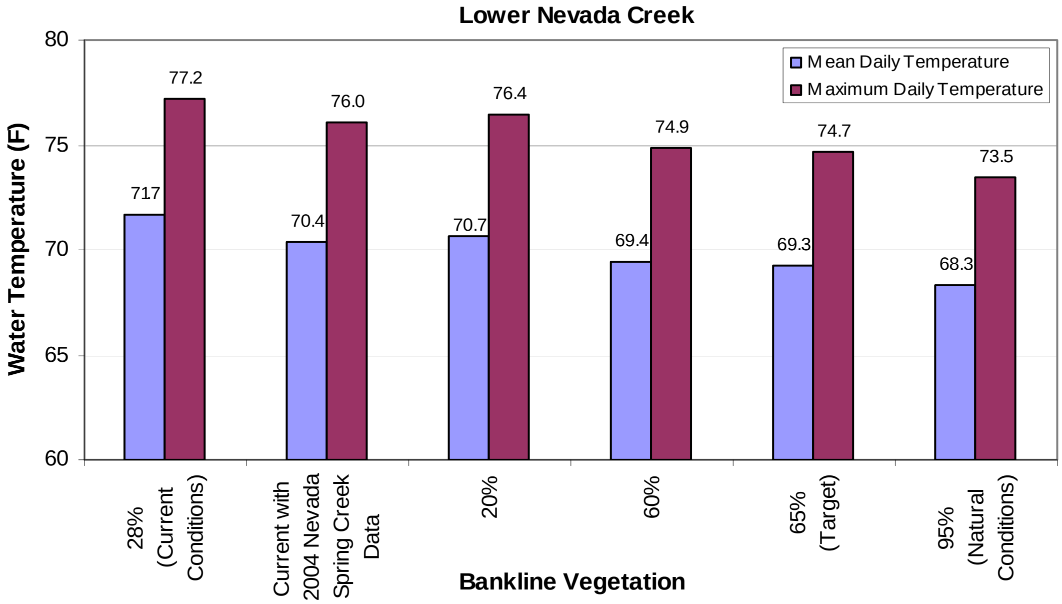


Figure 3-42. Simulated mean and maximum temperature with change in bankline vegetation for lower Nevada Creek.

3.3.3. Upper Douglas Creek Model

The upper Douglas Creek model consists of two short stream segments of Douglas Creek between three reservoirs (Figure 3-43). The observed change in temperature from above to below the reservoirs is approximately 20^{o} F (Table 3-22). Since SSTEMP or SNTEMP cannot simulate water temperatures in reservoirs, the SSTEMP model for upper Douglas Creek only simulated thermal conditions for the stream segments. The remaining thermal gain is therefore attributable to the three reservoirs.

Construction

The modeled portion of Douglas Creek extends for 1.82 miles between the reservoirs (Figure 3-43 and Table 3-20). Temperature monitoring sites located above the upper reservoir on Douglas Creek provided input temperature data for the model. Since temperature data from below the reservoirs include the heating impact of the reservoirs, no observed data was available for comparison with simulated output temperatures.

Modeling for upper Douglas Creek is for the period August 11, 1998. Table 3-20 lists stream geometry and general vegetation characteristics for Douglas Creek during the modeling period. About 40 percent of Douglas Creek has woody vegetation along its streambanks producing shade.

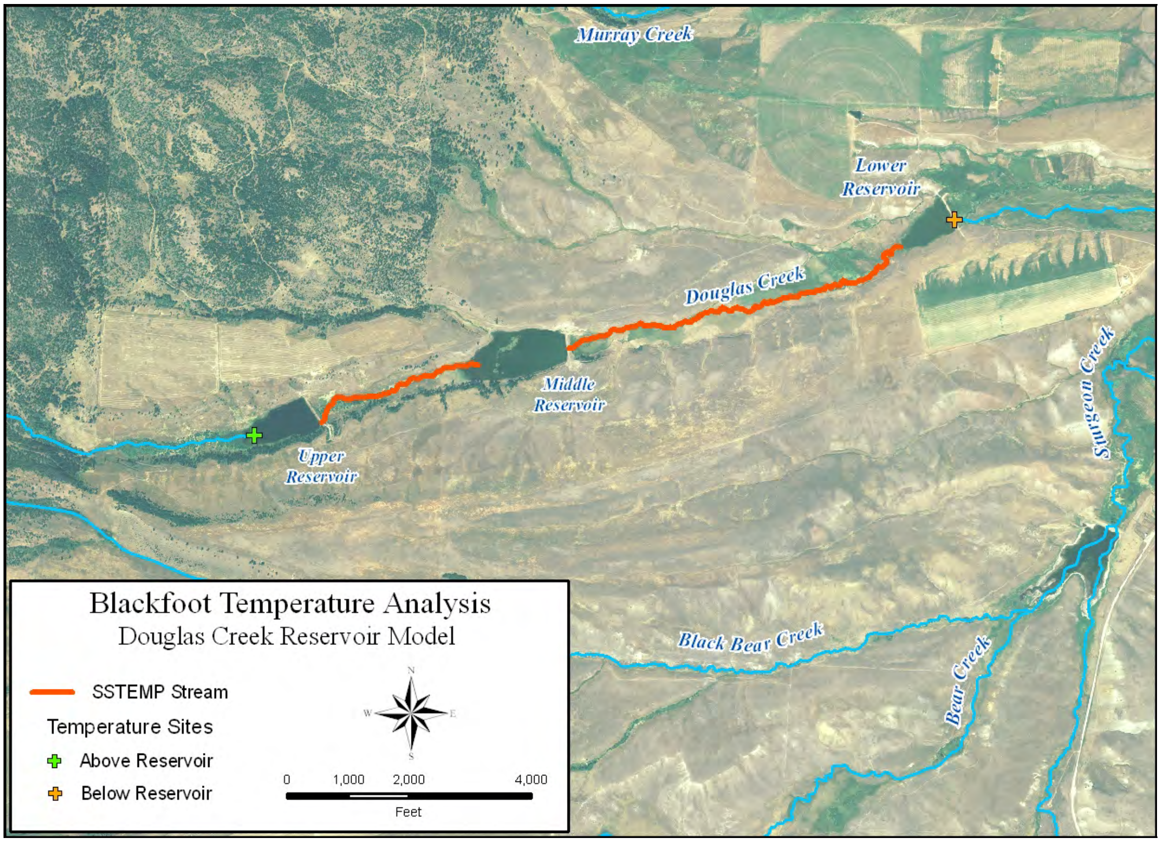


Figure 3-43. Schematic of the upper Douglas Creek SSTEMP model.

Stream	*Modeling Period*	*Length (mi)*	*Average Low Flow Width (ft)*	*Average Bankline Vegetation (%)*	*Average Shade (%)*
Douglas Creek	August 11, 1998	1.82	5.9	39.9	27.9

Table 3-20. Current stream conditions for the upper Douglas Creek SSTEMP model.

Meteorological data for August 11, 1998 (Table 3-21) reflect hot and dry conditions that lead to extreme maximum temperatures. The maximum temperature for this day, 88^{o} F, was one of the warmer temperatures in the summer of 1998.

Modeling Period	*Mean Air Temperature (F)*	*Mean Relative Humidity (%)*	*Mean WindSpeed (mph)*	*Possible Sun (%)*	*Dust Coefficient*	*Ground Reflectivity*
August 11, 1998	66	60	3.0	90	0.055	0.27

Table 3-21. Meteorological input data for the upper Douglas Creek SSTEMP model.

The Montana FWP temperature data for the modeling period indicates that Douglas Creek experiences large thermal gains of approximately 20^{o} F from above the reservoirs to below the reservoirs (Table 3-22). Input flow values are estimates. The mean water temperature above the reservoirs is 48.25° F, the coldest temperature tributary stream water observed in the Nevada Creek watershed. The observed mean water temperature below the third reservoir is 68.37°. SSTEMP simulated the mean temperature at the end of the stream segments (without the reservoirs) at approximately 53.4° F. Therefore, the stream segments accounts for approximately 5° F of the 20° F observed temperature increase.

Segment	Date	Flow in (cfs)	Flow out (cfs)	Water Temperature above Reservoir		Water Temperature below Reservoir	
				Mean	Max	Mean	Max
Douglas Creek from above to below the reservoirs	August 11, 1998	3	3	48.25	54.2	68.37	78.10

Table 3-22. Hydrologic data for Upper Douglas Creek Model.

Calibration

The presence of reservoirs in upper Nevada Creek precluded using the same calibration methods used for the other models. Therefore, a bracketed calibration method provided a pseudo calibration. With this method, multiple model simulations using the typical ranges of meteorological and Manning's n parameter values used for the lower Nevada Creek model provided calibration guidelines (Table 3-23). The first SSTEMP model run for upper Douglas Creek simulated temperatures based on unadjusted meteorological data. Three more simulations evaluated changing meteorological and/or Manning's n values to cover a possible range of conditions. This series of simulations yields a range of simulated temperature increases in the stream segments ranging from 3.8° to 6.2° F. The final SSTEMP calibration simulation used typical parameter values from the SNTEMP model created for lower Nevada Creek, lower Douglas Creek and Cottonwood Creek.

Model Run	Manning's n	Relative Humidity	Wind Speed (mph)	% Sun	Dust	Ground Reflectivity	Simulated Temperature	
							Mean (F)	Max (F)
1	0.062	60	3	90	0.055	0.27	54.42	68.05
2	0.062	45	5	80	0.075	0.20	53.38	65.05
3	0.062	30	7	70	0.100	0.18	52.05	62.06
4	0.080	30	7	70	0.100	0.19	52.05	61.36
Final*	0.080	45	5	80	0.075	0.20	53.38	64.18

*Represents the model used to simulate current and natural conditions on the stream portion of the upper Doulgas Creek model.

Table 3-23. Model iterations and temperature results used to establish parameters for Douglas Creek SSTEMP model.

Simulations

Three simulations for upper Douglas Creek evaluated the effect different levels of riparian shade have on stream temperatures. Note that these simulations only address the stream segment portion of upper Douglas Creek. The first simulation modeled current streambank vegetation conditions, (40% streambank vegetation). A second simulation modeled natural conditions, defined by Montana DEQ as 95% of the streambanks having woody vegetation. A final simulation determined the one-degree allowable increase from natural conditions as the TMDL target for streambank vegetation.

Results illustrate that for current conditions, SSTEMP simulated an increase in Douglas Creek mean water temperature of 5.13 degrees F (Table 3-24). With natural conditions, the simulated mean temperature in Douglas Creek is 51.87 degrees F. This is 4.48 degrees F less than temperatures with current conditions. Simulating 69% streambank vegetation yields the one-degree allowable increase from natural conditions. This requires an increase from 40% to 69% of streambanks having woody vegetation cover.

Model Run	Temperature (F)		Difference from Calibration		Comments
	Mean	Max	Mean	Max	
Observed Temperature	NA	NA	NA	NA	No observed temperature data due to the presence of reservoirs.
Calibrated Temperature	53.38	64.18	NA	NA	Bracketed calibration (described above)
Simulation 1	53.38	64.18	0.00	0.00	Current conditions, 40% streambank woody vegetation (same as bracketed calibration)
Target Conditions	52.85	60.72	-0.53	-3.46	69% streambank woody vegetation
Natural Conditions	51.87	57.45	-1.51	-6.73	95% streambank woody vegetation

*SSTEMP simulation results are for the stream segments only. The reservoirs are discussed below.

Table 3-24. Simulation results for the upper Douglas Creek temperature model.

Reservoirs

The reservoirs on upper Douglas Creek cause much of the temperature gain between the FWP temperature monitoring sites above and below the reservoirs. Temperature data indicate that the increase in stream temperature between these sites is approximately 20^{o} F. SSTEMP modeling indicates that the stream segments between the reservoirs contribute approximately 5^{o} F (25%) of this increase. Therefore, the reservoirs are responsible for approximately 15^{o} F (75%) of the increase in temperature.

Reasonable agricultural practices fall within the natural conditions defined by Montana DEQ. However, in upper Douglas Creek, the temperature gains are excessive. Modifications to the water storage and delivery system that would improve stream temperatures are possible based on field observations and air photo assessment of the irrigation system. These data suggest that the lowermost reservoir has the smallest surface area and is the shallowest (Table 3-25). Locations of the reservoirs and the conveyance to irrigated areas suggest that if the lowermost reservoir were consolidated with the upper and middle reservoirs, overall water availability would still be adequate to meet agricultural requirements. This would effectively reduce the total reservoir surface area by approximately 20 percent and temperature gain from the reservoirs by a similar amount. This results in a further 3^{o} F reduction in temperature (15^{o} F X 20%). The lowermost reservoir is shallower than the upper and middle reservoirs and may heat faster as a result. Therefore, the temperature improvements realized from consolidating the reservoirs may be larger than 3^{o} F.

Reservoir	***Area (acres)***	***% of Reservoir Area***
Upper	11.10	27.8%
Middle	20.88	52.3%
Lower	7.91	19.8%

Table 3-25. Reservoir sizes, upper Douglas Creek.

4. Results: Middle Blackfoot Planning Area

This section contains results for the Blackfoot River and Kleinschmidt Creek in the Middle Blackfoot planning area. Results include development of shade parameter data, temperature data analysis, and temperature modeling.

4.1. Shade

The shading value applied to each segment of the mainstem Blackfoot River modeling network is a function of topographic conditions, channel width, and shading vegetation type and extent. Section 2.2 describes the methods used to calculate each of these parameters.

4.1.1. Riparian Vegetation

For the modeled segments of the Nevada Creek Planning area, base parameter assessment data (DTM and AGI, 2005) and field photos allowed definition of the vegetation categories along the streams of interest. For each of these categories, field photos and notes provided the data for estimates of vegetation offset (Vo), diameter (Vd), and height (Vh). The median values of these estimates define typical conditions for each vegetation type. (Figure 4-1 through Figure 4-3; Table 4-1).

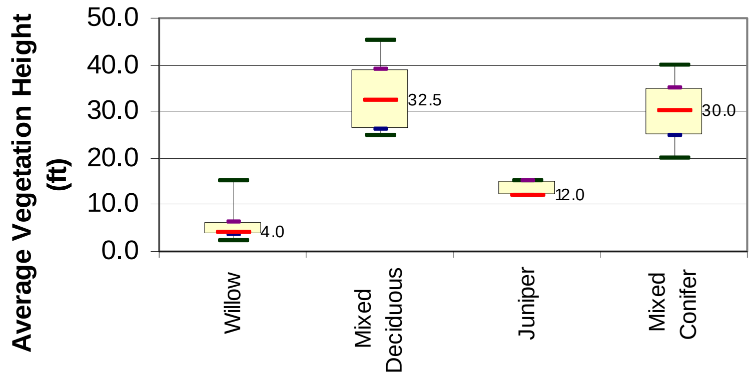


Figure 4-1. Estimated average heights for each vegetation type with median values labeled.

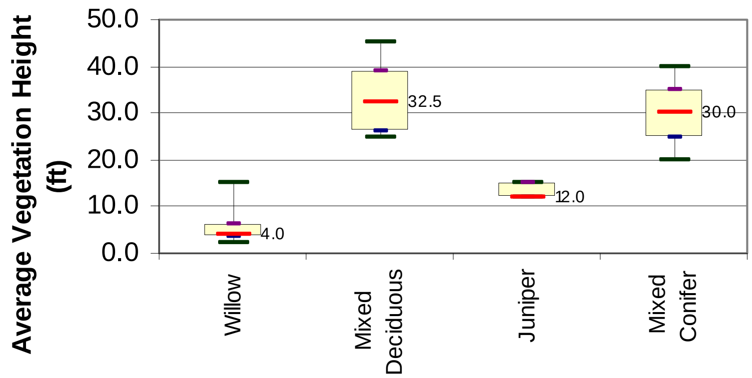


Figure 4-2 Estimated average crown diameter for each vegetation type with median values labeled.

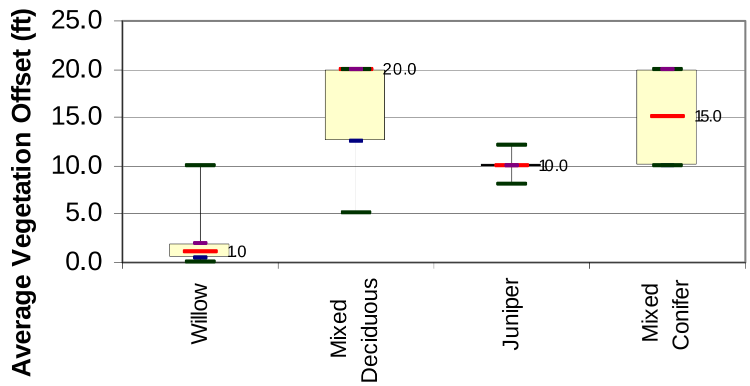


Figure 4-3. Estimated average offset for each vegetation type with median values labeled.

Calculation of filtering values for each stream segment requires a filtering value for each vegetation type in addition to vegetation density. Vegetation density (Vd) is equal to the filtering value multiplied by the percent of shaded bank length within a reach. Preliminary default filtering values used for each vegetation type ranged from 0.2 to 0.7 (Table 4-1). Literature that addressed similar vegetation types (Manoukian and Marlow, 2002; Risley, 1997; Bartholow, 2004) guided the selection of the filtering values.

Table 4-1. Shade parameter values utilized for each vegetation category.

Vegetation Type	*Filtering*	*Vh: Crown Height (ft)*	*Vd:Crown Diameter (ft)*	*Vo: Offset (ft)*
Willow	0.5	4	5	1
Mixed Deciduous	0.7	32.5	11.0	20.0
Juniper	0.8	12.0	10.0	10.0
Mixed Conifer	0.7	30.0	12.0	15.0

4.1.2. Topographic Shade

The mainstem Blackfoot River flows through canyon sections that provide some topographic shade to the river. However, the extent of shading contributed by topography during the modeling period is less than six percent for all reaches, and less than two percent for the vast majority of reaches. Topographic shade values calculated for each reach of the mainstem Blackfoot River are in Table 4-2.

4.1.3. Channel Width

Channel width under low flow conditions was estimated from NAIP 2005 color air photos. Ten channel widths were measured at random locations throughout each reach, and the mean of that value represents the reach. The measured widths for each reach are quite variable; however, the overall trend shows downstream widening (Figure 4-4).

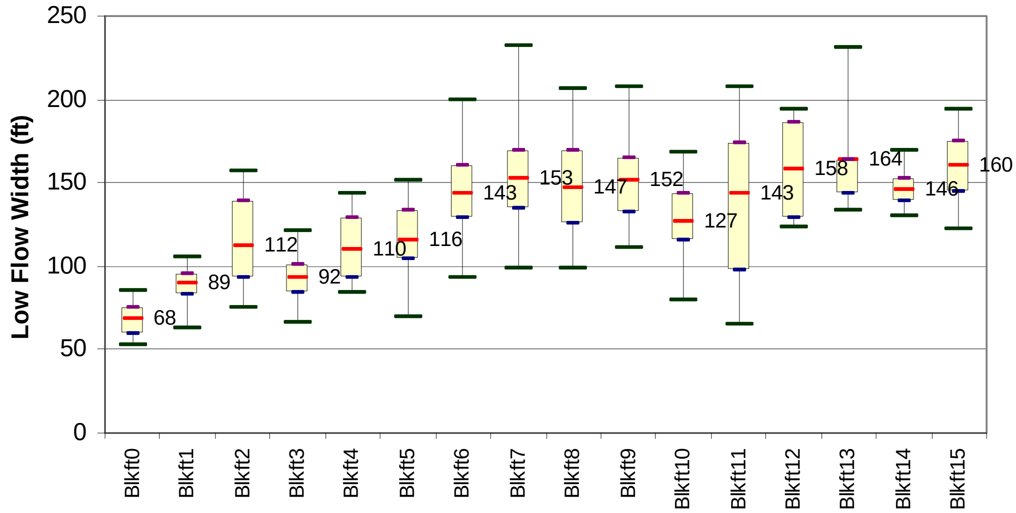


Figure 4-4. Measured low flow widths from aerial photography, mainstem Blackfoot River.

4.1.4. Total Shade Calculations

Using the input parameters described above, a total shade value for the modeling period was calculated for each reach (Figure 4-5 and Table 4-2). The total shade value is the sum of the topographic and vegetation shade. The tree height, offset, diameter, and shade density values all reflect weighted averages that account for all vegetation types identified. Note that all values are below 12 percent shading due to large channel widths. In addition, reaches with in excess of 70 percent streambank woody vegetation had no more than 8.75% shade due to large channel widths.

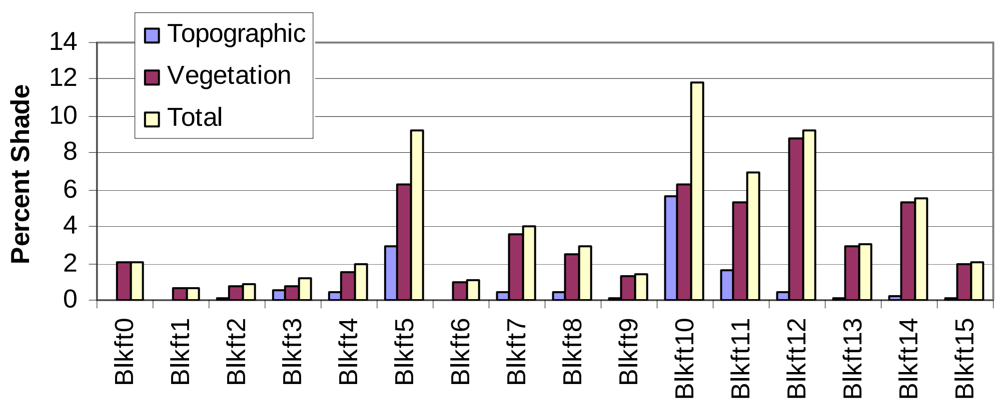


Figure 4-5. Total shade values calculated for modeled reaches, Middle Blackfoot Planning Area.

Table 4-2. Calculated topographic, vegetation, and total shading parameter for August 15, Middle Blackfoot Planning Area modeled assessment reaches.

Reach	*Reach Length (ft)*	*Pct Shaded Bank*	*Est Low Flow Wid (ft)*	*Stream Azimuth Degrees*	*West Topo Degrees*	*East Topo Degrees*	*Crown Diameter (ft)*	*Tree Height (ft)*	*Offset Distance (ft)*	*Shade Density decimal*	*% SHADE*		
											Topographic %	*Vegetation %*	*Total %*
Blkft0	26945	19.8	68	36.3	0.00	0.00	8.4	14.2	9.2	0.15	0.00	2.10	2.10
Blkft1	8432	21.0	89	-78.1	2.65	1.10	10.7	25.6	16.6	0.07	0.01	0.61	0.62
Blkft2	15225	13.0	112	-35.1	3.69	2.53	10.0	12.0	10.0	0.10	0.12	0.74	0.86
Blkft3	12182	9.2	92	-47.2	9.19	6.34	11.0	21.2	12.6	0.07	0.51	0.73	1.24
Blkft4	9517	14.3	110	-35.6	6.72	4.97	12.0	30.0	15.0	0.04	0.44	1.49	1.93
Blkft5	26441	51.4	116	-4.6	13.77	9.07	11.9	30.1	15.3	0.34	2.97	6.29	9.26
Blkft6	15232	23.3	143	-72.2	8.13	2.48	11.7	30.8	16.5	0.08	0.04	1.02	1.06
Blkft7	17604	79.8	153	-68	13.31	9.67	11.1	26.7	13.2	0.51	0.45	3.55	3.99
Blkft8	9091	41.7	147	-33.3	0.75	6.13	8.7	17.9	8.5	0.37	0.41	2.53	2.94
Blkft9	22565	43.9	152	-84.9	2.86	5.30	9.3	22.2	12.1	0.23	0.08	1.35	1.43
Blkft10	10485	70.9	127	19	15.78	17.69	11.8	29.2	14.6	0.59	5.62	6.26	11.88
Blkft11	24852	69.1	143	54.5	15.56	11.15	12.0	30.0	15.0	0.63	1.62	5.30	6.92
Blkft12	10065	79.9	158	14.3	3.00	6.29	12.0	30.0	15.0	0.68	0.44	8.74	9.18
Blkft13	13311	69.4	164	-76.4	3.31	4.50	12.0	30.0	15.0	0.35	0.08	2.97	3.06
Blkft14	8072	79.2	146	60.8	5.71	9.46	12.0	30.0	15.0	0.61	0.23	5.34	5.57
Blkft15	35686	56.9	160	-72.8	14.23	3.30	7.6	13.7	6.2	0.29	0.07	1.95	2.03

4.2. Temperature Conditions

The following sections describe the stream temperature conditions for each 303(d) listed stream in the Nevada Creek Planning Area. This includes important tributaries to these streams.

4.2.1. Kleinschmidt Creek

The Montana FWP temperature database has 2001 and 2004 temperature measurements for one site on Kleinschmidt Creek above its confluence with Rock Creek (Figure 4-6). In addition to temperature data, BBCTU collected flow data in 2004 at three locations on Kleinschmidt Creek (Blackfoot Challenge, 2004). These data served as input to the SNTEMP temperature model for Kleinschmidt Creek.

Kleinschmidt Creek underwent significant restoration downstream of Highway 200 from 1990 through 2001, resulting in significantly reduced channel width and surface area, and increased channel sinuosity (Hydrometrics, 2005). The majority of restoration took place in 2000-2001.

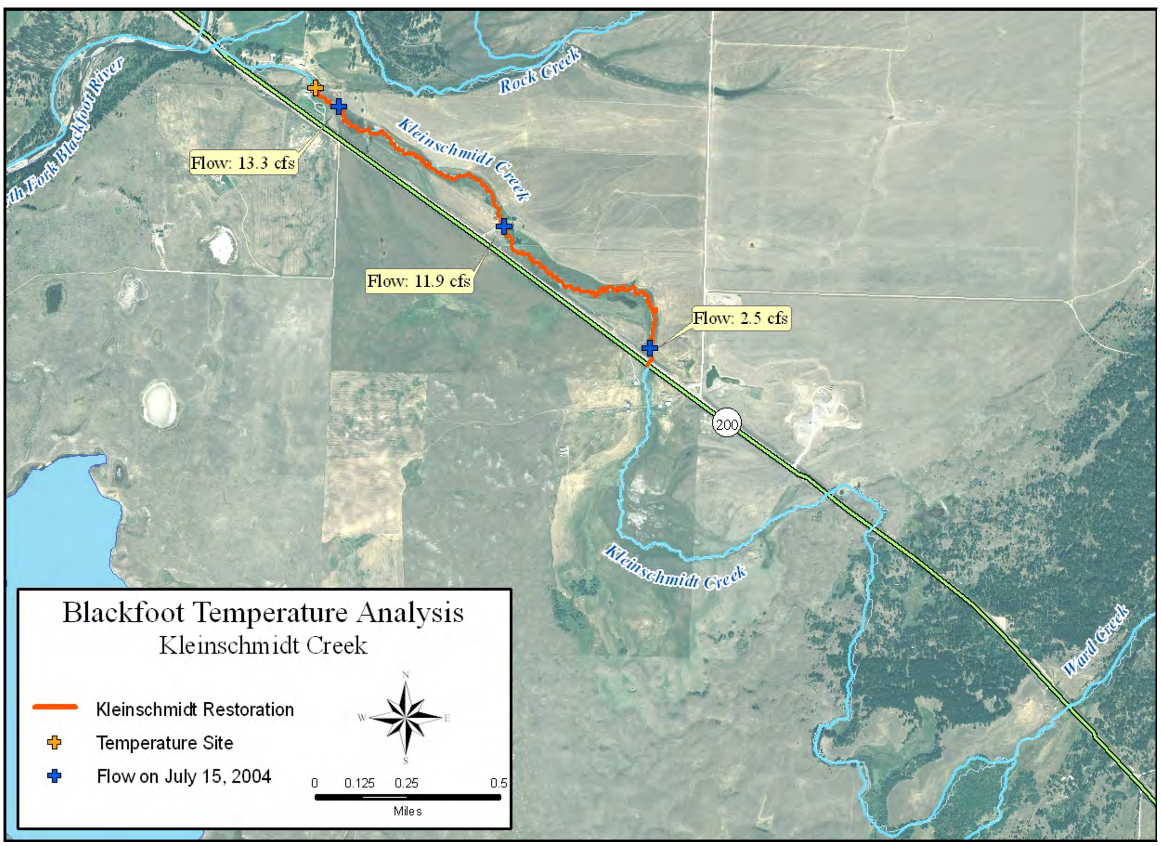


Figure 4-6. Kleinschmidt Creek and related data.

A comparison of 2001 with 2004 continuous temperature graphs for Kleinschmidt Creek indicates significant improvement in stream temperatures after 2001 restoration (Figure 4-7 and Figure 4-8). Minimum temperatures are similar; however, maximum temperatures and the amount of diurnal fluctuation are much lower in 2004.

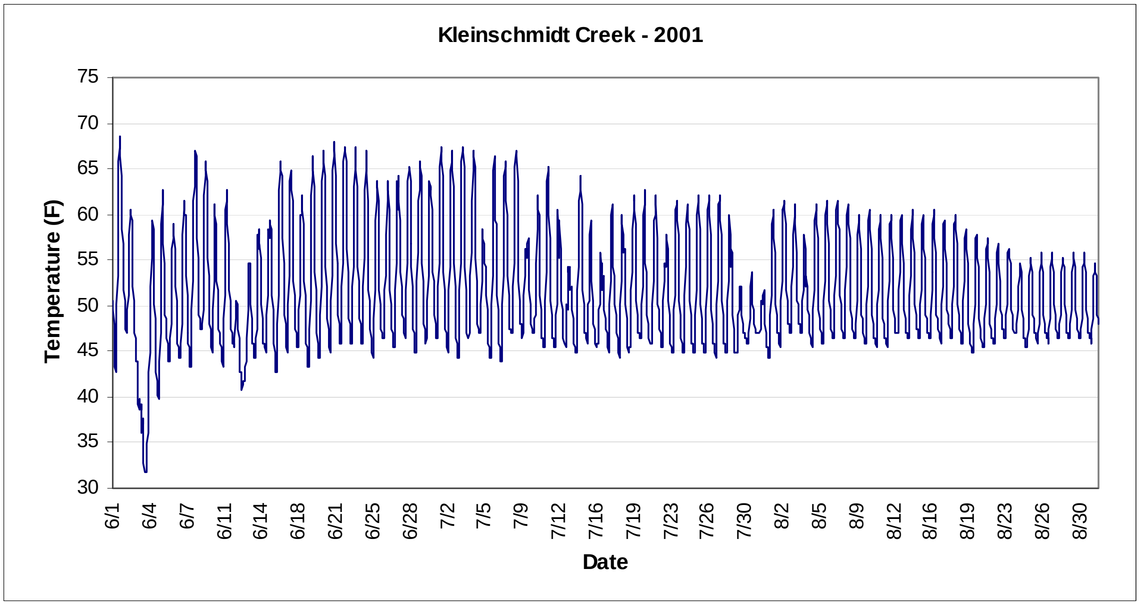


Figure 4-7. Continuous water temperature, Kleinschmidt Creek, 2001.

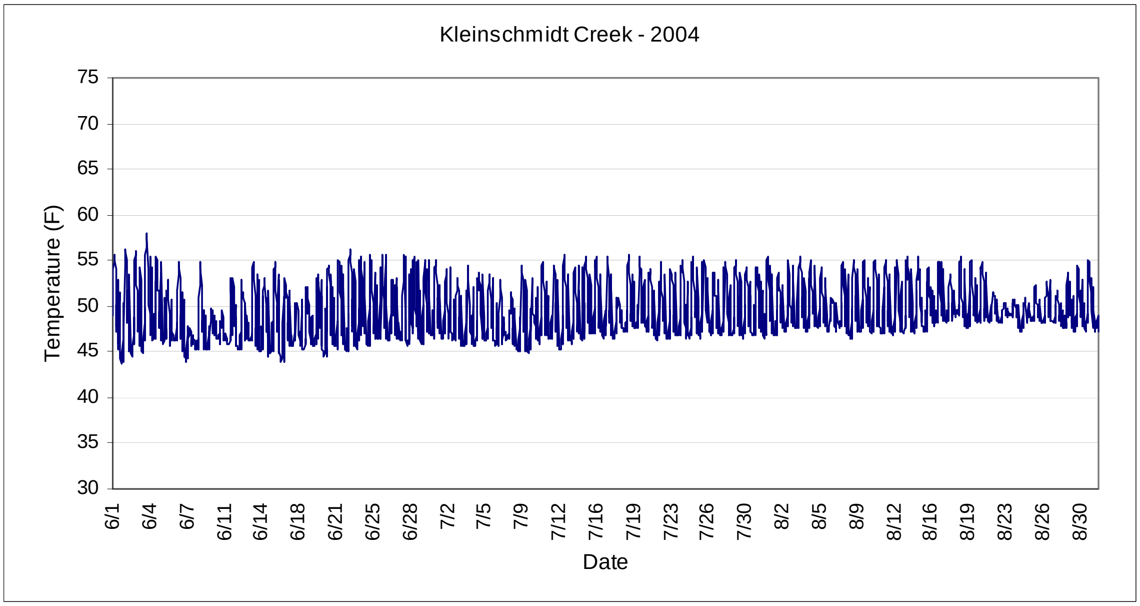


Figure 4-8. Continuous water temperature, Kleinschmidt Creek, 2004.

Figure 4-9 shows the difference in summer temperatures between 2001 and 2004 at the monitoring site above Rock Creek. This plot illustrates that the range in summer temperatures decrease dramatically post-restoration. Fifty percent of the temperature readings over the summer of 2004 fall within a 5° F range, centered on 50° F.

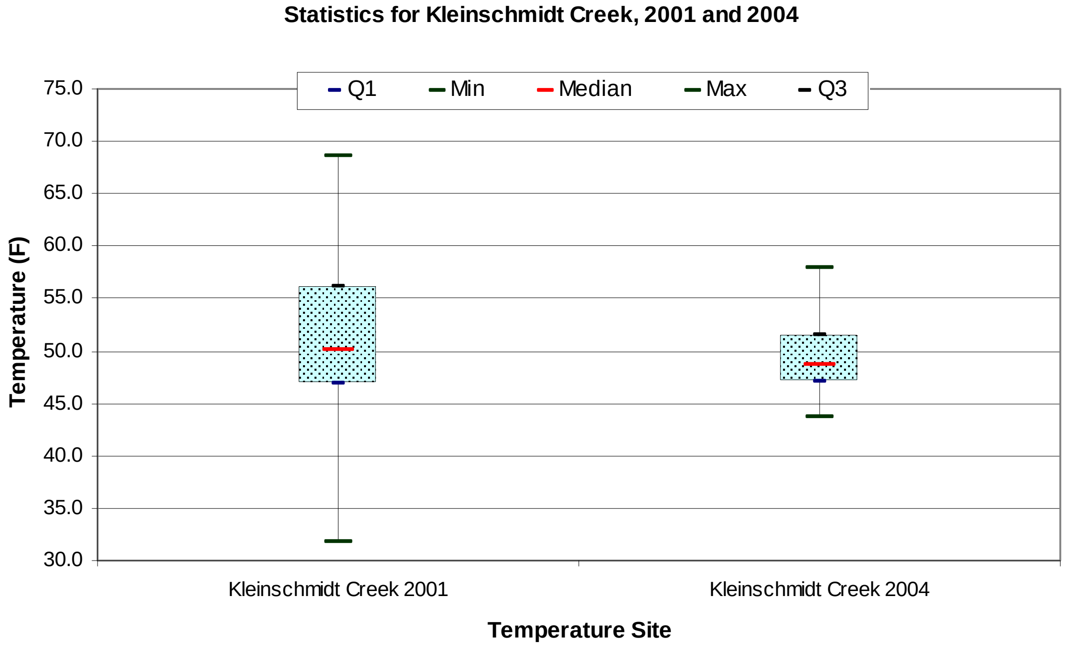


Figure 4-9. Temperature variation between years 2001 and 2004, Kleinschmidt Creek.

Figure 4-10 through Figure 4-13 display the daily maximum and seven-day average maximum temperatures at the monitoring site on Kleinschmidt Creek during the summers of 2001 and 2004. A comparison of 2001 and 2004 data shows that maximum water temperatures frequently are in the low to upper 60s F in 2001, while temperatures rarely exceed 55° F in 2004. Maximum water temperatures also fluctuate more in 2001 than in 2004. Precipitation and air temperature plotted on the maximum daily water temperature graph illustrate their influence on water temperature in both 2001 and 2004, although the degree of influence is smaller in 2004 than in 2001.

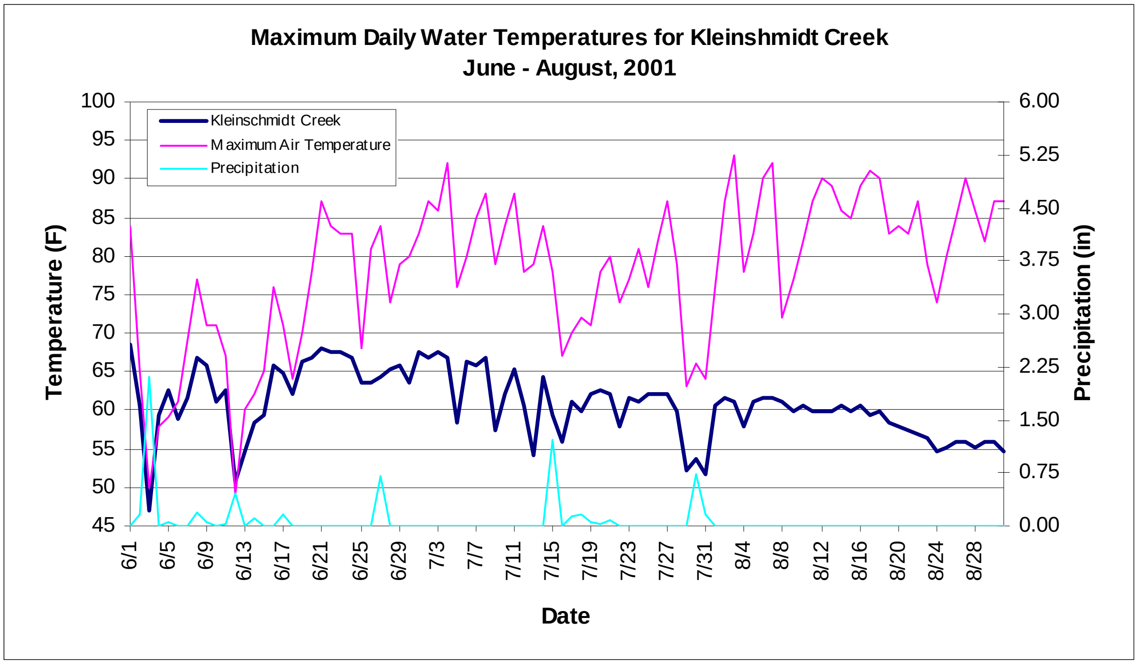


Figure 4-10. Maximum daily water temperature, air temperature, and precipitation, Kleinschmidt Creek, 2001.

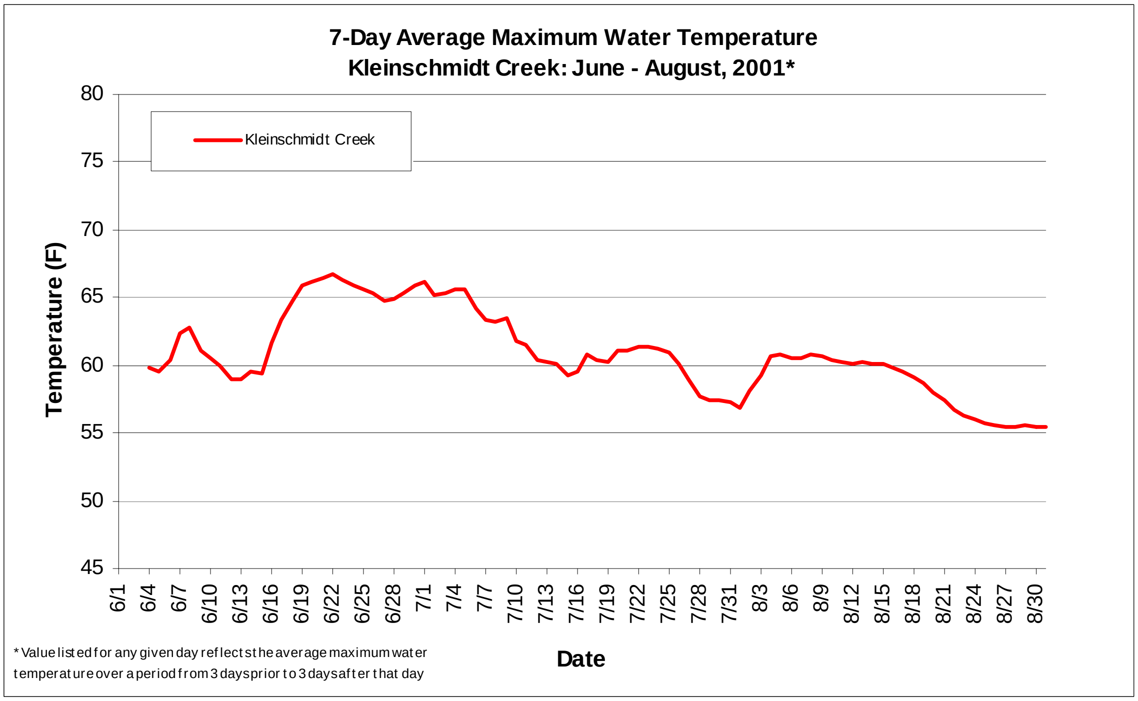


Figure 4-11. 7-day average maximum daily temperatures, Kleinschmidt Creek, 2001.

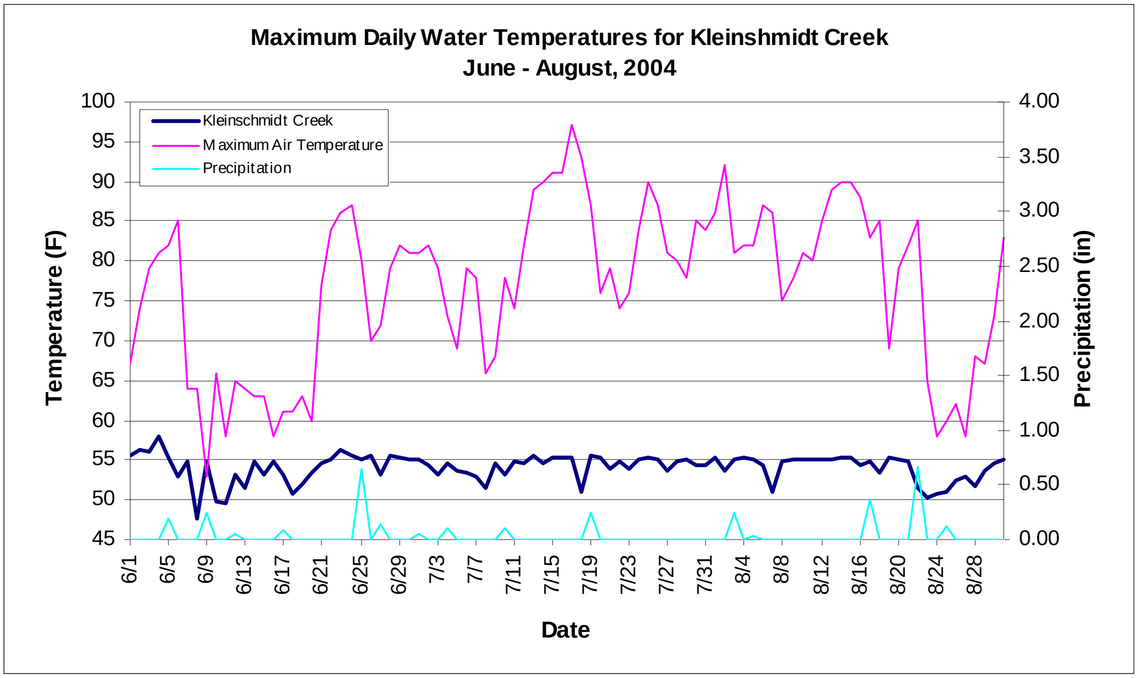


Figure 4-12. Maximum daily water temperature, air temperature, and precipitation, Kleinschmidt Creek, 2004.

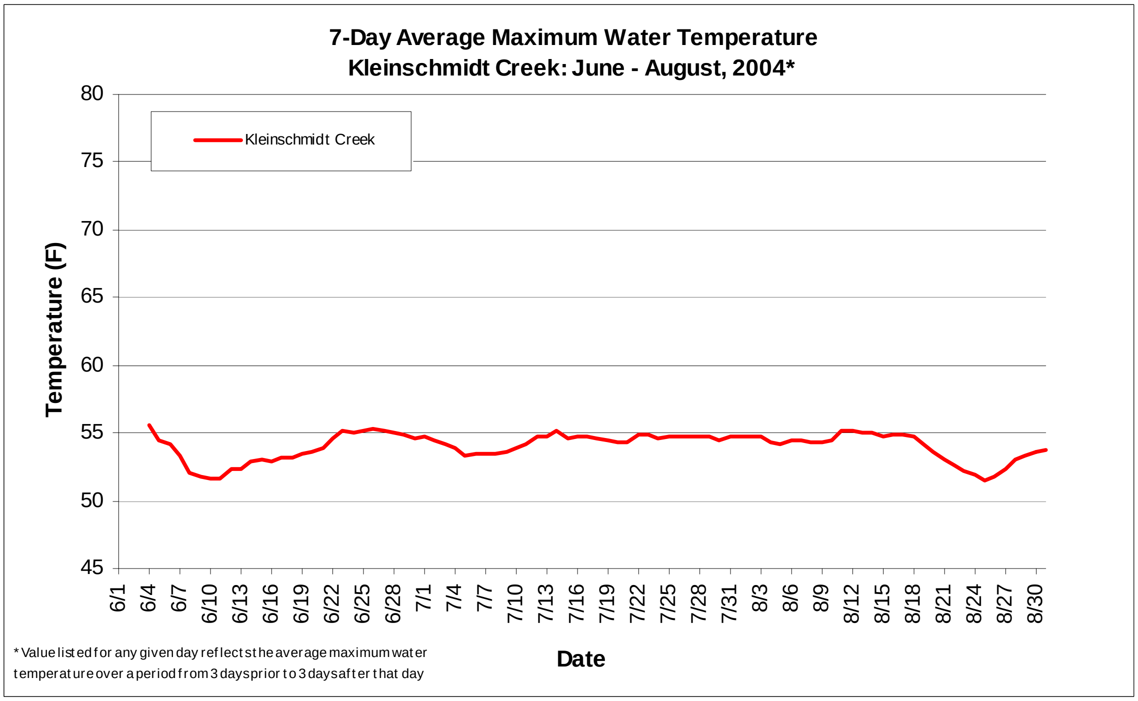


Figure 4-13. 7-day average maximum daily temperatures, Kleinschmidt Creek, 2004.

Kleinschmidt Creek originates in a riparian meadow where Ward Creek splits into the continuation of Ward Creek towards Browns Lake and Kleinschmidt Creek (Figure 4-6). Kleinschmidt Creek then continues through a conifer riparian zone for approximately ½ mile before it enters a highly degraded valley bottom area where it crosses Highway 200 three times. Thermal gains are likely in this area. Below Highway 200, abundant cold groundwater reduces stream temperature. 2004 flow data shows an increase in flow from 2.5 cfs at the third Highway 200 crossing to 11.9 cfs less than a mile downstream (Figure 4-6). This reach is located at the toe of the large deposit of glacial outwash that makes up Kleinschmidt Flat and thus gains water from groundwater traveling through the outwash.

4.2.2. Blackfoot River

The Montana FWP temperature database contains data collected in 2000 for four sites on the Blackfoot River and eight sites on tributary streams in the Midddle and Lower Blackfoot TMDL planning areas. In addition, the database contains data collected in other years for two key tributaries, Monture Creek (1999) and the Clearwater River (2003). Figure 4-14 through Figure 4-27 (upstream to downstream) display continuous water temperature readings collected at the twelve monitoring sites during the summer of 2000, and for Monture Creek in 1999 and the Clearwater River in 2003. These figures illustrate that for all sites in 2000, temperatures peak around July 30. The drop in water temperature around July 5, 2000 corresponds to a cool and rainy storm cycle.

Figure 4-9 shows the statistical distribution of summer temperatures during 2000 for the four sites on the Blackfoot River and tributaries. From the plot, it is apparent that temperatures are coolest on the Blackfoot River at the site at Cutoff Bridge, and increase dramatically at Raymond Bridge, site of the warmest temperatures on the Blackfoot River. Nevada Creek, Elk Creek, and the Clearwater River all contributed warm water to the Blackfoot River during the summer of 2000, with water temperatures reaching greater than 75^{o} F during that summer. However, the volumes of warm water are small compared to the Blackfoot. The North Fork of the Blackfoot River and Monture Creek are cold-water streams, and contributed significant volumes of cold water to the Blackfoot River with temperatures topping out in the mid-60s F for both streams. Yourname, Wales, Creek

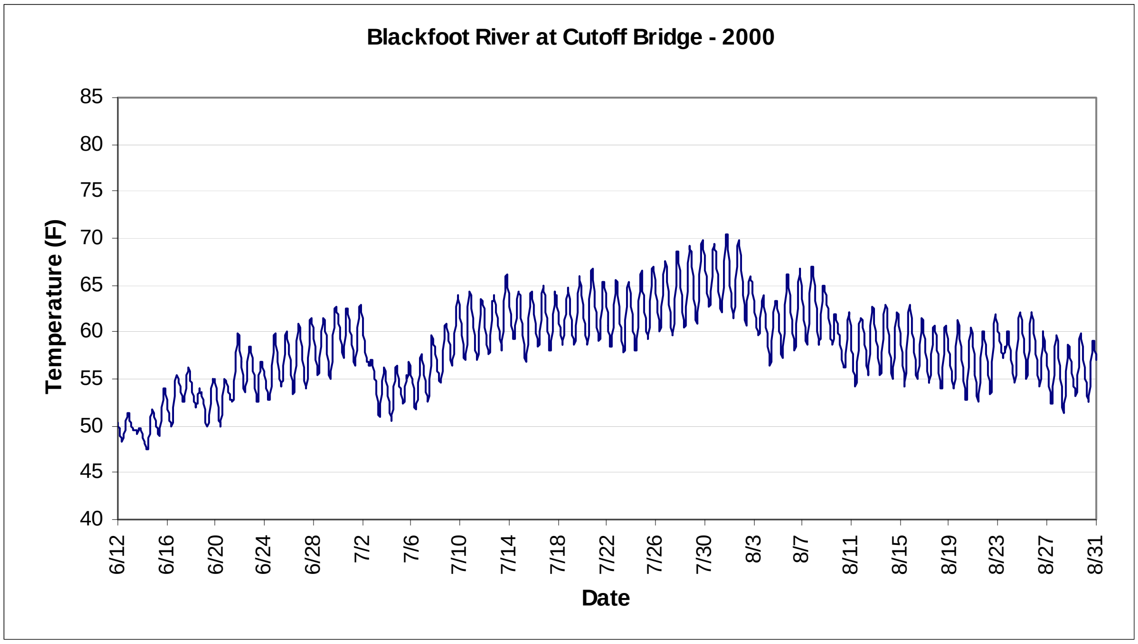


Figure 4-14. Continuous water temperature, Blackfoot River at Cutoff Bridge, 2000.

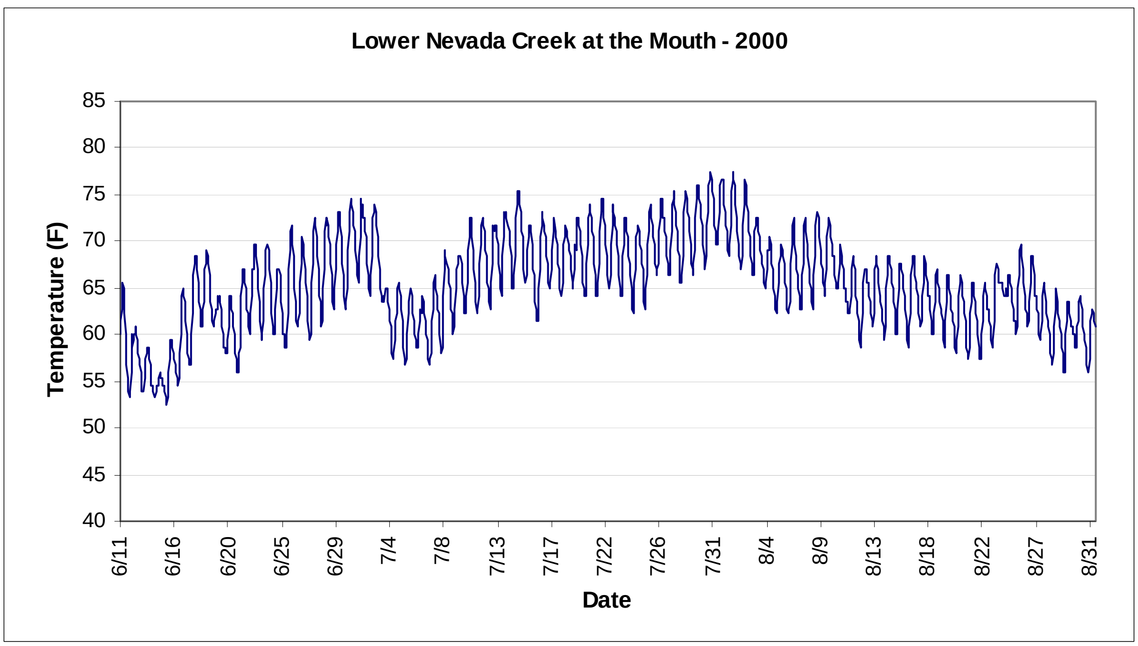


Figure 4-15.. Continuous water temperature, lower Nevada Creek at the mouth, 2000.

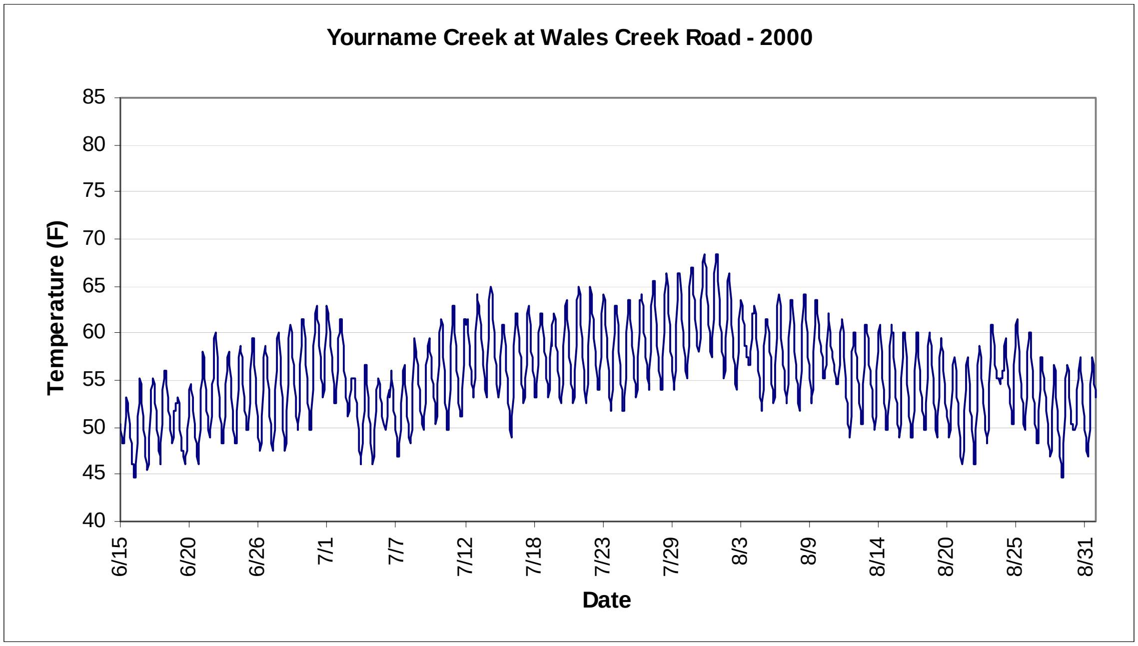


Figure 4-16. Continuous water temperature, Yourname Creek at Wales Creek Road, 2000.

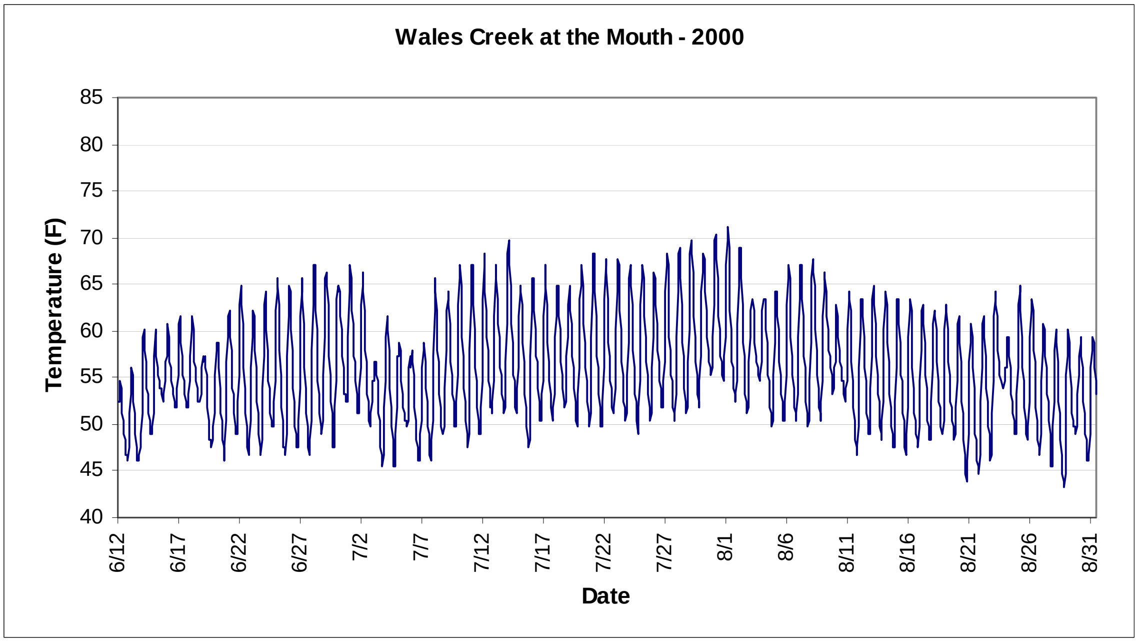


Figure 4-17. Continuous water temperature, Wales Creek at the mouth, 2000.

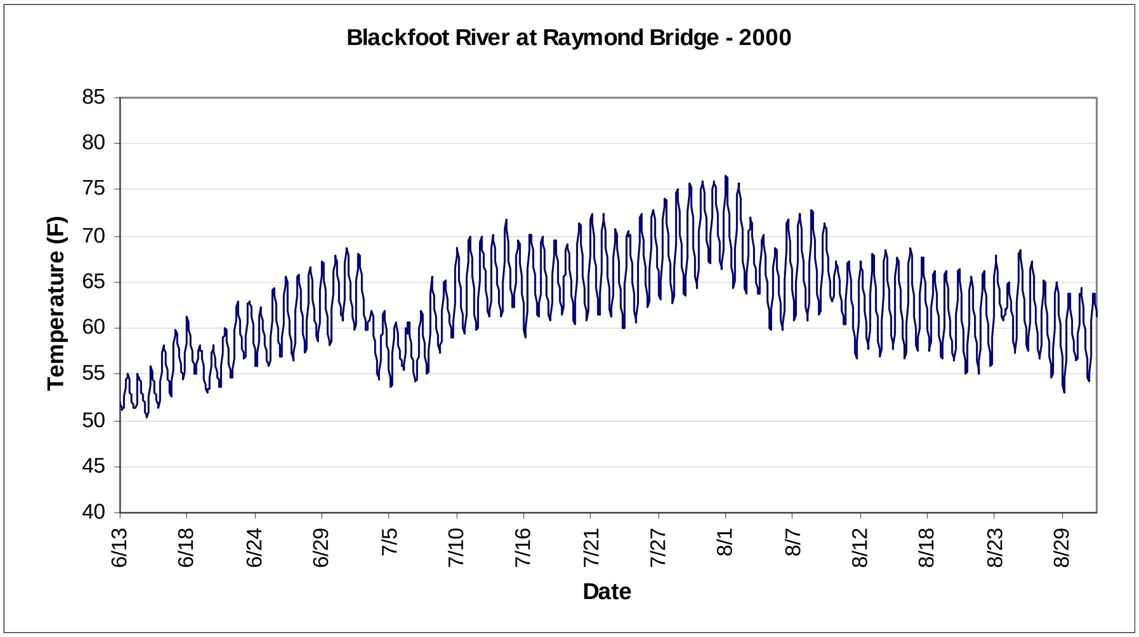


Figure 4-18. Continuous water temperature, Blackfoot River at Raymond Bridge, 2000.

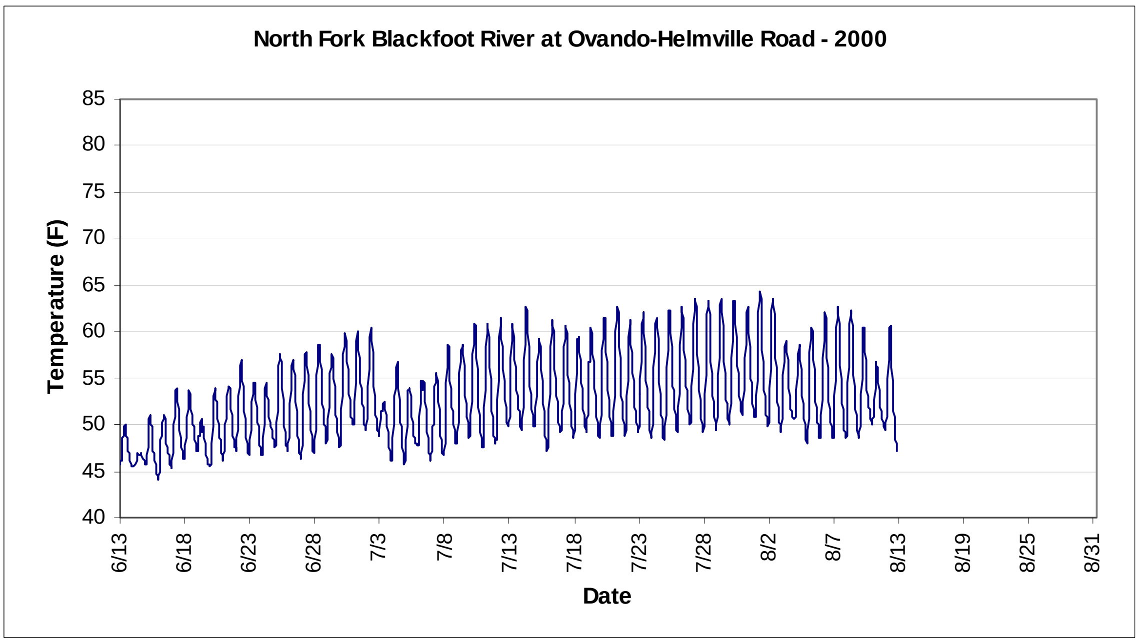


Figure 4-19. Continuous water temperature, North Fork Blackfoot River, 2000.

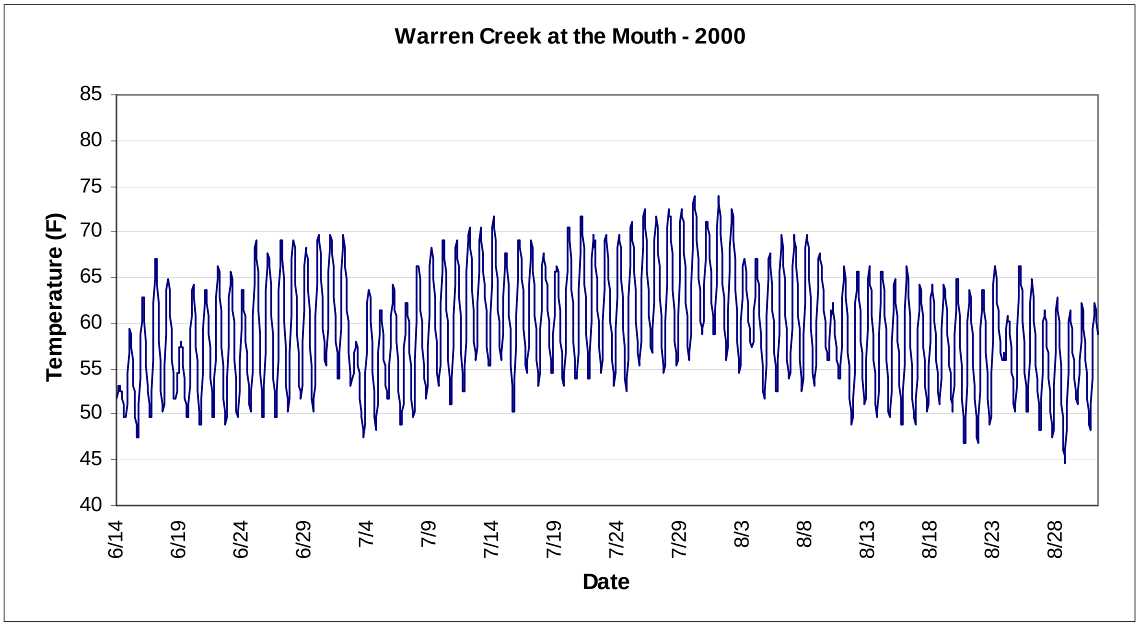


Figure 4-20. Continuous water temperature, Warren Creek at the mouth, 2000.

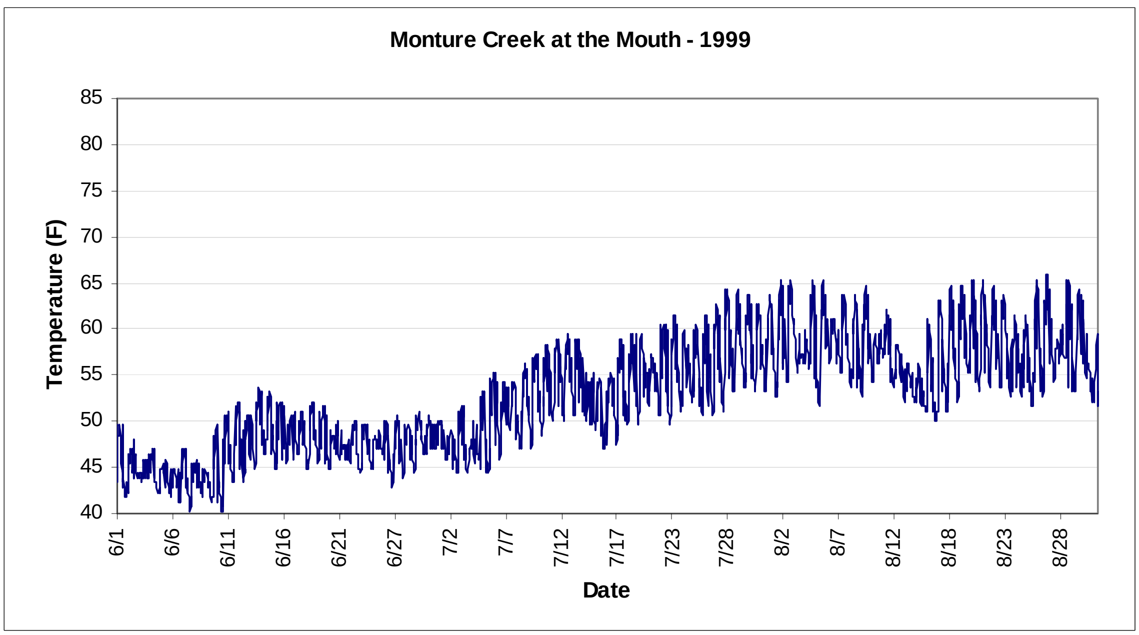


Figure 4-21. Continuous water temperature, Monture Creek, 1999.

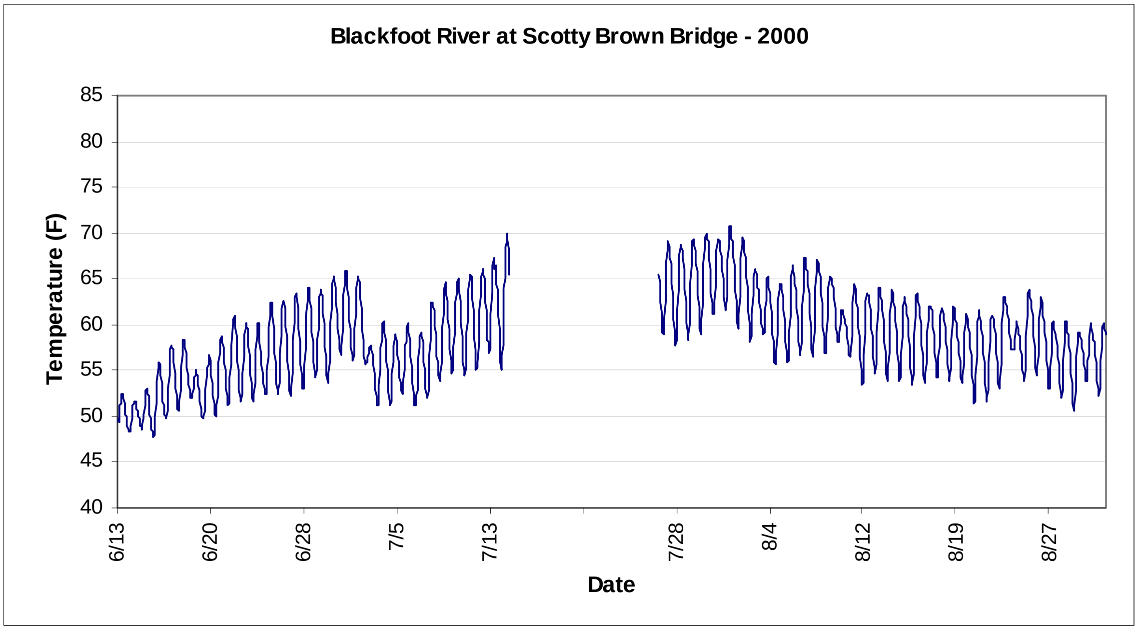


Figure 4-22. Continuous water temperature, Blackfoot River at Scotty Brown Bridge, 2000.

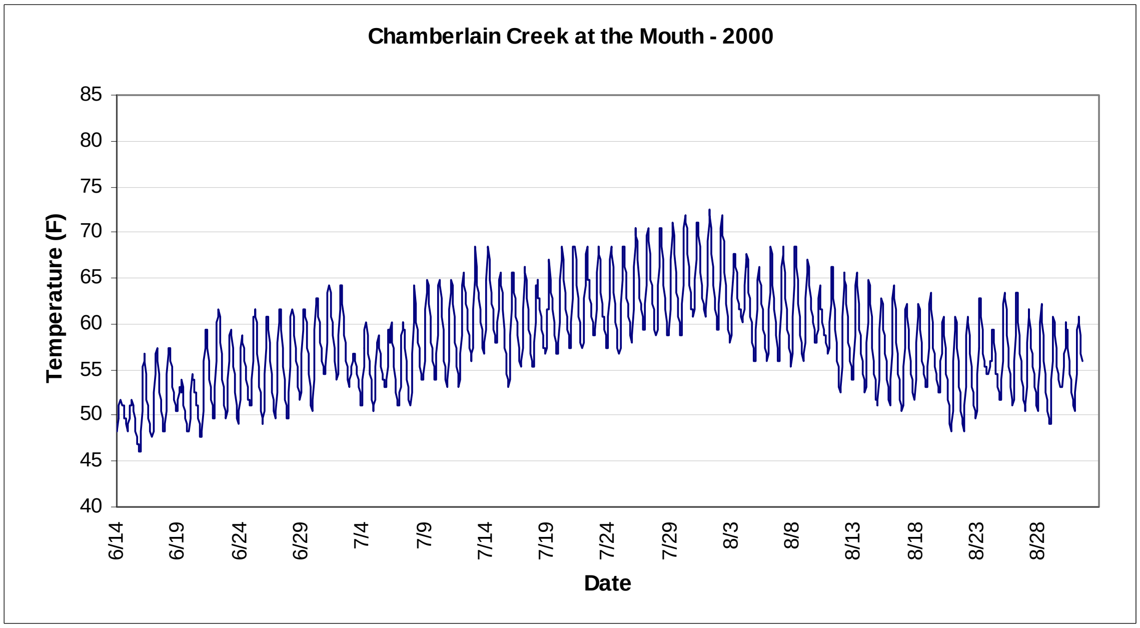


Figure 4-23. Continuous water temperature, Chamberlain Creek at the mouth, 2000.

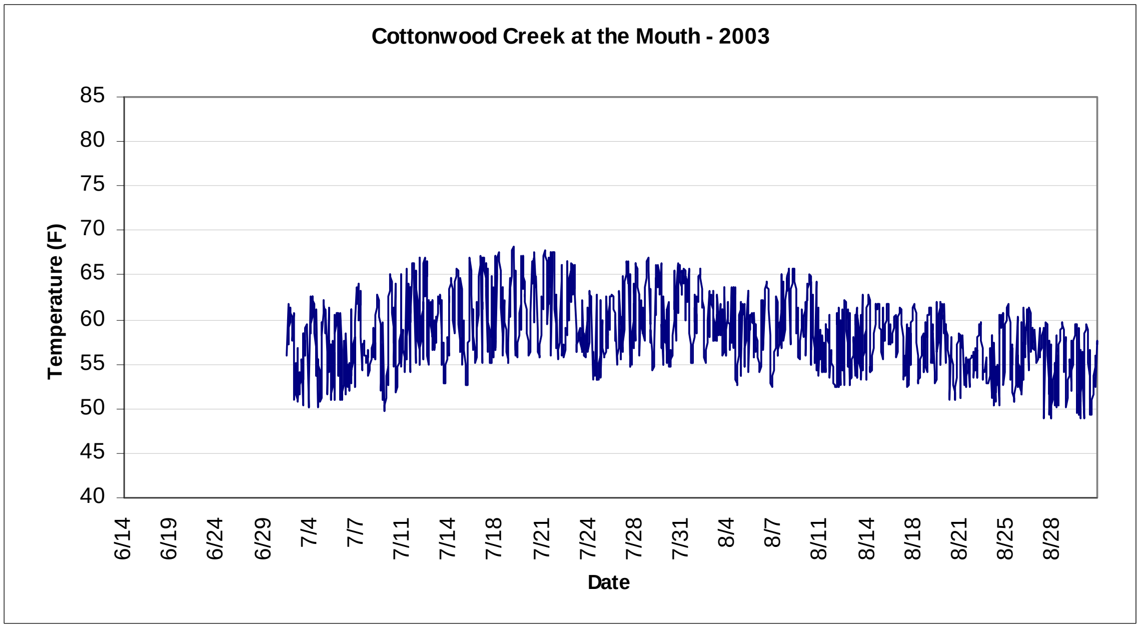


Figure 4-24: Continuous water temperature, Cottonwood Creek at the mouth, 2003.

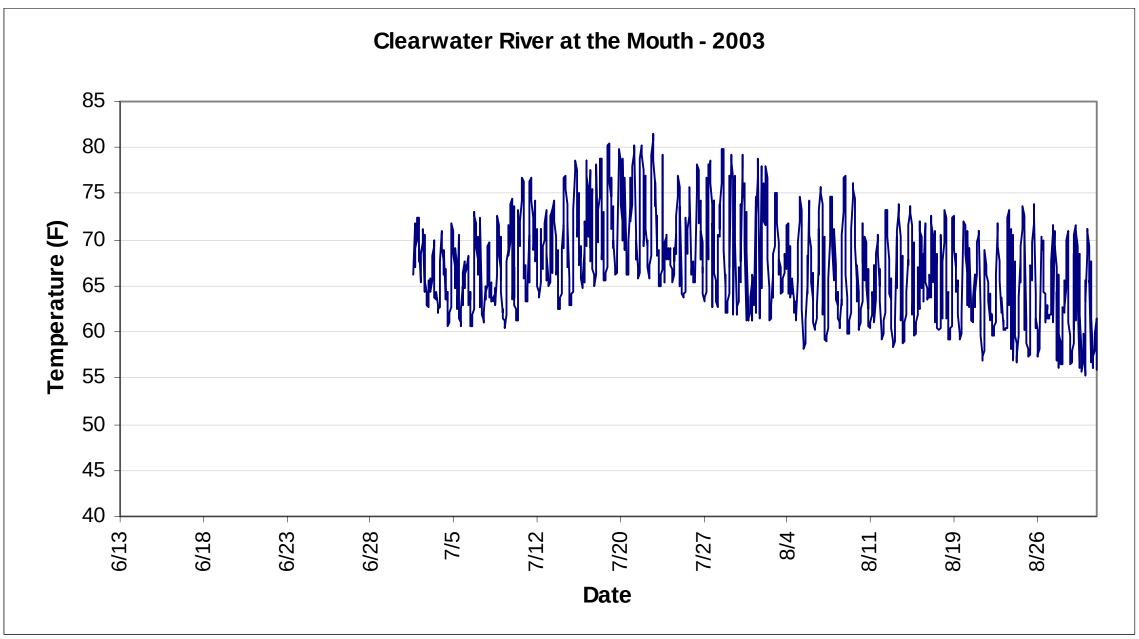


Figure 4-25. Continuous water temperature, Clearwater River at the mouth, 2003.

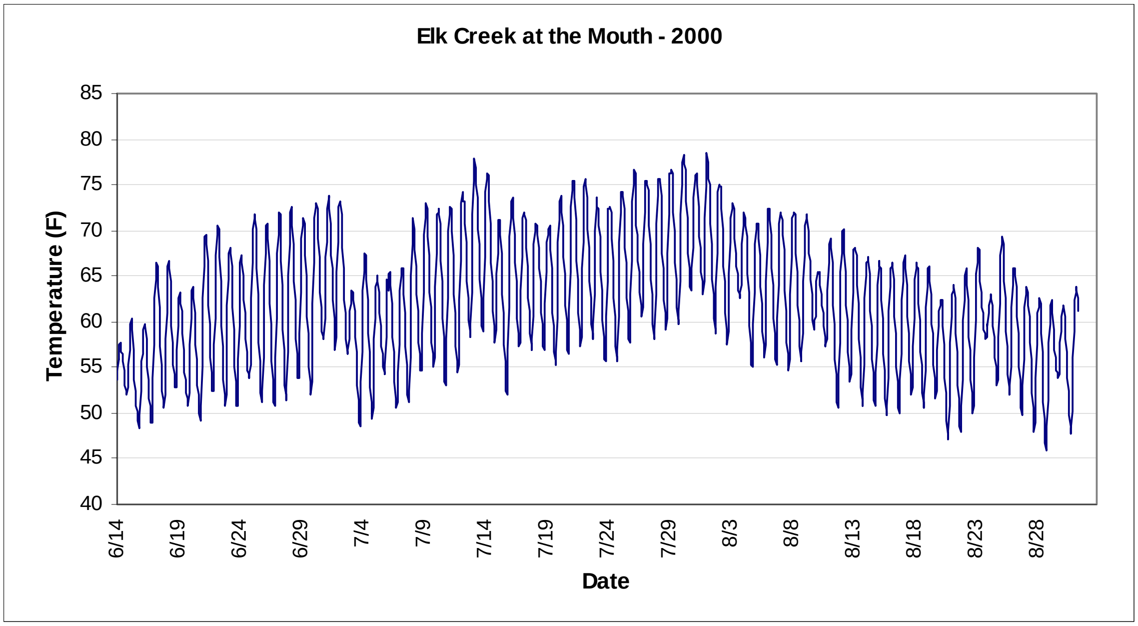


Figure 4-26. Continuous water temperature, Elk Creek at the mouth, 2000.

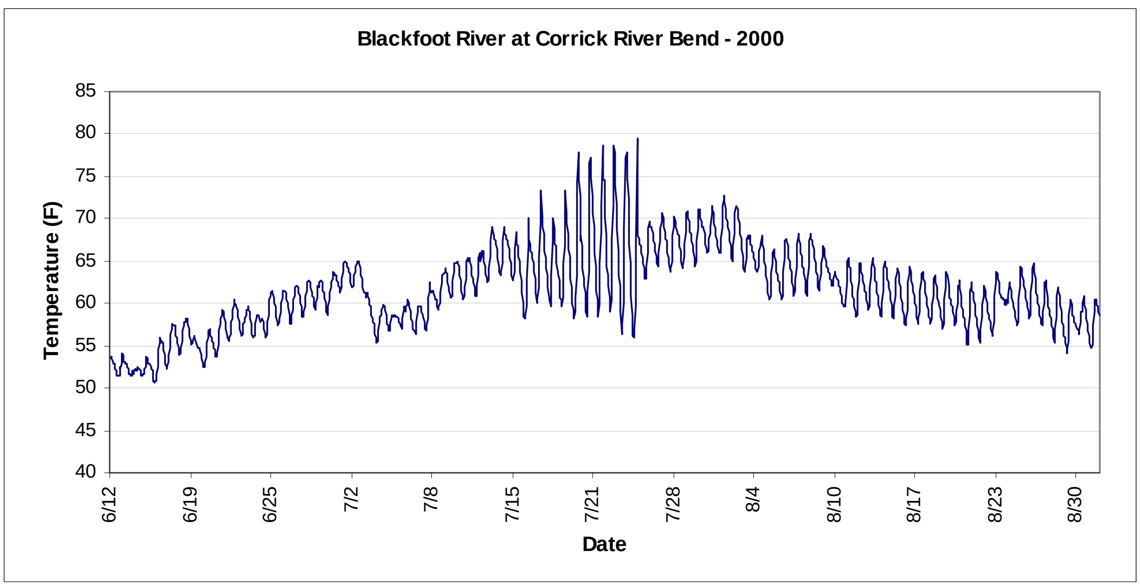


Figure 4-27. Continuous water temperature, Blackfoot River at Corrick River Bend, 2000.

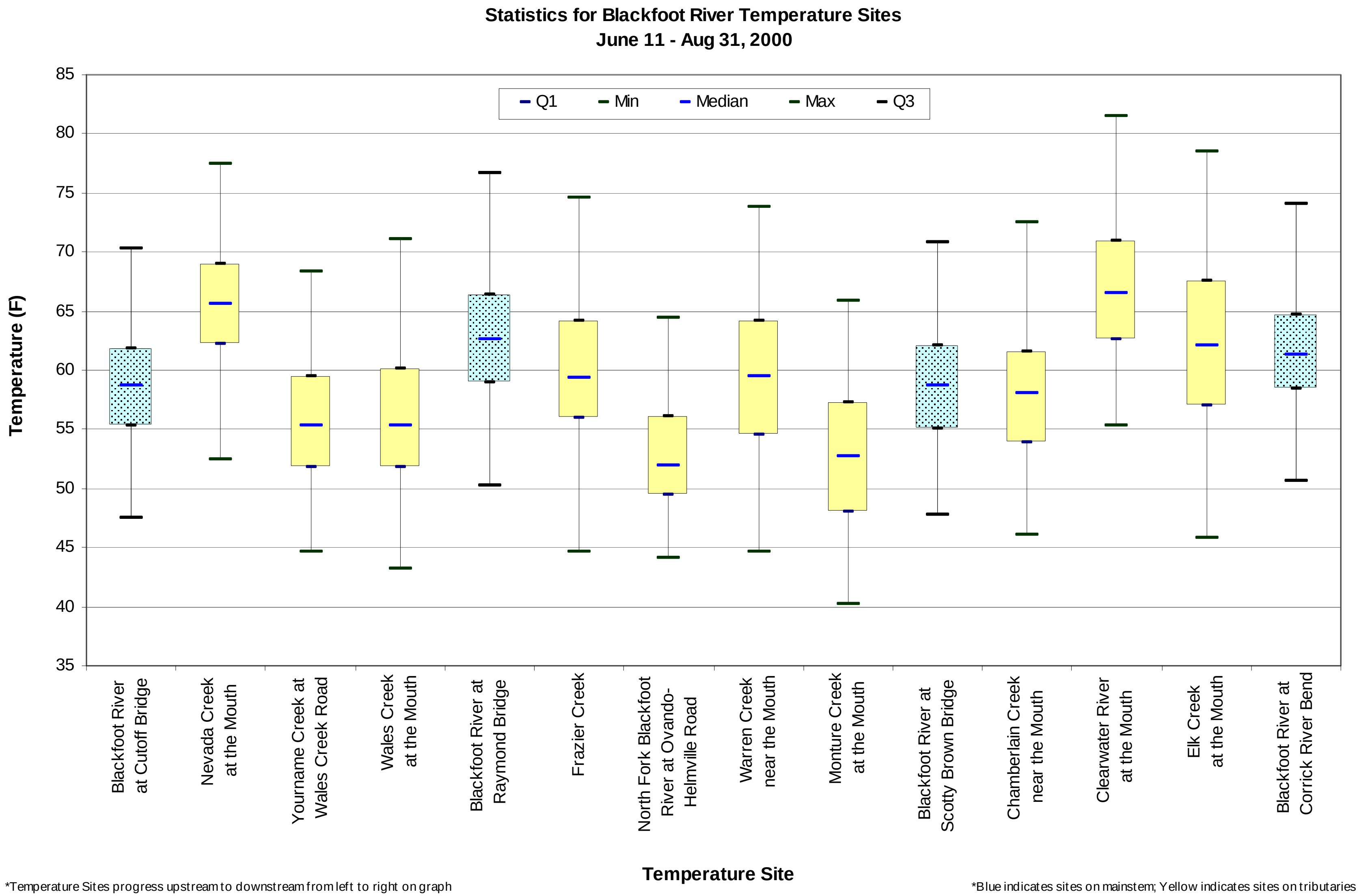


Figure 4-28. Upstream to downstream temperature variation, Blackfoot River, 2000.

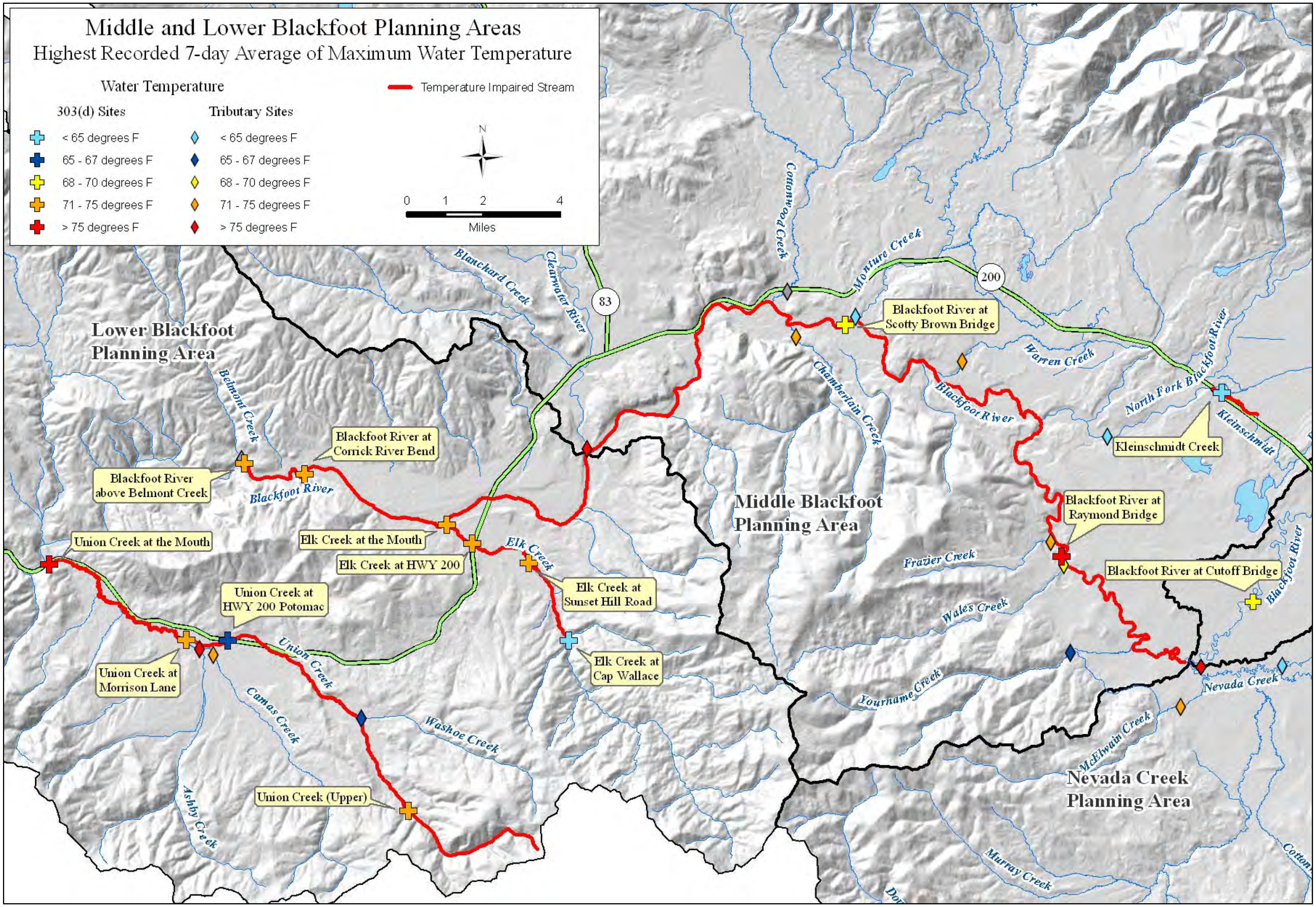


Figure 4-29: Highest 7-day average maximum temperature, Middle Blackfoot planning area, 2000.

Figure 4-30 and Figure 4-31 display the daily maximum and seven-day average maximum temperatures respectively at the four monitoring sites on the Blackfoot River during the summer of 2000. The site at Cutoff Bridge had the coolest maximum temperature throughout the summer, while the site at Raymond Bridge had the warmest maximum temperature for most of the summer. Maximum temperatures are slightly cooler at the other two sites at Scotty Brown Bridge and at Corrick River Bend. Figure 4-29, which displays the highest maximum temperature recorded during the summer of 2000 at all the sites, shows that Raymond Bridge is located upstream from these two sites. Thus, the largest increase in water temperatures on the Blackfoot River occurs between Cutoff Bridge and Raymond Bridge

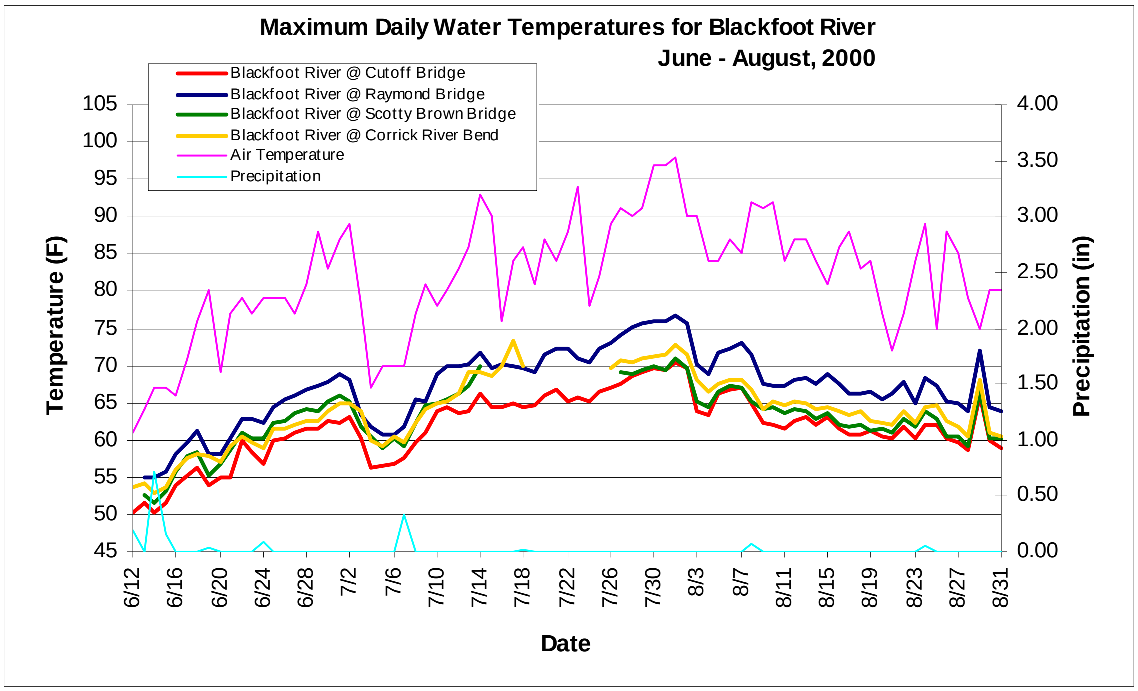


Figure 4-30. Maximum daily water temperature, air temperature, and precipitation, Blackfoot River, 2000.

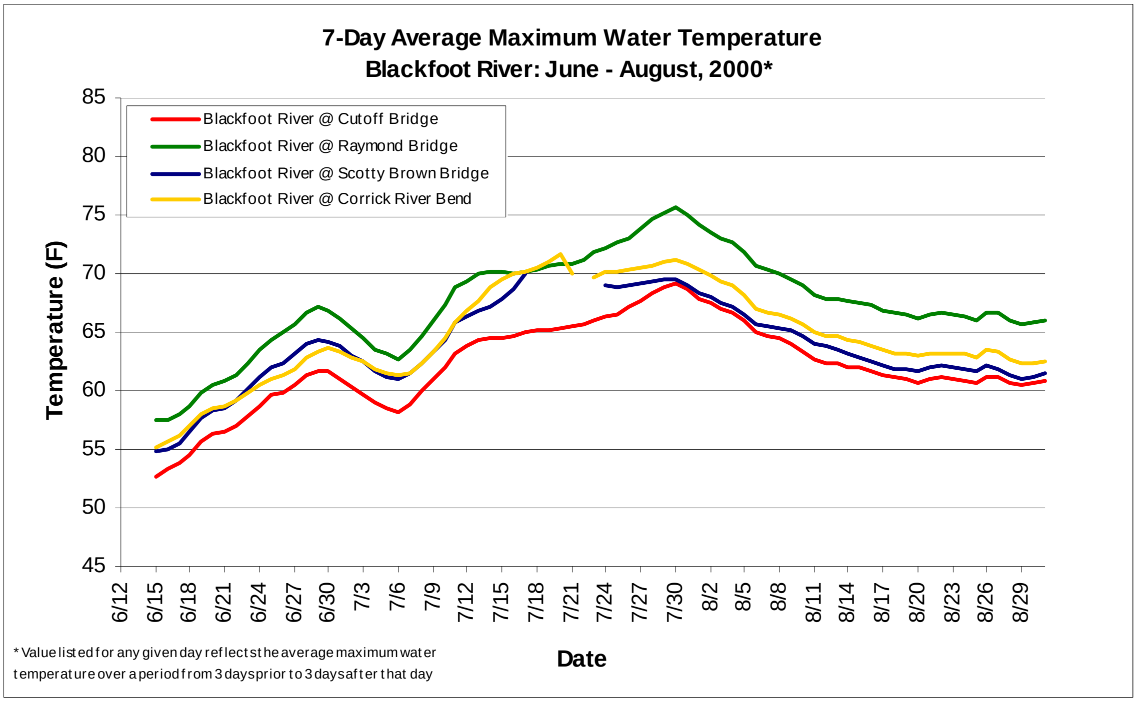


Figure 4-31. 7-day average maximum daily temperatures, Blackfoot Rvier, 2000.

Water temperatures measured at Cutoff Bridge, located above the confluence with Nevada Creek in the upper Blackfoot planning area, are relatively cool for much of the summer of 2000. Flow is 180 cfs during the late July 2000 modeling period. Water temperatures increased moderately at this site from late July through early August. Interpretation of aerial photos indicates that irrigation diversions near this site reduce flow in this reach, resulting in thermal gains during hot summer periods. The Blackfoot then meets Nevada Creek, which contributes approximately 22 cfs of relatively warm water. Because 22 cfs is only 12% of the Blackfoot River flow of 180 cfs, the increase in Blackfoot River temperature is relatively small. However, the Blackfoot then travels through a wide, un-shaded reach with irrigation withdrawals, where thermal gains are significant. By the time water reaches the Raymond Bridge, it has warmed significantly.

Farther downstream, cooler Blackfoot River water temperatures measured at Scotty Brown Bridge are indicative of cold-water contribution from the North Fork of the Blackfoot River and Monture Creek. Both of these streams contribute large volumes of cool water to the Blackfoot River throughout the summer. Between the site at Scotty Brown Bridge and the site downstream at Corrick River Bend the Clearwater River has the highest water temperatures of any Blackfoot River tributary and contributes a substantial amount of water. This is reflected in slightly warmer temperatures on the Blackfoot River at Corrick River Bend.

4.2.3. Elk Creek

The Montana FWP temperature database has temperature data collected at four sites on Elk Creek. However, not all four sites have available data for any one year. Three of the sites have data from 2002, while one site at the mouth of Elk Creek has data from 2003. Figure 4-32 through Figure 4-35 display continuous water temperature readings collected at the four monitoring sites during the summers of 2002 and 2003. For all sites, the highest water temperatures of the summer occur around mid-July. Note the increased range in diurnal temperature variation from the site at Cap Wallace downstream to the site at Highway 200, while minimum temperatures remain similar. This reflects an increase in maximum daily temperatures from site to site, upstream to downstream. The range in diurnal temperature is similar between the Highway 200 site and the next site downstream at the mouth of Elk Creek.

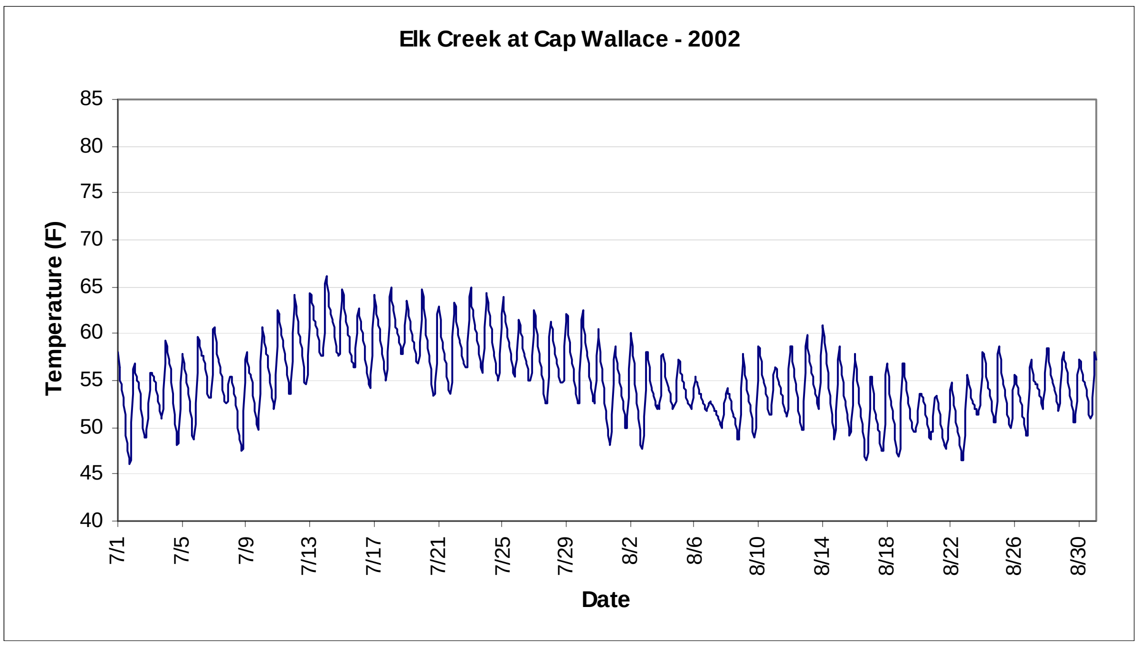


Figure 4-32. Continuous water temperature, Elk Creek at Cap Wallace, 2002.

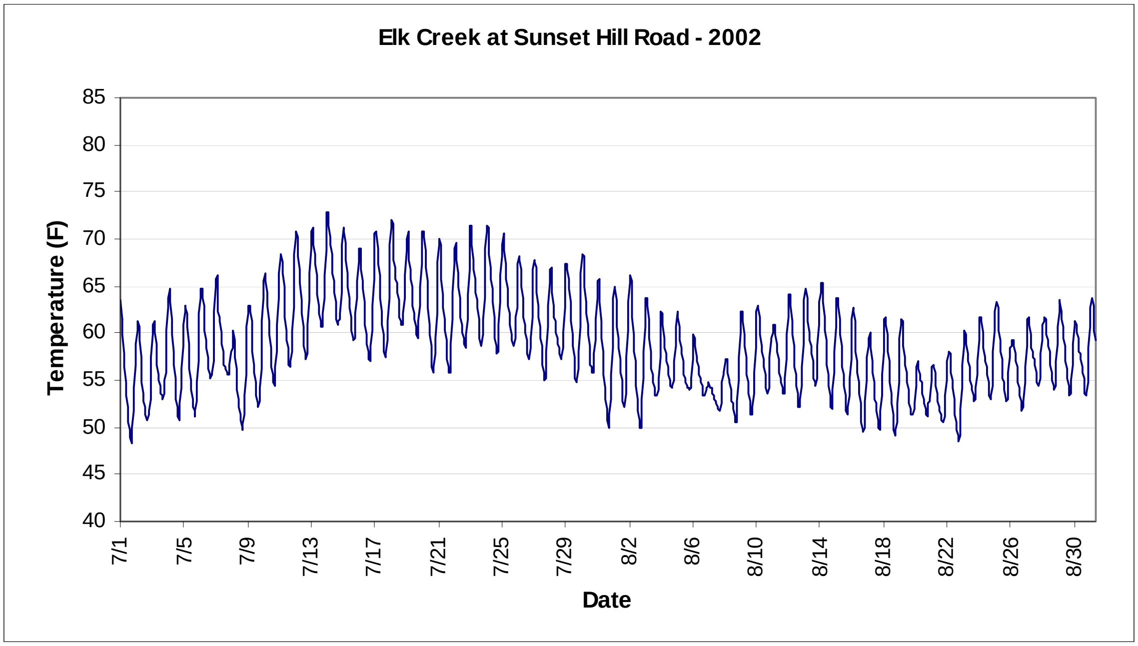


Figure 4-33. Continuous water temperature, Elk Creek at Sunset Hill Road, 2002.

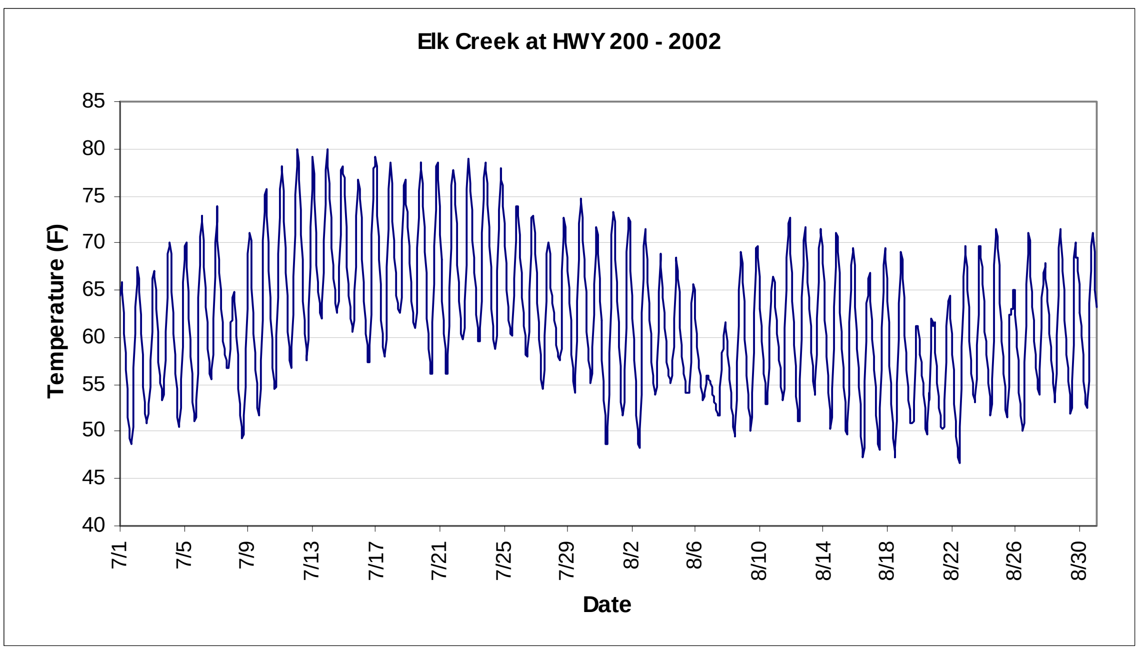


Figure 4-34. Continuous water temperature, Elk Creek at Highway 200, 2002.

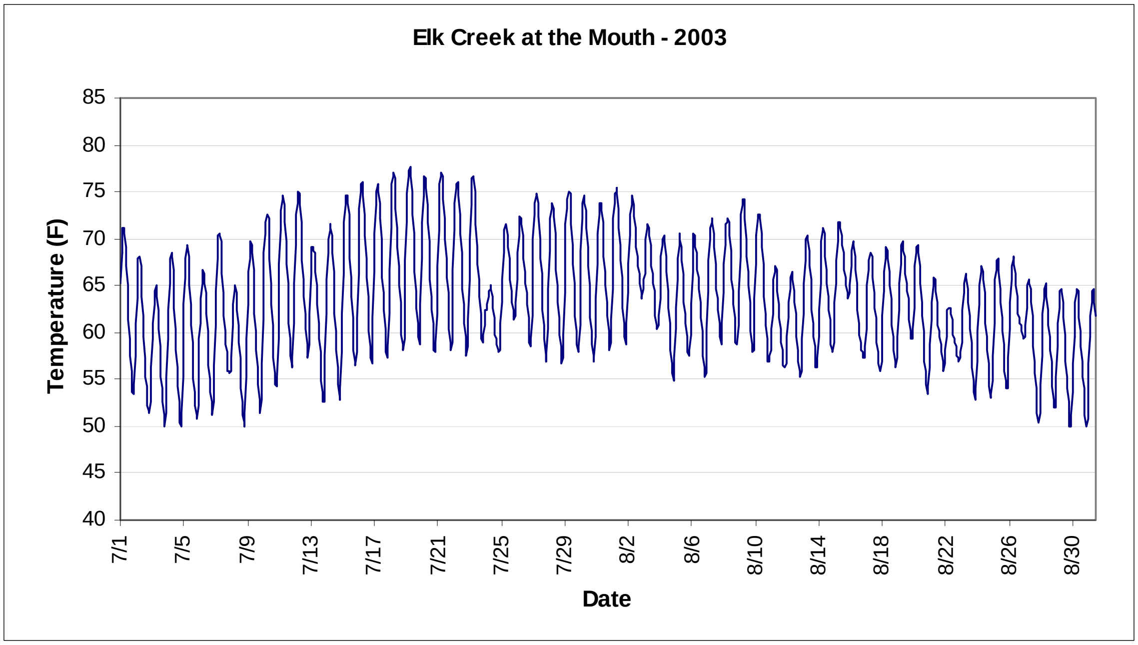


Figure 4-35. Continuous water temperature, Elk Creek at the mouth, 2003.

The statistical distribution of temperatures at the four monitoring sites also illustrates the trends seen in the daily temperatures graphs (Figure 4-36).

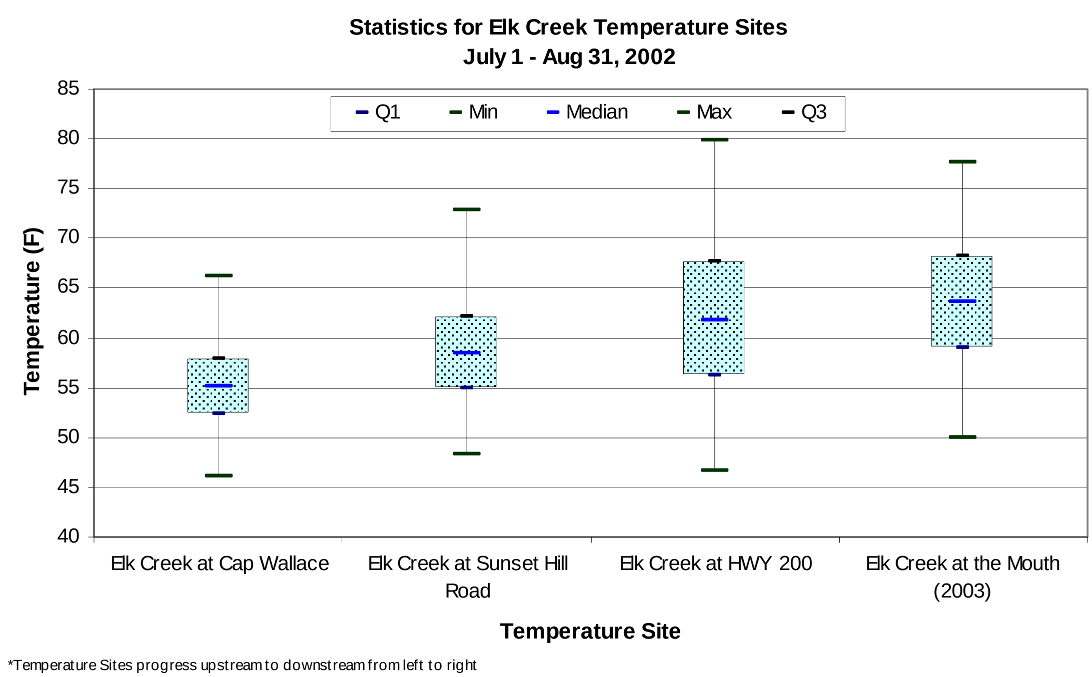


Figure 4-36. Upstream to downstream temperature variation, Elk Creek, 2002.

Daily maximum and seven-day average maximum temperatures at the four monitoring sites on Elk Creek during the summer of 2002 and 2003 also show the coolest maximum water temperatures recorded at the upstream site, Cap Wallace. The warmest maximum water temperatures are at Highway 200 or the mouth of Elk Creek. Maximum water temperatures increase steadily from upstream to downstream, and were highest during the summer in mid-July for all sites.

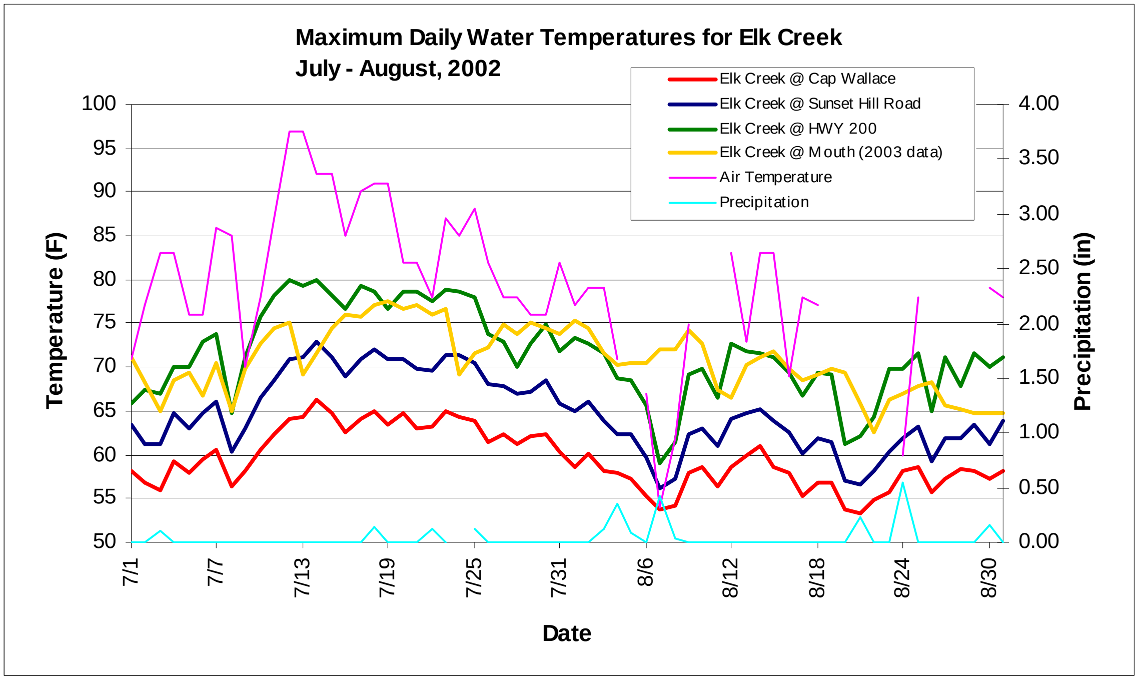


Figure 4-37. Maximum daily water temperature, air temperature, and precipitation, Elk Creek, 2002.

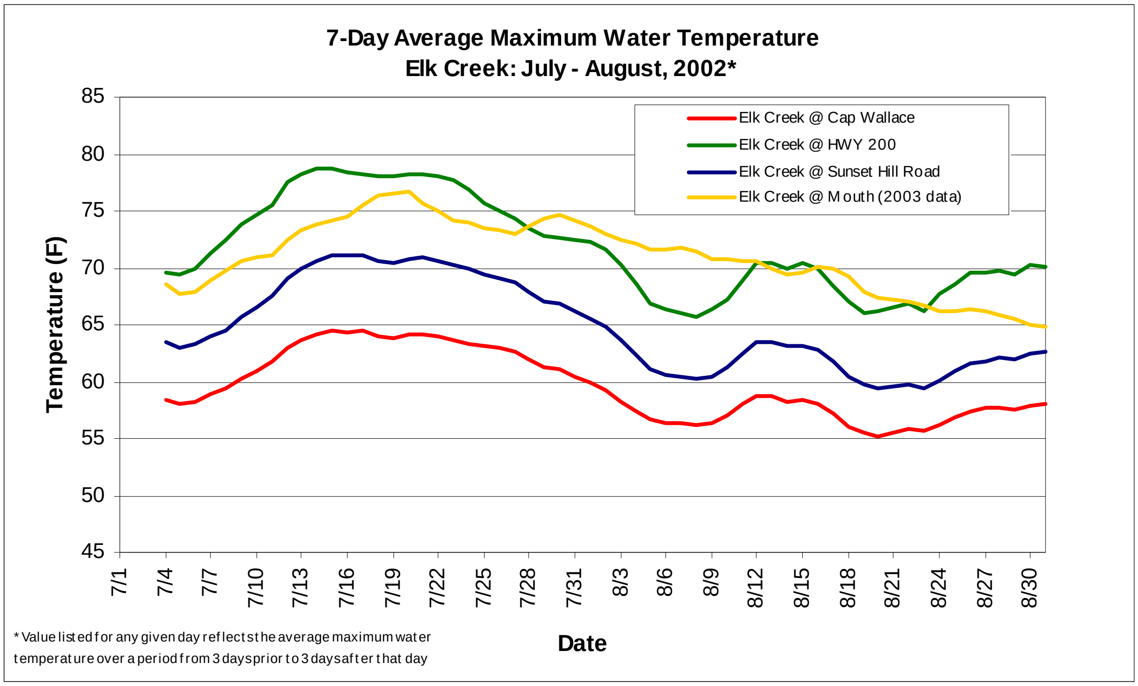


Figure 4-38. 7-day average maximum daily temperatures, Elk Creek, 2002.

Above Cap Wallace Gulch, Elk Creek is cold from headwater streams that flow through drainages with dense coniferous forests. Downstream from Cap Wallace, the valley widens considerably, and air photos depict a lack of riparian shading on much of Elk Creek downstream to Highway 200. This likely produces large thermal gains during hot summer days, as confirmed by warm stream temperature measurements on Elk Creek at Sunset Hill Road and at Highway 200. Further downstream, temperatures measured at the mouth of Elk Creek are similar to temperatures measured Highway 200. Although these data represent different years, air photos and field reconnaissance conducted during the summer of 2006 indicate that this reach of Elk Creek has a high density of woody vegetation that shades much of Elk Creek. This suggests that Elk Creek incurs little or no solar warming downstream of Highway 200.

4.2.4. Union Creek

Union Creek, like Elk Creek, is located within the Lower Blackfoot Planning Area. Although no tributaries of Union Creek are on the 303(d) list for temperature impairments, temperature data is available for some tributaries that contribute water to Union Creek. The Montana FWP temperature database contains data collected in 2002 for four sites on Union Creek and for three sites on tributary streams. Figure 4-39 through Figure 4-45 display continuous water temperature data collected at the seven monitoring sites during the summer of 2002. These figures illustrate that for all the sites the warmest temperatures during the summer of 2002 occurred in mid-July, although for some sites water temperatures in mid-August were also high. The drop in temperature around Aug 8 at all sites indicates a cool and rainy period (Figure 4-47).

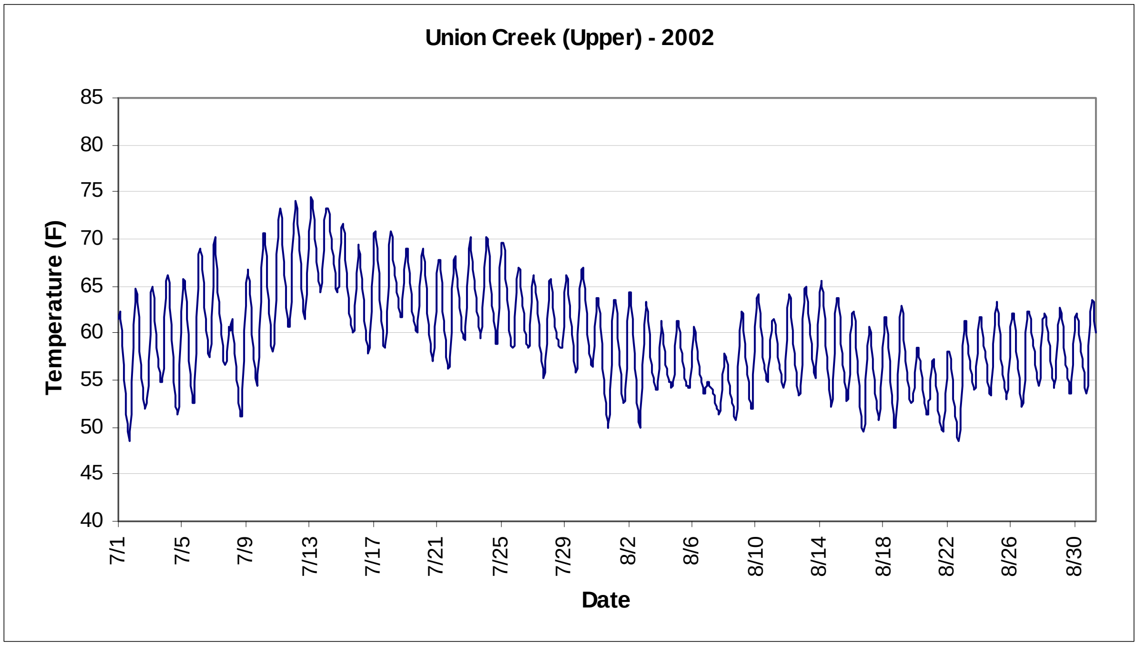


Figure 4-39. Continuous water temperature, Union Creek (Upper), 2002.

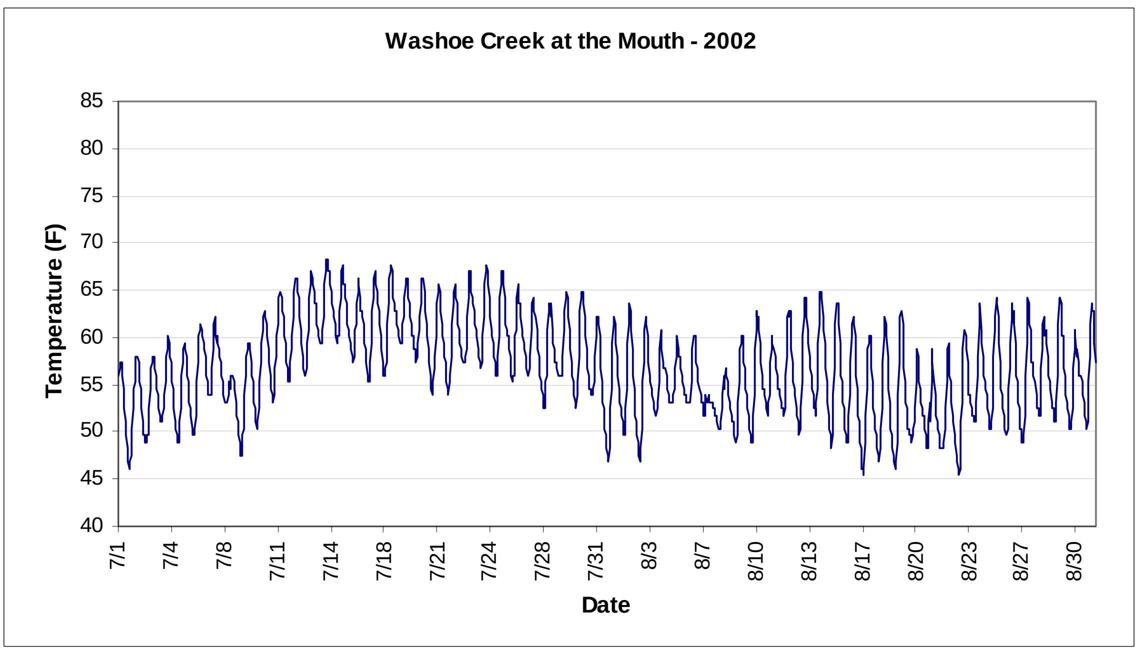


Figure 4-40. Continuous water temperature, Washoe Creek at the mouth, 2002.

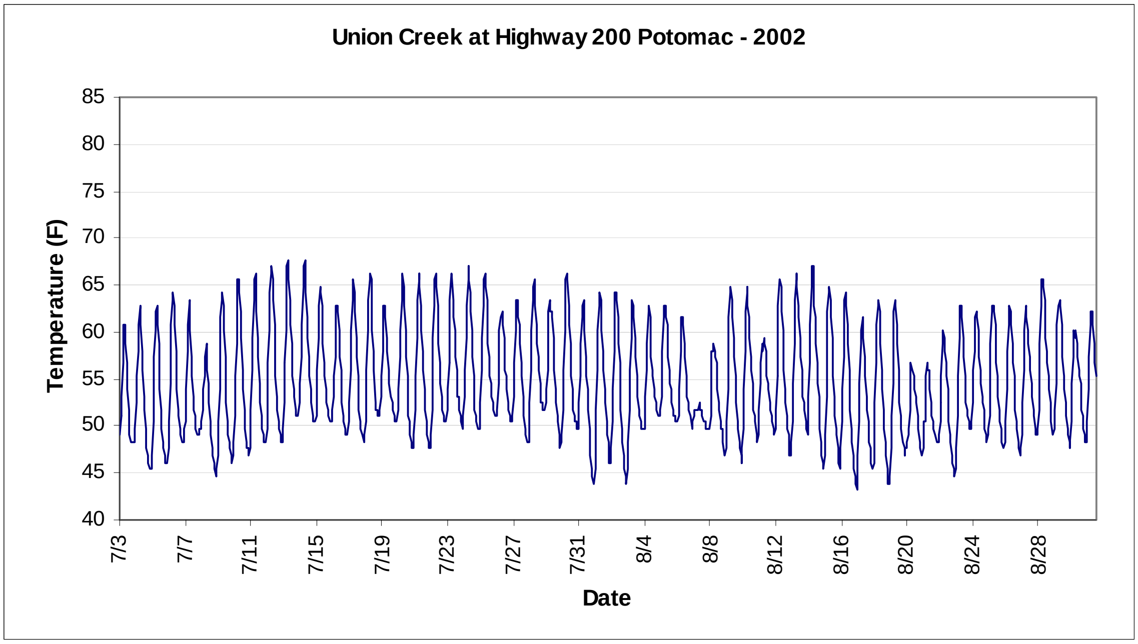


Figure 4-41. Continuous water temperature, Union Creek at Highway 200 Potomac, 2002.

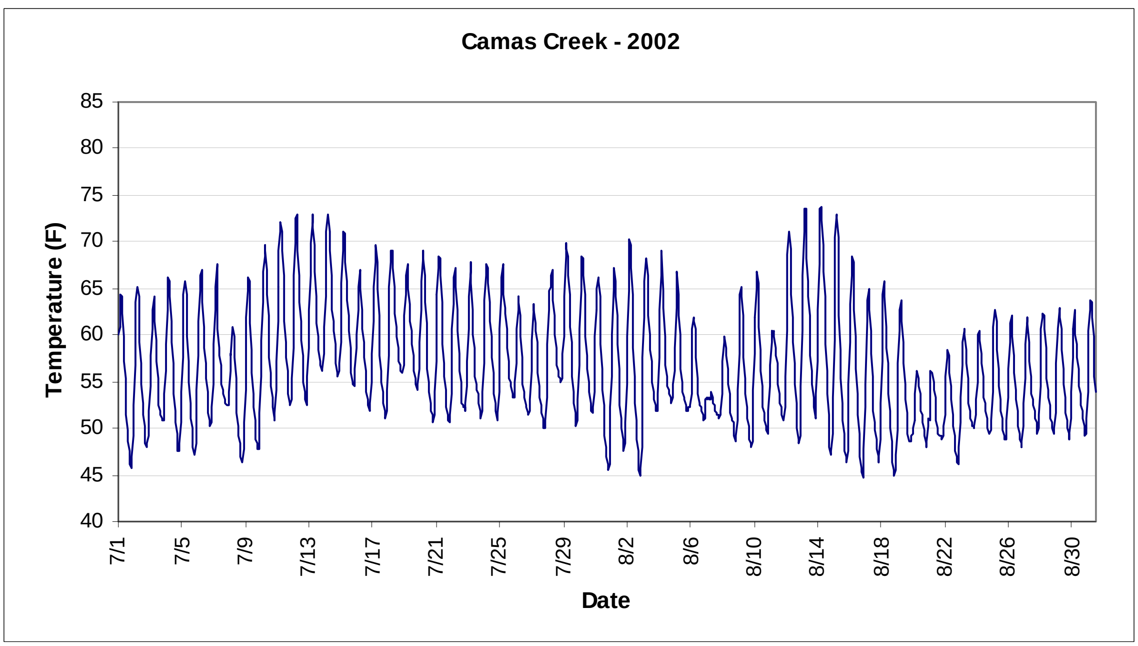


Figure 4-42 Continuous water temperature, Camas Creek, 2002.

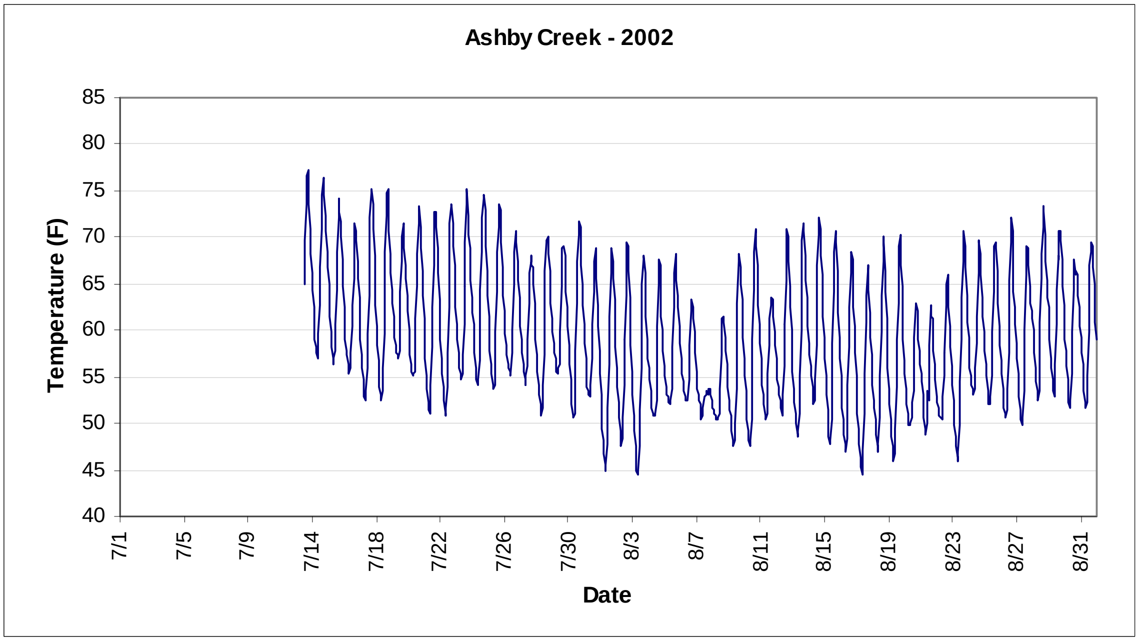


Figure 4-43. Continuous water temperature, Ashby Creek, 2002.

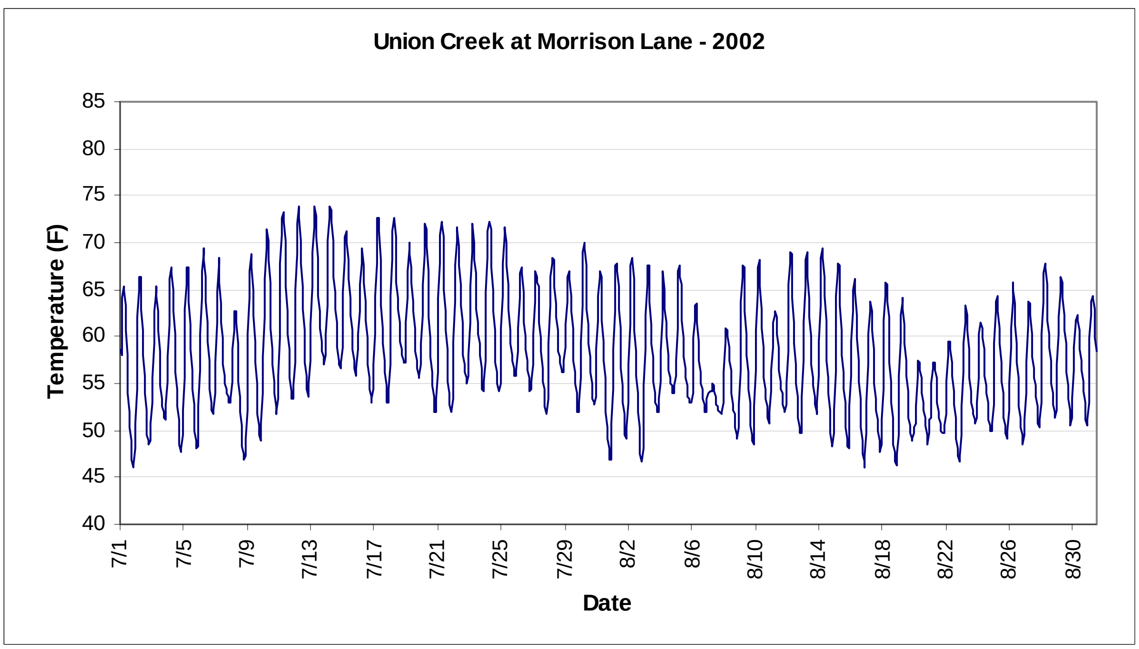


Figure 4-44. Continuous water temperature, Union Creek at Morrison Lane, 2002.

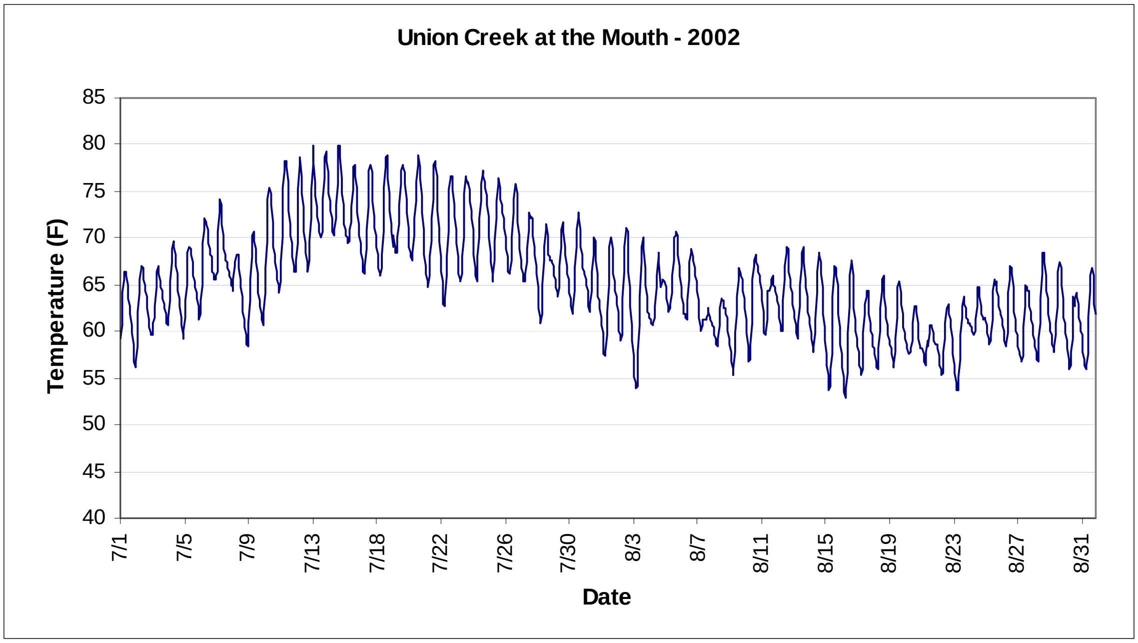


Figure 4-45. Continuous water temperature, Union Creek at the mouth, 2002.

The plot of the distribution of summer temperatures shows that upper Union Creek has a wide range of water temperatures and high daily maximum temperatures (Figure 4-46). The maximum temperature and range in measured temperatures decreases slightly at Highway 200 before increasing again at Morrison Lane and at the mouth of Union Creek. Tributary streams Camas Creek and Ashby Creek both had high maximum temperatures and a wide range in measured temperatures. Washoe Creek has a much narrower range in measured water temperatures and a lower measured maximum water temperature.

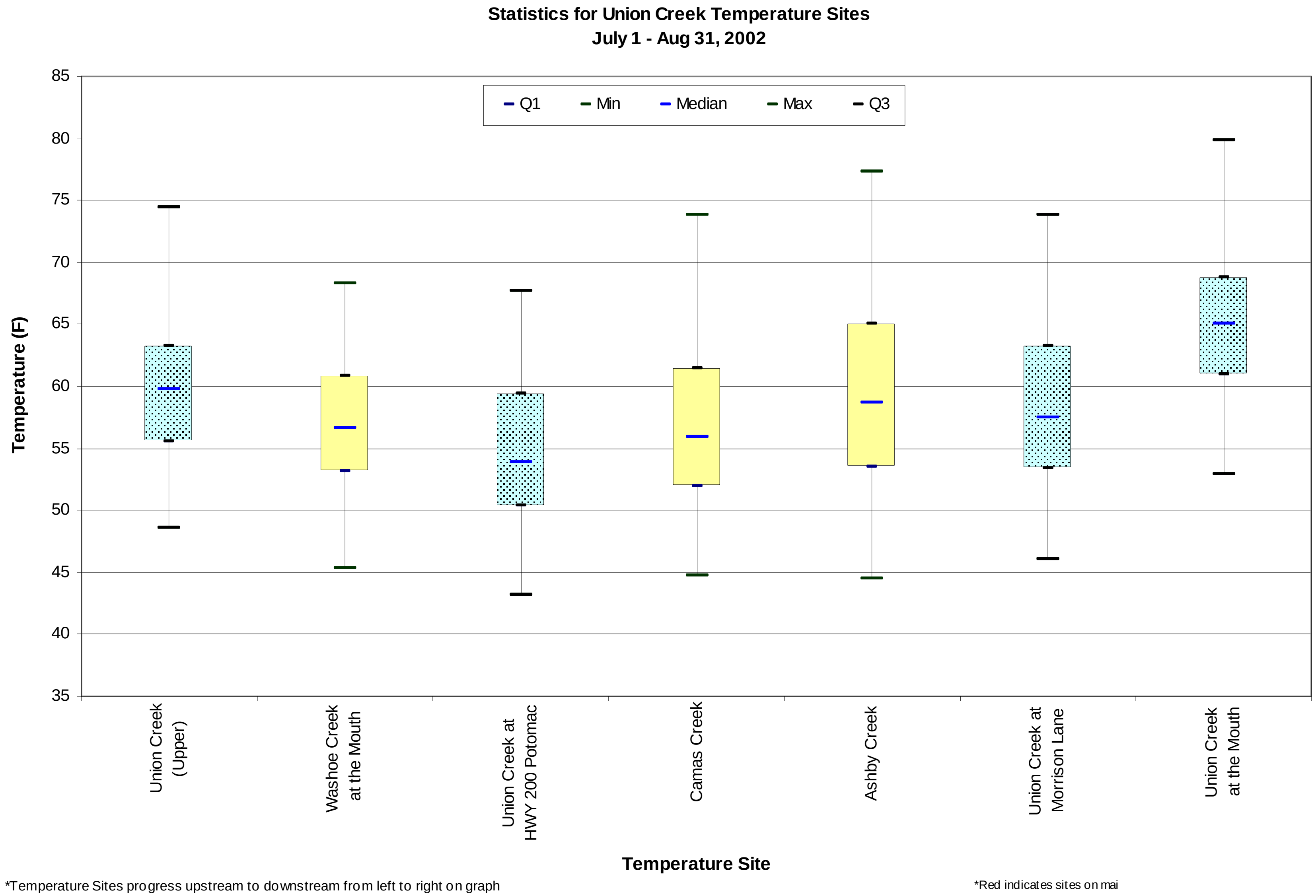


Figure 4-46. Upstream to downstream temperature variation, Union Creek, 2002.

The daily maximum and seven-day average maximum temperature graphs show that the highest temperatures in mid July, concurrent with sustained warmest air temperatures (Figure 4-47 and Figure 4-48). Unlike the other streams on the 303(d) list, however, the site farthest upstream, located in upper Union Creek, does not have the lowest maximum temperature. Maximum temperatures decrease downstream from this site at Morrison Lane, before rising again further downstream at Highway 200. The site at the mouth of Union Creek has the highest maximum temperatures for much of the summer of 2002.

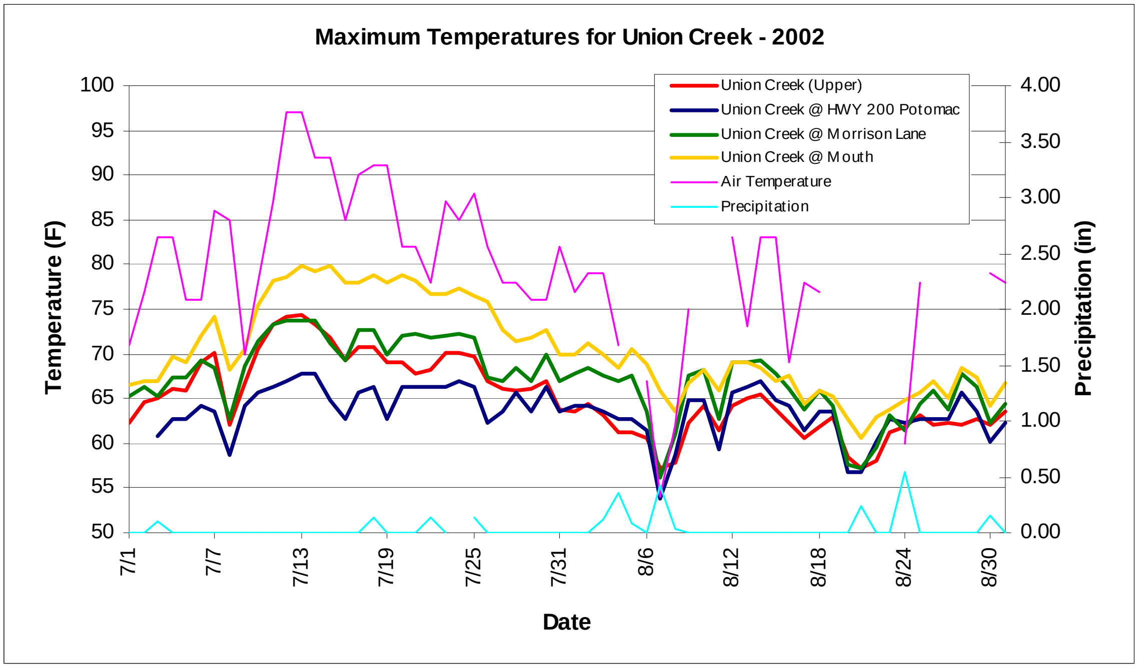


Figure 4-47. Maximum daily water temperature, air temperature, and precipitation, Union Creek, 2002.

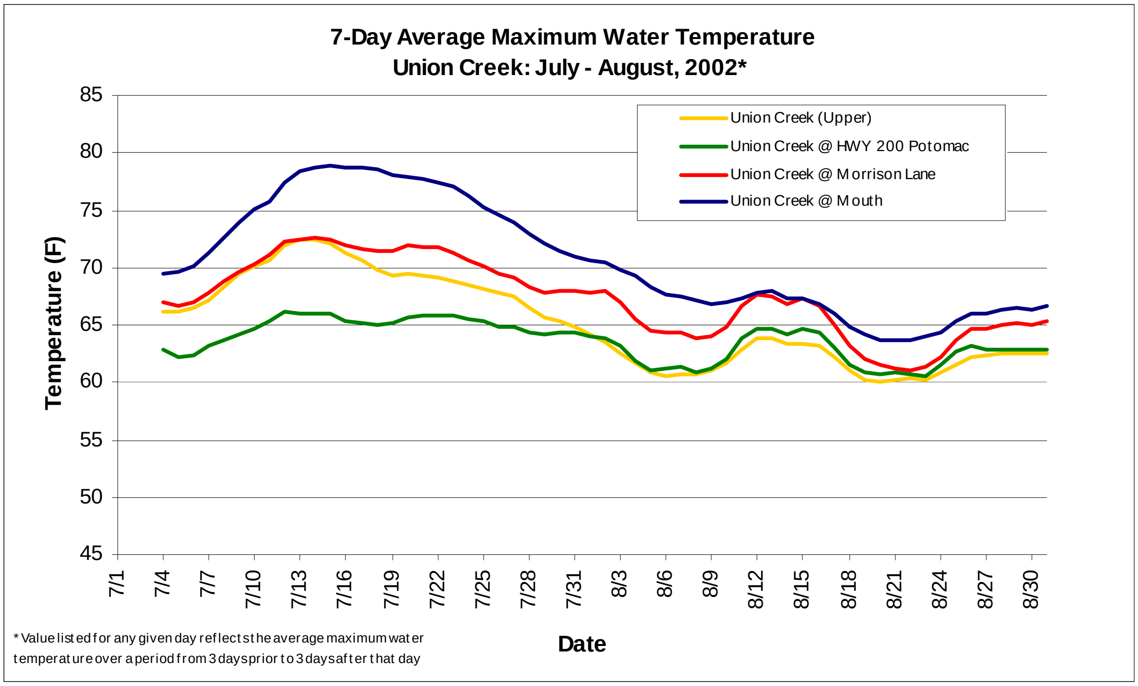


Figure 4-48. 7-day average maximum daily temperatures, Union Creek, 2002.

Warm water temperatures measured at the upper Union Creek site are not typical of other headwater streams in this study. Air photos depict extensive timber harvest in the area above this site. The reduction in vegetation cover may result in increased solar heating of Union Creek and other tributaries. In addition, the geology of the headwaters area of Union Creek consists mostly of Proterozoic sedimentary rocks that are less likely to host springs than Paleozoic sedimentary rocks or Cretaceous granitic rocks in nearby drainages. Therefore, the higher headwater temperatures in Union Creek may be natural, anthropogenic, or a combination.

Union Creek enters a wide agricultural valley bottom area after it leaves its headwaters area. Several irrigation diversions remove flow and numerous ranchettes with horse pastures cause habitat, sediment, temperature, and nutrient impairments. Union Creek receives cool water from Washoe Creek that partially mitigates these impacts. About one mile further downstream, Union Creek passes through a small canyon constricted by Proterozoic bedrock. Groundwater upwelling in this area likely provides additional cool water. Downstream of this canyon, Union Creek is a losing stream until about ½ mile past the first Highway 200 crossing where it picks up cold groundwater from Tertiary sedimentary rocks to the north. By the second crossing, one mile further downstream, Union Creek has gained considerable flow. Between the second Highway 200 crossing and Morrison Lane, Union Creek flows through a highly impacted agricultural valley bottom where lack of shade contributes to higher water temperatures. In addition, Camas Creek and Ashby Creek contribute warm water to Union Creek in this reach. Downstream from Morrison Lane, air photos depict a lack of riparian shading on much of Union Creek. In addition to limited riparian vegetation, irrigation diversions reduce flow in these reaches. This likely results in large thermal gains during hot summer days, as seen in warm stream temperature measurements at the mouth of Union Creek.

4.3. Temperature Modeling

The following sections describe the SNTEMP temperature modeling conducted for the Blackfoot River and Kleinschmidt Creek in the Middle Blackfoot Planning Area.

4.3.1. Blackfoot River

The Blackfoot River model simulated temperatures for the Blackfoot River within the Middle Blackfoot planning area by modeling the Blackfoot River from Cutoff Bridge to Corrick River Bend. This section of the Blackfoot River extends for 49.8 miles (Figure 4-49). However, Corrick River Bend is located in the Lower Blackfoot planning area . To model temperatures for the Blackfoot River only in the Middle Blackfoot planning area, temperatures were simulated at a location below the Clearwater River.

Construction

Point, calibration, diversion, segment, and temperature output nodes are included in the Blackfoot River model (Figure 4-49). All tributaries in the model are included as point sources to the Blackfoot River. An additional point source below Chamberlain Creek accounted for return flow from the prairie pothole area around the mouth of Cottonwood Creek. Three calibration points in the network are located at Raymond Bridge, Scotty Brown Bridge, and at the end of the network at Corrick River Bend. Only one diversion point is in the model, below Yourname Creek to account for several irrigation pumps.

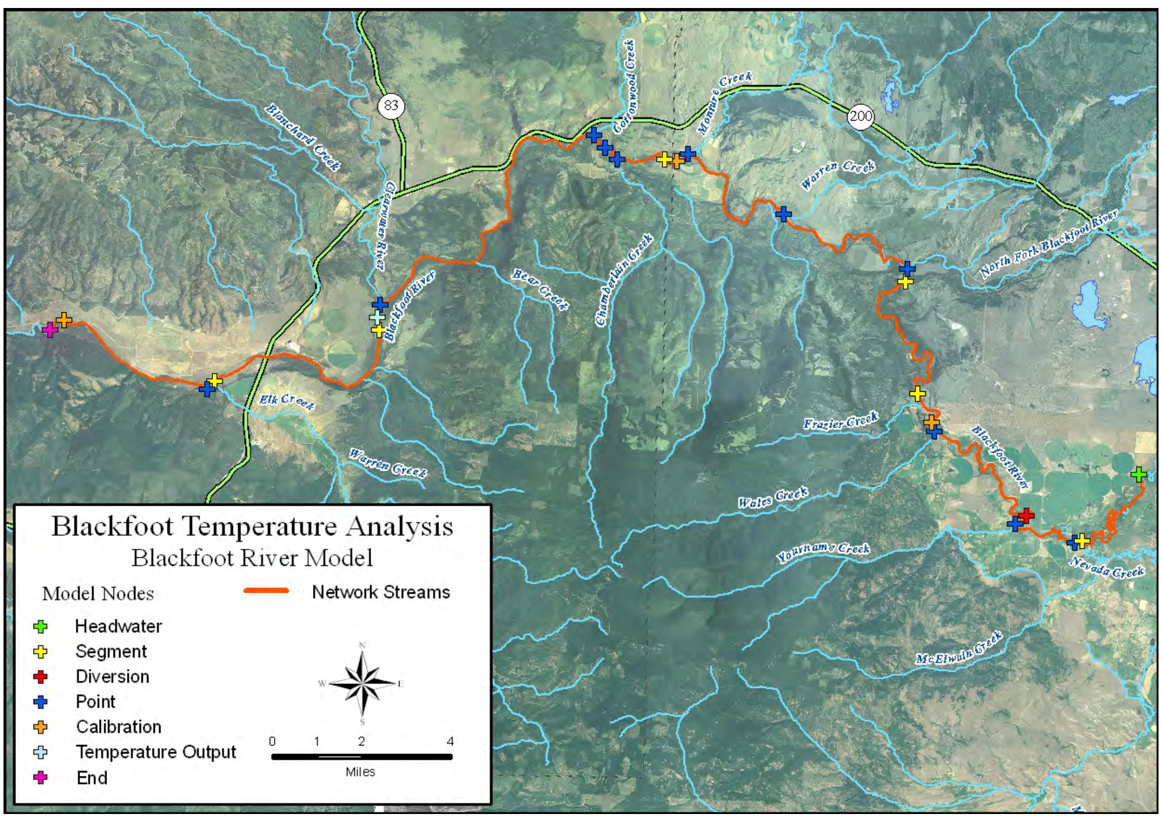


Figure 4-49. Schematic of the Blackfoot River model network and model nodes.

Modeling for the Blackfoot River is for the period July 27 – 29, 2000. A three-day modeling period ensured that water completed travel through the network during the modeling period. Table 4-3 lists stream geometry and general vegetation characteristics for the Blackfoot River model. About 47 percent of the Blackfoot River has streambank woody vegetation. However, since the Blackfoot River is wide, with an average low flow width of 130 feet, this vegetation provides little shade (maximum of 8.74% in reach Blkft12).

Stream	***Modeling Period***	***Length (mi)***	***Average Low Flow Width (ft)***	***Average Streambank Vegetation (%)***	***Average Shade (%)***
Blackfoot River	July 27 - 29, 2000	47.7	129.6	46.7	3.9

*Streambank vegetation is percent of total stream bank in model that consists of vegetation capable of producing shade. Shade is percent of total stream surface area covered by shade.

Table 4-3. Current stream conditions for the Blackfoot River SNTEMP model.

Stream geometry and hydrology data for the modeling period were input into the model (Table 4-5). For each segment and headwater node, flow, width, Manning's-n, and shade are input, while water temperature is required for headwater nodes. All other nodes receive only water temperature and/or flow data.

Water temperature input to the model at the Cutoff Bridge is 64.1^{o} F. Warm water contributions include Nevada Creek (70.9^{o} F) and the Clearwater River (69.9^{o} F). Monture Creek and the North Fork of the Blackfoot River contribute large volumes of cool water at 58.0^{o} F and 55.7^{o} F, respectively.

Meteorological data for the modeling period of July 27 – 29, 2000 were summarized and input into the model (Table 3-11). These data are representative of hot and dry conditions that lead to temperature extremes in the stream. The average daily maximum air temperature, 90.7^{o} F, was one of the hotter periods in the summer of 2000.

Modeling Period	***Air Temperature (F) (mean)***	***Relative Humidity (%) (mean)***	***Wind (mph) (mean)***	***Possible Sun (%)***	***Dust Coefficient***	***Ground Reflectivity***
July 27 - July 29, 2000	90.7	47.3	3.8	95	0.05103	0.27690

Table 4-4. Meteorological input data for the Blackfoot River SNTEMP model.

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Table 4-5. Input data for the Blackfoot River model.

Segment	*Node*	*Stream Mile*	*Water Temperature (F)*	*Flow (cfs)*	*Stream Width (ft)*	*Manning's n*	*Bankline Veg (%)*	*Shade (%)*	*Comments*
Cutoff Bridge to Nevada Ck	Headwater*	71.5	64.1	180	68.0	0.062	19.8	2.0	Network initiation at Cutoff Bridge
Nevada Ck to Frazier Ck	Segment	66.5	32.0	180	102.5	0.062	13.4	1.0	Above Nevada Creek
	Point	66.5	70.9	22					Nevada Creek
	Point	64.6	59.9	5					Yourname Creek
	Diversion	64.0		8					Below Yourname Ck
	Point	59.6	59.1	4					Wales Creek
	Calibration	59.3	69.0	203					Temperature site at Raymond Brdg
Frazier Ck to above North Fork Blackfoot River	Segment	58.3		203	116.0	0.062	51.4	9.2	Segment within canyon section
Above North Fork to below Monture Ck	Segment	53.3	32.0	203	148.0	0.062	50.6	2.6	Segment break above North Fork
	Point	53.3	55.7	219					North Fork Blackfoot River
	Point	49.2	63.9	8					Warren Creek
	Point	45.3	58.0	81					Monture Creek
	Calibration	45.1	64.2	511					Site at Scotty Brown Bridge
Below Monture Ck to below Clearwater River	Segment	45.0		511	143.3	0.062	60.3	5.7	Segment break below calibration
	Point	43.5	64.2	5					Chamberlain Creek
	Point	42.9	55.0	20					Point source return flow
	Point	42.5	60.8	27					Cottonwood Creek
	Point	34.4	69.9	73					Clearwater River
	Output	34.3		636					Middle Blackfoot temperature output

Segment	***Node***	***Stream Mile***	***Water Temperature (F)***	***Flow (cfs)***	***Stream Width (ft)***	***Manning's n***	***Bankline Veg (%)***	***Shade (%)***	***Comments***
Below Clearwater River to Elk Ck	Segment	34.2		636	157.4	0.062	75.3	5.5	Segment break below the Middle Blackfoot planning area
Elk Ck to Corrick River Bend	Segment	28.5		636	160.0	0.062	56.9	1.9	Segment break above Elk Ck
	Point	28.4	68.4	15					Elk Creek
	Calibration	24.0	67.4	651					Site at Corrick River Bend
	End	23.9		651					End of network

*Headwater is the starting point of each stream in the model network

Calibration

Model calibration used three sites on the Blackfoot River. The model required no calibration for the first two upstream sites, at Raymond Bridge and at Scotty Brown Bridge, since simulated and observed temperatures were within the required calibration tolerance (Table 4-6 and Table 4-7). However, calibration was necessary for the site at Corrick River Bend, with initial simulated mean and maximum temperatures 1.56^{o} F and 2.85^{o} F greater, respectively, than observed temperatures.

To calibrate temperatures at Corrick River Bend, the thermal gradient for the model segment from Scotty Brown Bridge to Corrick River Bend was adjusted (Table 4-8). Thermal gradient is a segment specific parameter that is a measure of thermal exchange between the streambed and water in joules/meter^{2}second/^{o}C (Bartholow, 2004). Streams that interact with groundwater typically have a higher thermal gradient and a suppressed diurnal temperature variation. Field observations suggest the between Monture Creek and Cottonwood Creek, the Blackfoot River receives and interacts with cool groundwater coming from the prairie pothole topography to the north of this reach. Increasing thermal gradient helped account for groundwater/surface water interactions and yielded satisfactory calibration results (Table 4-8).

Location: Blackfoot River at Raymond Bridge					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	69.04	74.96	NA	NA	NA
Initial Model Run	68.65	74.12	-0.39	-0.84	Default Parameter Values

Table 4-6. Initial model and calibration results for the Blackfoot River at Raymond Bridge.

Location: Blackfoot River at Scotty Brown Bridge					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	64.19	69.03	NA	NA	NA
Initial Model Run	64.53	69.80	0.34	0.77	Default Parameter Values

Table 4-7. Initial model and calibration results for the Blackfoot River at Scotty Brown Bridge.

Location: Blackfoot River at Corrick River Bend (End of Network)					
Calibration Iteration	***Temperature (F)***		***Difference from Observed Temp (F)***		***Parameter Changed***
	Mean	***Max***	***Mean***	***Max***	
Observed Temperature	67.43	70.59	NA	NA	NA
Initial Model Run	68.99	73.44	1.56	2.85	Default Parameter Values Thermal gradient = 1.65
1	68.59	72.93	1.16	2.34	Thermal Gradient - Increase to 2.65
2	68.36	72.34	0.89	1.75	Thermal Gradient - Increase to 3.25
3	68.20	72.45	0.77	1.35	Thermal Gradient - Increase to 3.65 Manning's n – Increase to 0.080

Table 4-8. Initial model and calibration results for the Blackfoot River at Corrick River Bend.

Simulations

The mainstem Blackfoot River covered by this model does not suffer from significant riparian degradation or channel widening. In addition, reaches of the Blackfoot that have up to 79% woody bankline vegetation only have up to 8.74% shade due the large channel width. Therefore, targets for vegetation are not applicable for the Blackfoot River. Temperature targets focused on Nevada Creek water temperatures input to the Blackfoot.

Two SNTEMP simulations were conducted for the Blackfoot River. One simulation was the calibrated model under current conditions. A second simulation modeled natural conditions, defined as current vegetation conditions with reduced Nevada Creek input temperatures to meet targets for that stream. The target for the mouth of Nevada Creek is to reduce mean daily temperature from 71.9^{o} to 69.2^{o} F. The results of this simulation show negligible change (0.23^{o} F) in Blackfoot River temperatures at Raymond Bridge (Table 4-9). Below the Clearwater River, the temperature reduction is negligible (Table 4-10).

Since Nevada Creek is the only known source of temperature impairments addressable by TMDLs and is currently causing less than a 0.5^{o} F increase in temperature in the Blackfoot River, then the Blackfoot River does not fit the TMDL temperature impaired criteria.

Model Run	Temperature (F)		Difference from Calibration (F)		Comments
	Mean	Max	Mean	Max	
Observed Temperature	69.04	74.96	NA	NA	NA
Calibrated Temperature	68.66	74.19	NA	NA	Simulated temperature with current stream conditions
Simulation 1	68.43	73.99	-0.23	-0.20	Natural Conditions: Reduce Nevada Creek temperature to 69.2° F

Table 4-9: Simulation results for the Blackfoot River at Raymond Bridge.

Model Run	Temperature (F)		Difference from Calibration (F)		Comments
	Mean	Max	Mean	Max	
Calibrated Model	66.60	70.14	NA	NA	Simulated temperature below the Clearwater River with current stream conditions
Natural Conditions	66.58	70.12	-0.02	-0.02	Current stream conditions; Nevada Creek input under natural conditions

Table 4-10. Simulation results for the Blackfoot River below the Clearwater River.

4.3.2. Kleinschmidt Creek

The Kleinschmidt Creek model is 5.65 miles long from Ward Creek downstream to Rock Creek. The model simulated temperatures at two locations in Kleinschmidt Creek, at Highway 200 and further downstream at Rock Creek (Figure 4-50). The section of Kleinschmidt Creek above Highway 200 extends for 3.4 miles, while the lower section of Kleinschmidt Creek below Highway 200 is 2.3 miles long.

Construction

Nodes in the model identify where hydrology, stream geometry, and temperature data are input in the stream network. No point sources are present in the Kleinschmidt Creek model. However, three flow points below Highway 200 reassign flow, accounting for diffuse groundwater contributions. A calibration point and end of the model network is above the confluence with Rock Creek. To simulate the temperature in the upper section of Kleinschmidt Creek, a temperature output point is in the model below Highway 200. No flow diversions are in the model.

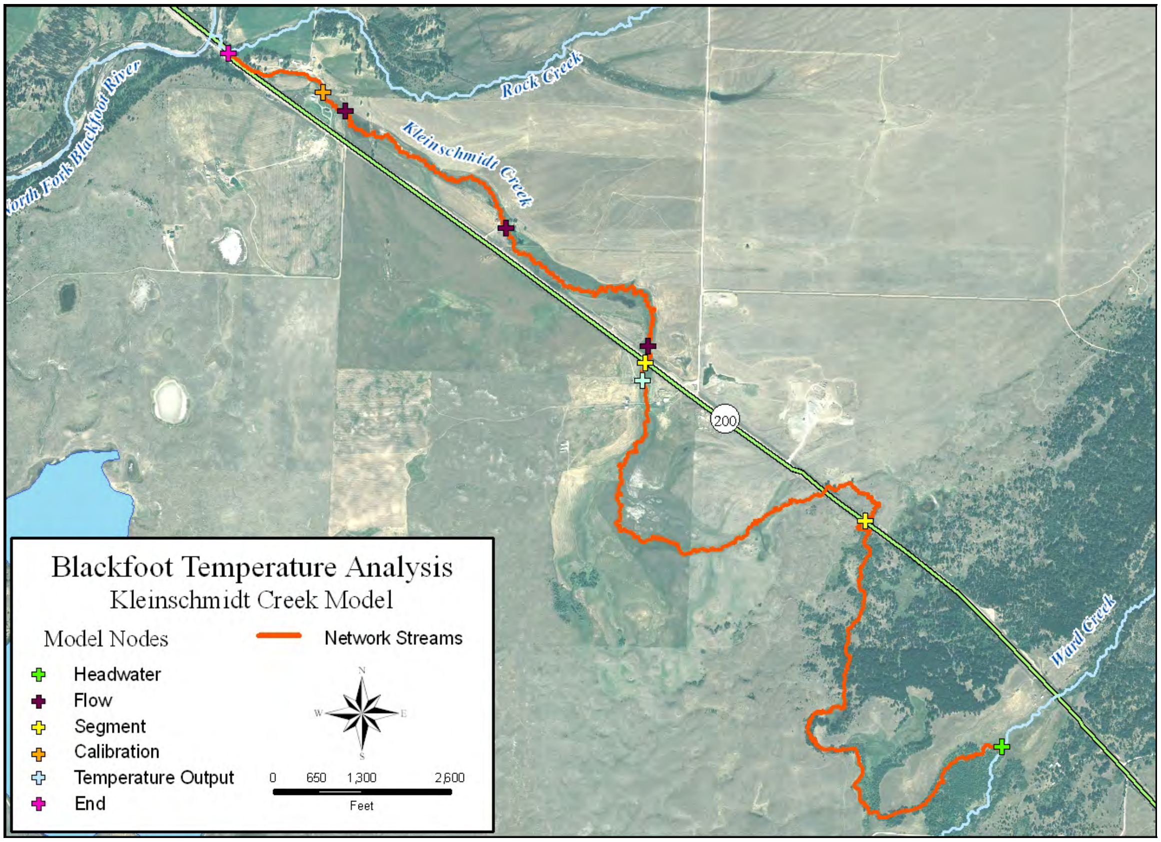

Figure 4-50. Schematic of the Kleinschmidt Creek model network and model nodes.

Modeling for Kleinschmidt Creek is for July 15, 2004. Table 4-11 lists stream geometry and general vegetation characteristics for the Kleinschmidt Creek model. About 23 percent of Kleinschmidt Creek has woody streambank vegetation. Because the width of Kleinschmidt is relatively narrow, this translates to approximately 15 percent shade.

Stream	*Modeling Period*	*Length (mi)*	*Average Low Flow Width (ft)*	*Average Streambank Vegetation (%)*	*Average Shade (%)*
Kleinschmidt Creek	July 15, 2004	5.8	3.0	23.3	14.7

*Streambank vegetation is percent of total stream bank in model that consists of vegetation capable of producing shade. Shade is percent of total stream surface area covered by shade.

Table 4-11. Current stream conditions for the Kleinschmidt Creek SNTEMP model.

Table 4-13 lists data input into the model. For each segment and headwater node, flow, width, Manning's n, and shade must be designated, while water temperature is required for headwater nodes. All other nodes receive only water temperature and/or flow data.

Kleinschmidt Creek from Ward Creek to the first Highway 200 crossing has 63 percent of streambank woody vegetation cover. The remainder of Kleinschmidt Creek downstream is largely devoid of streambank vegetation.

Kleinschmidt Creek flow increases from 2.5 cfs at Highway 200 to 14.4 cfs less than two miles downstream due to groundwater inputs (Blackfoot Challenge, 2005). The groundwater temperature input in the model is 47^{o} F. This temperature is the average of several historical summertime well and spring temperature measurements from this area.

Meteorological data for the July 15, 2004 modeling period were summarized and input into the model (Table 4-12). These data are representative of hot and dry conditions that lead to temperature extremes in the stream. The maximum air temperature this day, 91^{o} F, is one of the hotter days of the summer of 2004.

Modeling Period	***Air Temperature (F) (mean)***	***Relative Humidity (%) (mean)***	***Wind (mph) (mean)***	***Possible Sun (%)***	***Dust Coefficient***	***Ground Reflectivity***
July 15, 2004	70	37.3	8.2	80	0.05865	0.28677

Table 4-12. Meteorological input data for the Kleinschmidt Creek model.

Table 4-13. Input data for the Kleinschmidt Creek model.

Segment	*Node*	*Stream Mile*	*Water Temperature (F)*	*Flow (cfs)*	*Stream Width (ft)*	*Manning's n*	*Bankline Veg (%)*	*Shade (%)*	*Comments*
Ward Ck to HWY 200 (1st crossing)	Headwater[1]	5.8	63.7	2.5	3.0	0.062	63.0	39.8	Divergence of Ward Creek
To HWY 200 (Third Crossing)	Segment	4.0		2.5	3.0	0.062	6.0	4.1	First Highway 200 crossing
	Output	2.4		2.5					Above third HWY 200 crossing
HWY 200 to Rock Ck	Segment	2.3		2.5	3.0	0.062	5.0	3.0	At third HWY 200 crossing
	Flow	2.2	47.0	2.8*					Below HWY 200 crossing
	Flow	1.3	47.0	11.9*					At Tom Rue's house
	Flow	0.5	47.0	14.4*					At Rue/Friede fence
	Calibration	0.4	50.3	14.4					Above Rock Creek
	End	0.1		13.2**					Segment within canyon section

Headwater[1] is the starting point of the model network. * indicates flow adjustment from ground water recharge in reach above this point at a temperature of 47 degrees F. ** indicates flow adjustment from loss of stream flow to ground water.

Calibration

Initial model runs for Kleinschmidt Creek required little calibration (Table 4-14). The first model run simulated a mean and maximum daily temperature within the margin of 0.9° F for calibration. One small adjustment to possible sun percent improved the results slightly.

Location: Kleinschmidt Creek above Rock Creek					
Calibration Iteration	*Temperature (F)*		*Difference from Observed Temp (F)*		*Parameter Changed*
	Mean	*Max*	*Mean*	*Max*	
Observed Temperature	50.34	55.38	NONE	NONE	NONE
Initial Model Run	50.83	55.90	0.49	0.52	Default Parameter Values
1	50.72	55.42	0.38	0.04	Sunshine % - Decrease to 80%

Table 4-14. Initial model and calibration results for Kleinshmidt Creek above Rock Creek.

Simulations

Five SNTEMP simulations evaluated the effect of shade on stream temperatures in the upper and lower sections of Kleinschmidt Creek. Shade is expressed as percent of streambanks with woody vegetation. One simulation was the calibrated model that used current streambank vegetation conditions. A second simulation modeled natural conditions defined by Montana DEQ (ARM, 2006) as 95% streambank woody vegetation. Two additional simulations modeled streambank vegetation at levels between current and natural condition. A final simulation assessed the amount of vegetation required to keep temperatures within the one degree F allowable increase from natural conditions.

Kleinschmidt Creek above Highway 200

For Kleinschmidt Creek from Ward Creek downstream to Highway 200, the model simulated a mean temperature of 62.53° F under natural conditions (Table 4-15 and Figure 4-51). This value is lower than the temperature simulated with current stream conditions by 2.52° F. Increasing streambank vegetation to 60 percent reduces mean temperature by 1.17° F from current conditions, while reducing streambank vegetation to 20 percent increases mean temperature by 0.36° F. Simulating 69 percent streambank woody vegetation resulted in a simulated mean temperature of 63.52° F. This is the one-degree allowable increase from natural conditions, and is the target for Kleinschmidt Creek above Highway 200.

Model Run	***Temperature (F)***		***Difference from Calibration (F)***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Calibrated Model	65.05	72.99	NA	NA	Simulated temperature with current stream conditions
Simulation 1	65.41	72.43	0.36	-0.56	20% of bank with vegetation cover
Simulation 2	63.88	68.88	-1.17	-4.11	60% of bank with vegetation cover
Target	63.52	68.09	-1.53	-4.90	69% of bank with vegetation cover
Natural Conditions	62.53	65.84	-2.52	-7.15	95% of bank with vegetation cover

Table 4-15. Simulation results for Kleinschmidt Creek above Highway 200.

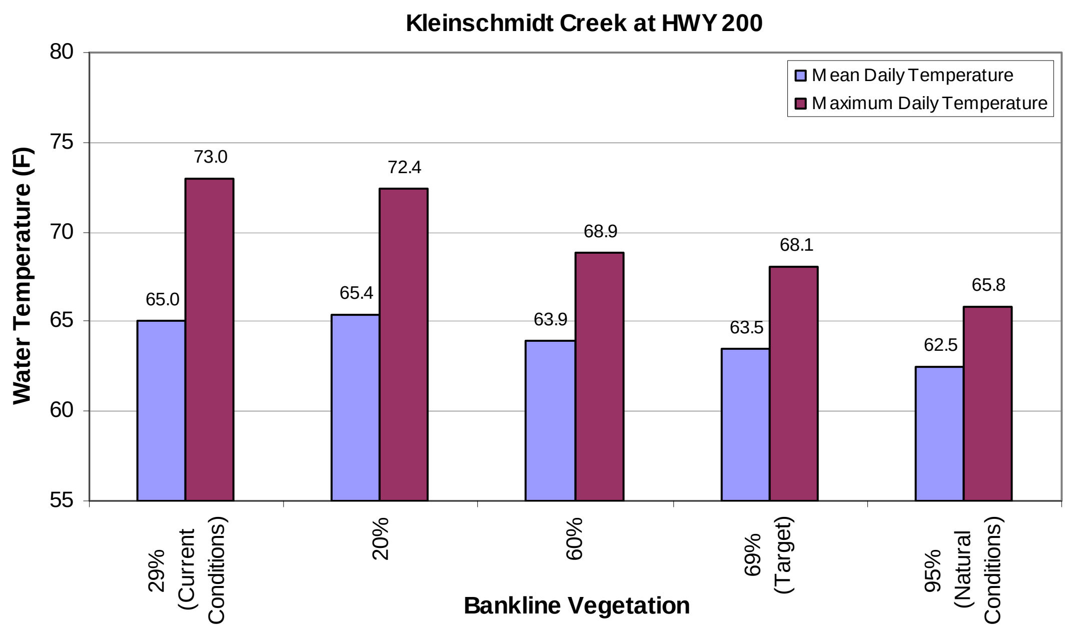

Figure 4-51. Simulated mean and maximum temperature with change in bankline vegation for Kleinschmidt Creek above Highway 200.

Kleinschmidt Creek below Highway 200

For natural conditions, the model simulated a mean temperature of 50.04^{o} F for Kleinschmidt Creek at Rock Creek (Table 4-16 and Figure 4-52). This value is lower than temperatures simulated with current stream conditions by 0.84^{o} F, indicating that current temperatures fall within the one-degree allowable increase from natural conditions established by Montana DEQ (ARM, 2006).

Model Run	Temperature (F)		Difference from Calibration (F)		Comments
	Mean	Max	Mean	Max	
Calibrated Model	50.88	55.78	NA	NA	Simulated temperature with current stream conditions
Simulation 1	50.83	55.26	-0.05	-0.52	20% of bank with vegetation cover
Simulation 2	50.40	53.65	-0.48	-2.13	60% of bank with vegetation cover
Natural Conditions	50.04	52.34	-0.84	-3.44	95% of bank with vegetation cover

Table 4-16. Simulation results for Kleinschmidt Creek above Rock Creek.

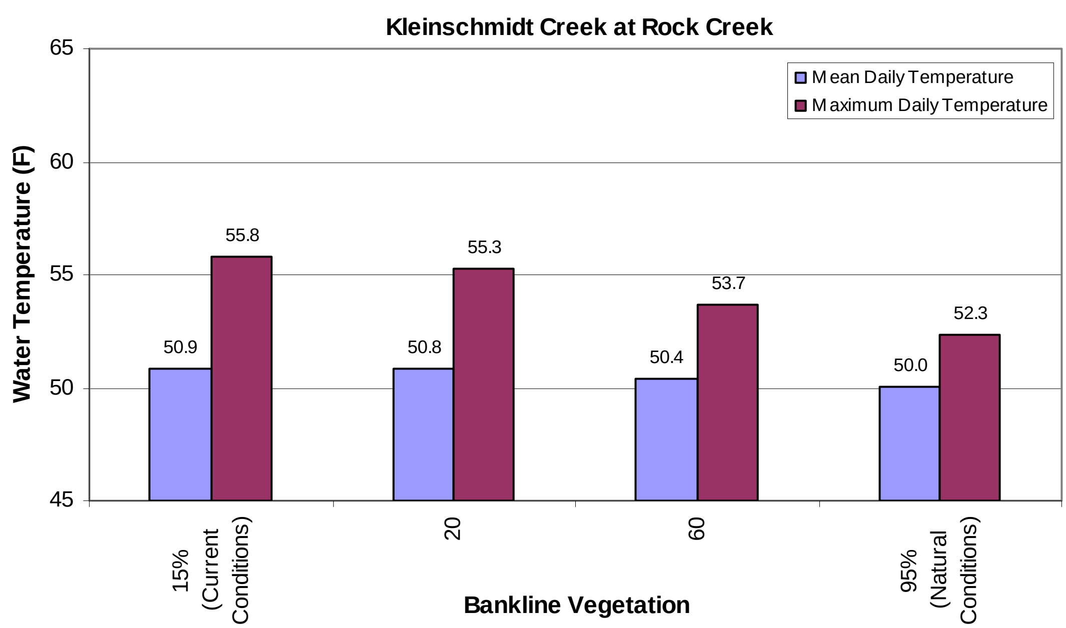

Figure 4-52. Simulated mean and maximum temperature with change in bankline vegation for Kleinschmidt Creek above Rock Creek.

These results indicate that Kleinschmidt Creek from Highway 200 downstream to Rock Creek currently does not fit the TMDL temperature impairment criteria. Restoration efforts on Kleinschmidt Creek downstream from Highway 200 reduced stream surface area and improved temperatures over prior conditions (see Section 4.2.1). Above Highway 200, establishment of woody vegetation on 69 percent of Kleinschmidt Creek reduces temperature in the SNTEMP simulations by 1.53^{o} F, highlighting the difference between the two reaches.

5. Summary

The Montana FWP database was a robust source of input and calibration temperature data for the models. The base parameter field data and filed photos provided a reliable data source from which to derive shade data necessary for the models. Hydrologic gage data, instantaneous flow measurements, and visual estimates from July 2004 provided acceptable flow data for input to the models. Combined, these data sources allowed modeling of stream temperatures using SNTEMP and provided the results necessary to establish temperature targets for 303(d) list streams in the Blackfoot River watershed. Table 5-1 below summarizes the results of the SNTEMP modeling and presents the targets that provide the necessary data for TMDL development.

Table 5-1: Temperature and target summary, Nevada Creek and Middle Blackfoot planning areas.

Model	*Stream*	*Sources of Temperature Impairment*	*Current Conditions Mean Daily Temperature °F*	*Natural Condition*	*Natural Conditions Mean Daily Temperature °F*	*TMDL Target*	*Comments*
Upper Nevada SNTEMP	Upper Nevada Creek	Lack of shade	64.15	95% bankline vegetation	60.66	73% streambank woody vegetation	Results indicate 1° F allowable increase in mean temperature requires 73% bankline vegetation
Lower Nevada SNTEMP	Lower Nevada Creek	Lack of shade, irrigation withdrawals, channel widening	70.41	95% bankline vegetation,	68.29	65% streambank woody vegetation	15% reduction in irrigation withdrawals gave minimal improvement in temperature, channel narrowing is not a natural condition
	Cottonwood Creek	Lack of shade, irrigation withdrawals	69.55	95% bankline vegetation	62.67	87% streambank woody vegetation	15% reduction in irrigation withdrawals gave minimal improvement in temperature
	Lower Douglas Creek	Lack of shade, irrigation withdrawals	69.30	95% bankline vegetation	63.37	84% streambank woody vegetation	15% reduction in irrigation withdrawals gave minimal improvement in temperature

Model	***Stream***	***Sources of Temperature Impairment***	***Current Conditions Mean Daily Temperature °F***	***Natural Condition***	***Natural Conditions Mean Daily Temperature °F***	***TMDL Target***	***Comments***
Upper Douglas SSTEMP	Upper Douglas Creek	Lack of shade, irrigation withdrawals, large reservoir surface area	68.37	95% bankline vegetation on stream segments, reduced reservoir surface area by 20% (consolidation into 2 reservoirs)	63.87	65% streambank woody vegetation (-1.5° F) and 20% reduction in thermal heating from reservoirs (-3° F)	SSTEMP results indicate that ~5° F of the 20° F temperature increase in this area is attributable to lack of shade. The remaining 15° F is from reservoir heating.
Kleinschmidt SNTEMP	Kleinschmidt Creek	Lack of shade	50.88	95% bankline vegetation	50.04	69% streambank woody vegetation in reach above 3rd Highway 200 crossing	Natural condition scenarios in the upper part of Kleinschmidt Creek (above Hwy 200) improve temperature. Below Hwy 200, groundwater influx lowers temperature.
Blackfoot SNTEMP	Blackfoot River	Tributary inputs	66.60	Nevada Creek input under natural conditions scenario	66.58	Anthropogenic temperature increases on the Blackfoot River are less than the 1° F allowable increase. No target required.	Natural condition scenario in Nevada Creek improves mainstem water temp by only 0.23° F at the Raymond Bridge. Suggests the Blackfoot is not impaired for temperature

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Tennessee Valley Authority, 1972. Heat and Mass Transfer between a Water Surface and the Atmosphere. Water Resource. Lab. Rep. 14. Norris, TN. 166 pp.

A. Appendix A: Additional Continuous Water Temperature Graphs

Upper Nevada Creek – 2001

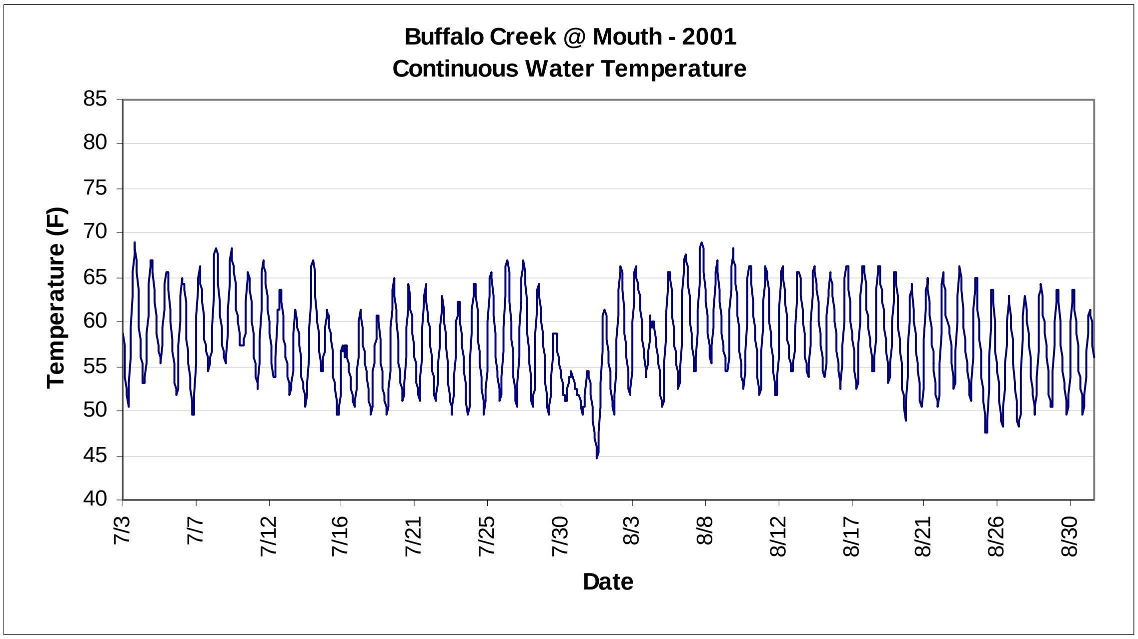


Figure A-1. Continuous water temperature, Buffalo Creek, July 3 – August 31, 2001.

Lower Nevada Creek – 2004

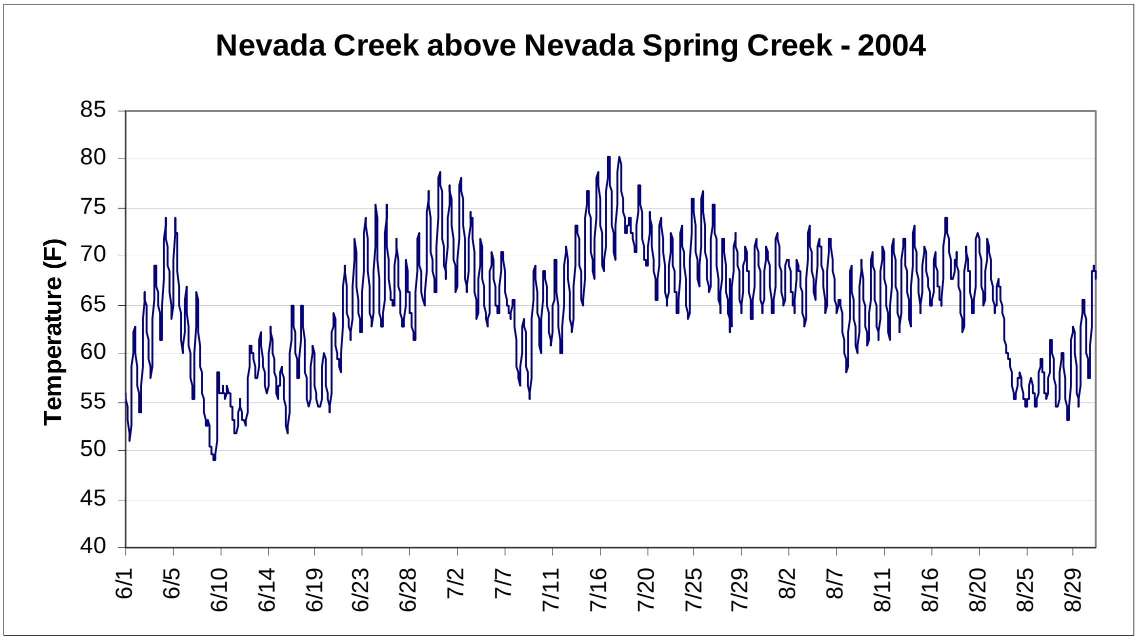


Figure A-2. Continuous water temperature, Nevada Creek above Nevada Spring Creek, June 1 – August 31, 2004.

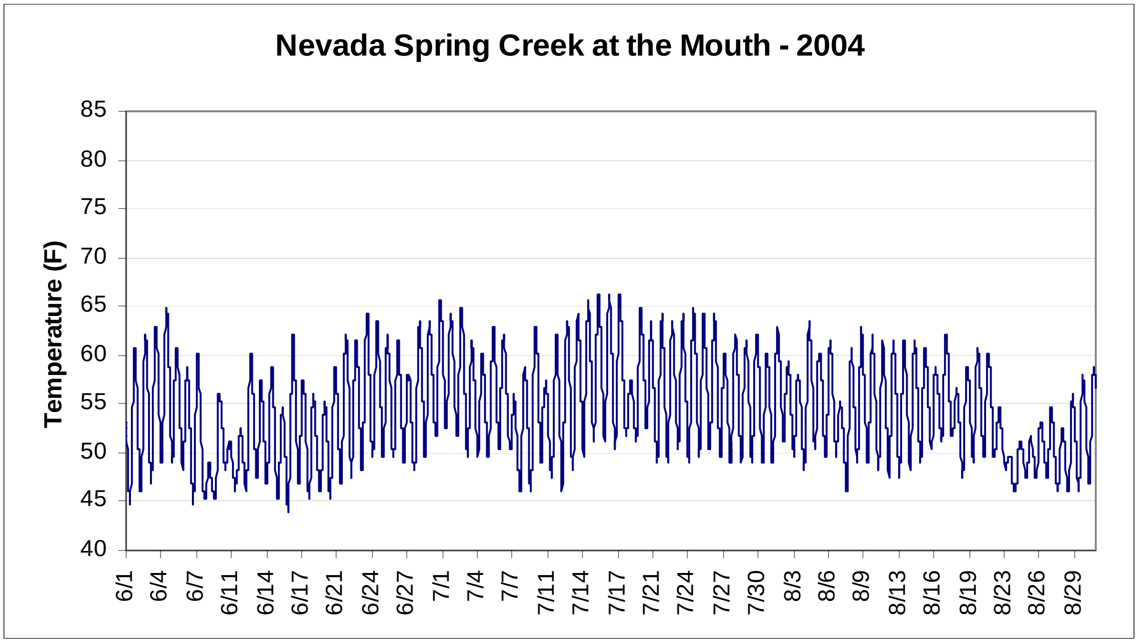


Figure A-3. Continuous water temperature, Nevada Spring Creek, MT, June 1 – August 31, 2004.

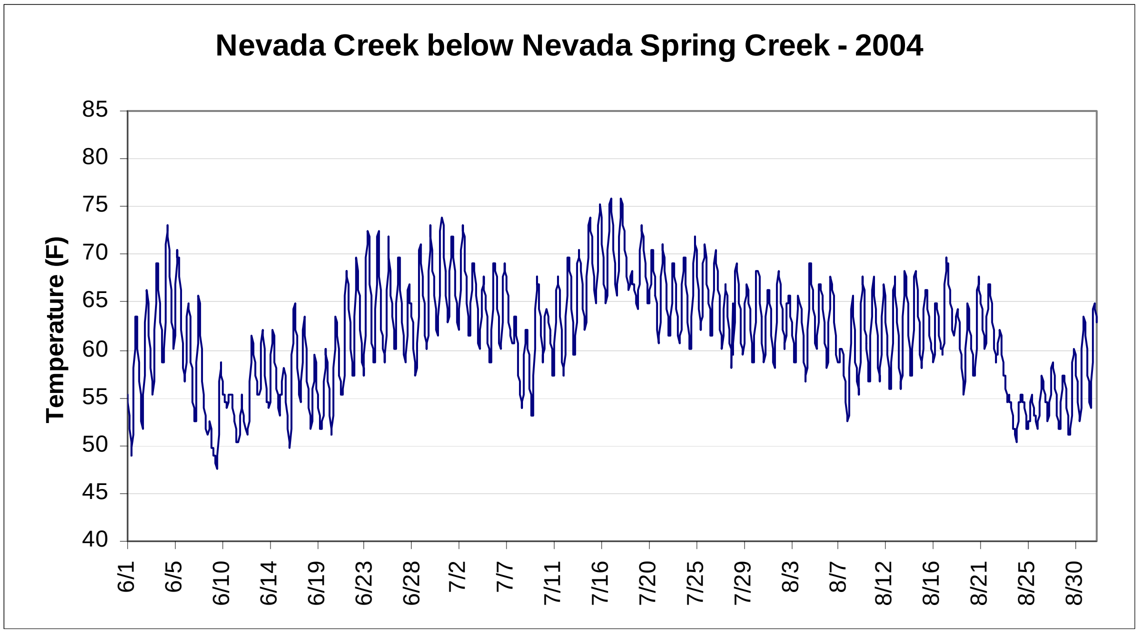


Figure A-4. Continuous water temperature, Nevada Creek below Nevada Spring Creek, June 1 – August 31, 2004.

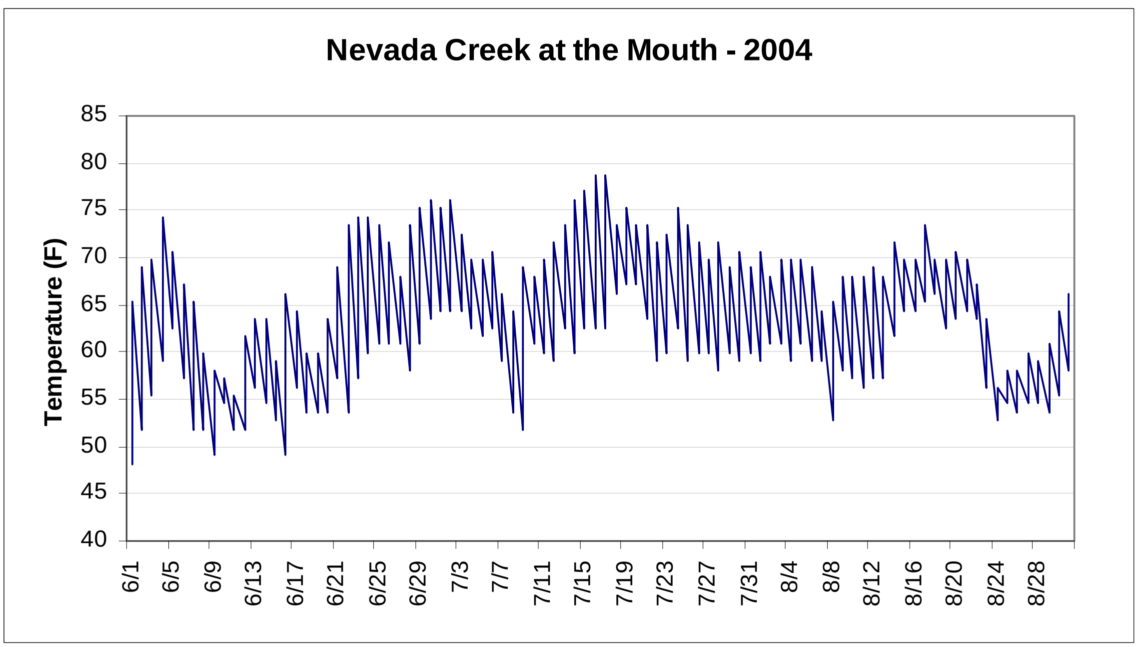


Figure A-5. Continuous water temperature, Nevada Creek at the mouth, June 1 – August 31, 2004.

Lower Nevada Creek – 1998

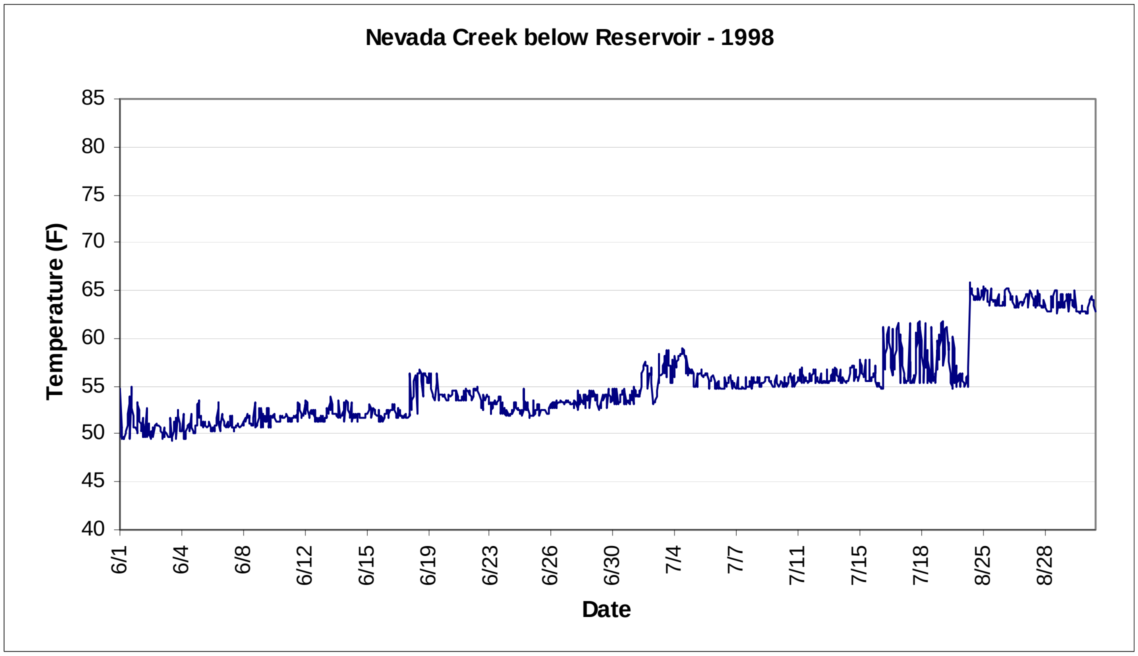


Figure A-6. Continuous water temperature, Nevada Creek below the reservoir, June 1 – August 31, 1998.

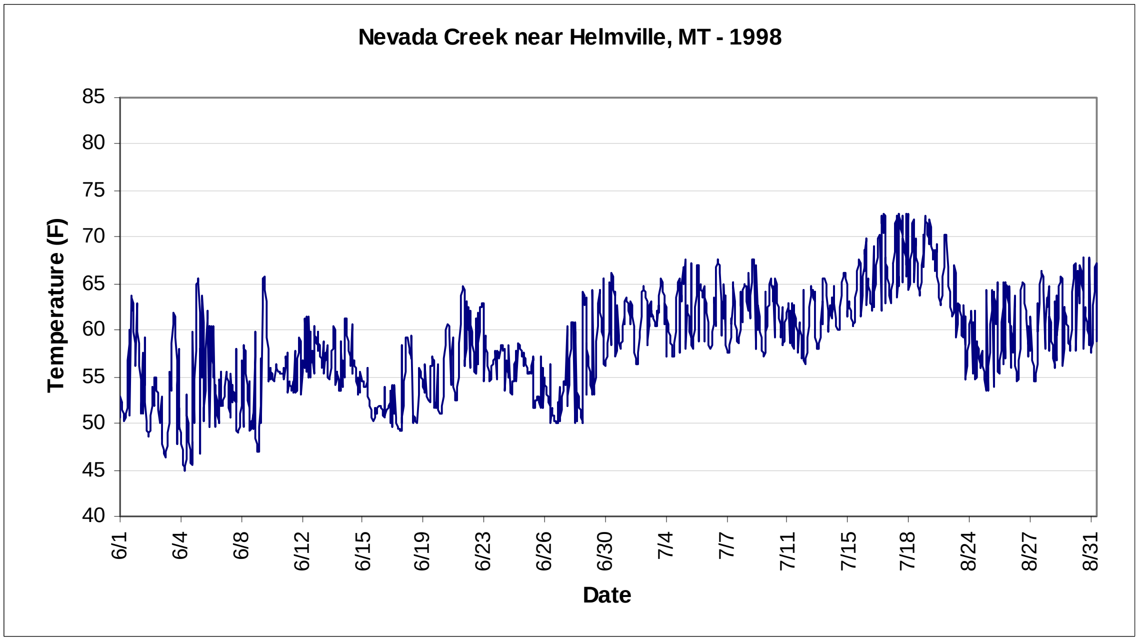


Figure A-7. Continuous water temperature, Nevada Creek near Helmville, June 1 – August 31, 1998.

Kleinschmidt Creek

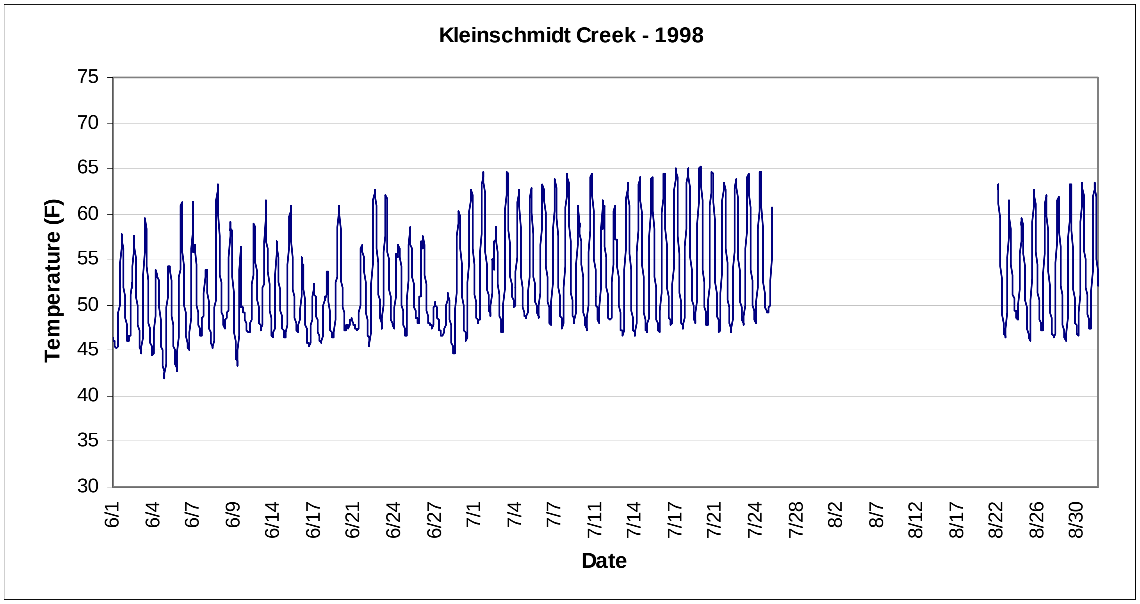


Figure A-8. Continuous water temperature, Kleinschmidt Creek, June 1 – August 31, 1998.

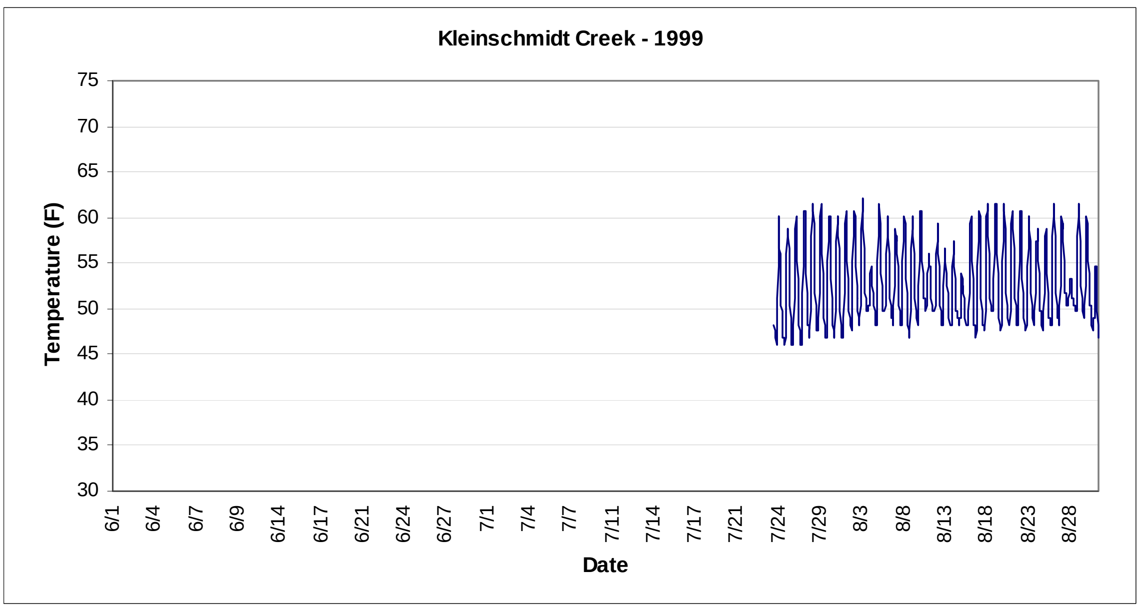


Figure A-9. Continuous water temperature, Kleinschmidt Creek, June 1 – August 31, 1999.

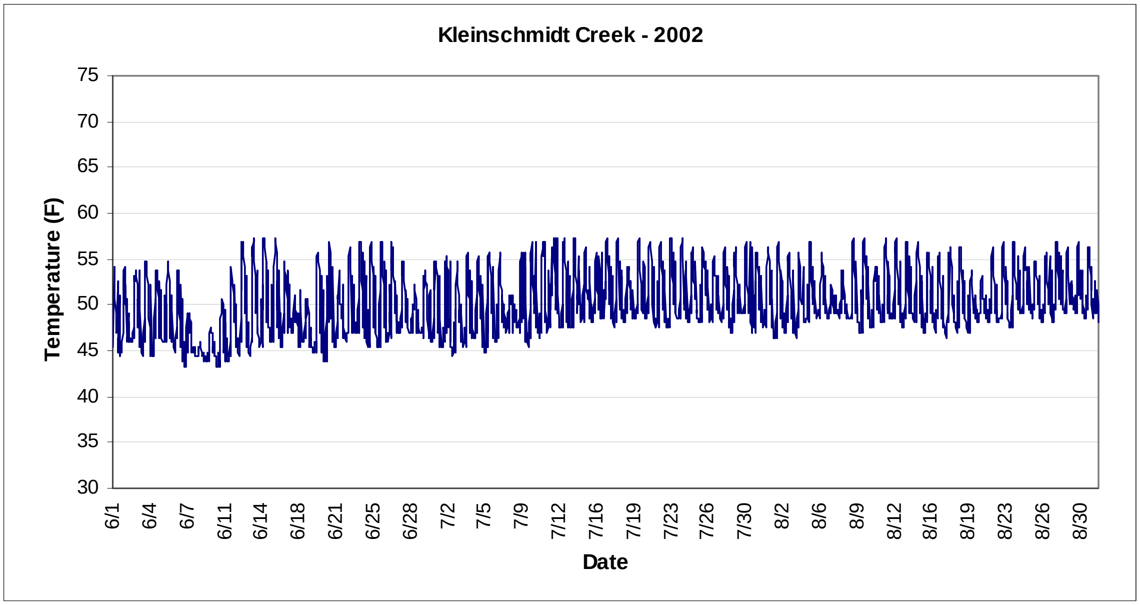


Figure A-10. Continuous water temperature, Kleinschmidt Creek, June 1 – August 31, 2002.

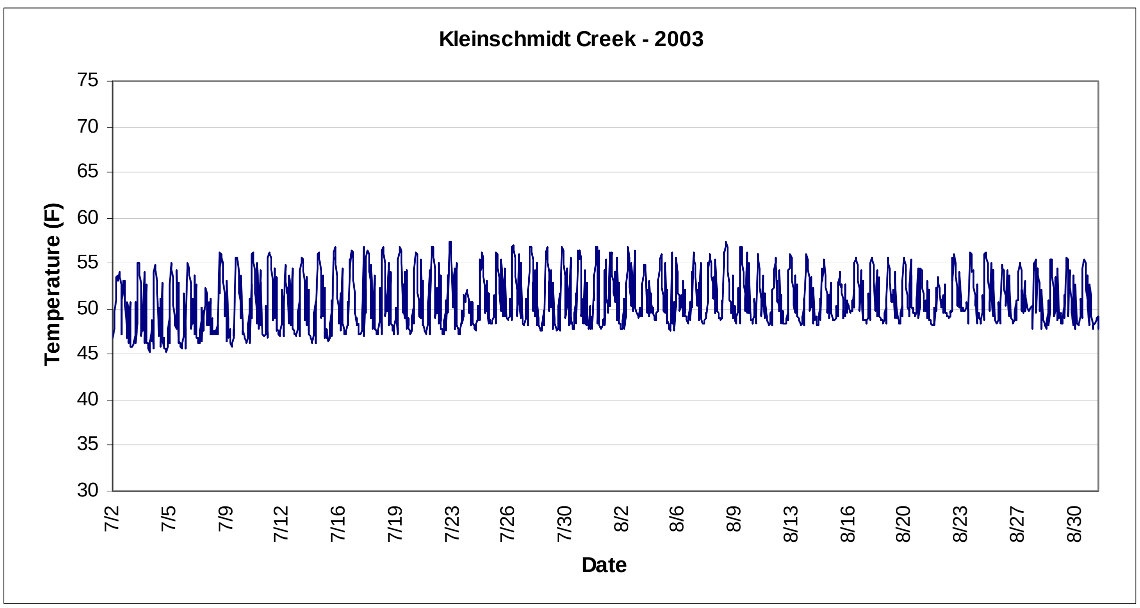


Figure A-11. Continuous water temperature, Kleinschmidt Creek, June 1 – August 31, 2003.

Union Creek – 2001

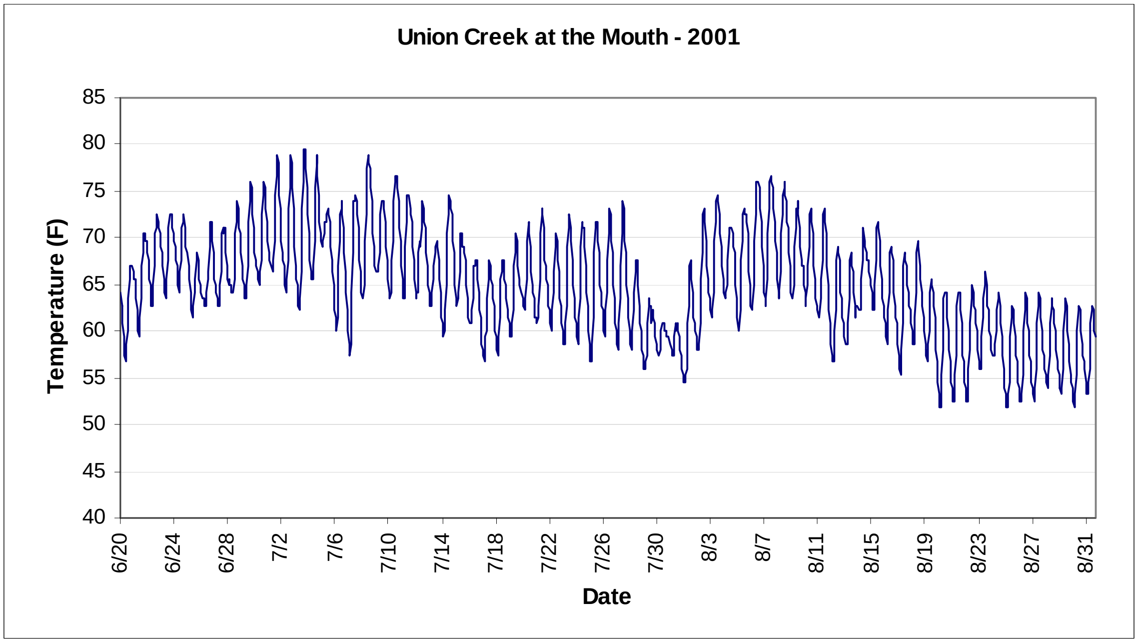


Figure A-12. Continuous water temperature, Union Creek at the mouth, June 20 – August 31, 2001.

Elk Creek – 2003

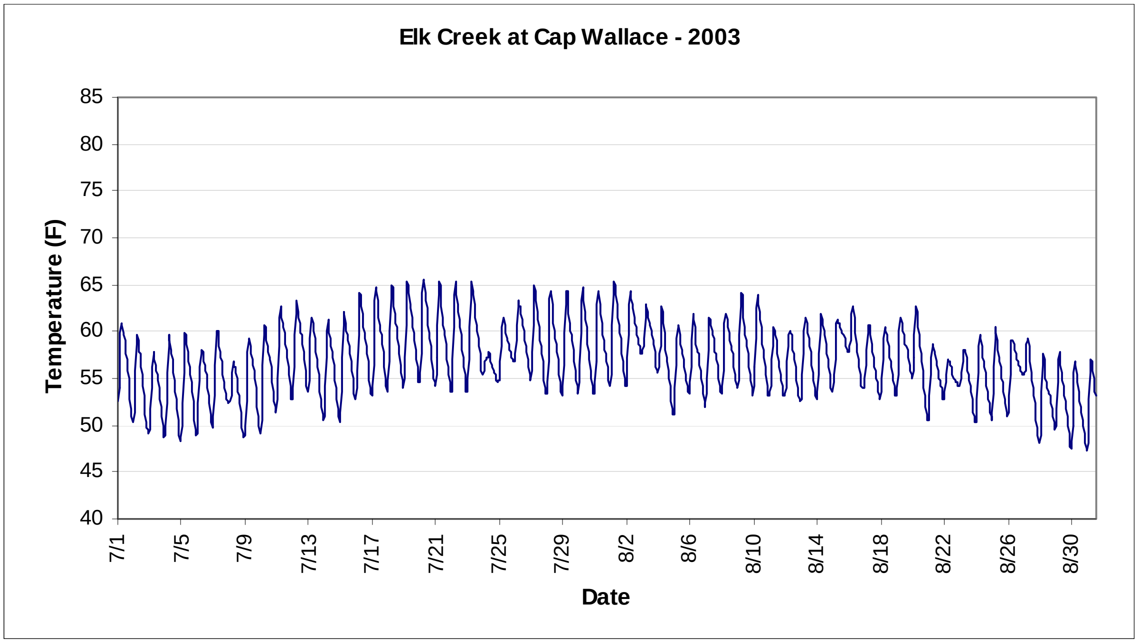


Figure A-13. Continuous water temperature for Elk Creek at Cap Wallace, July 1 – August 31, 2003.

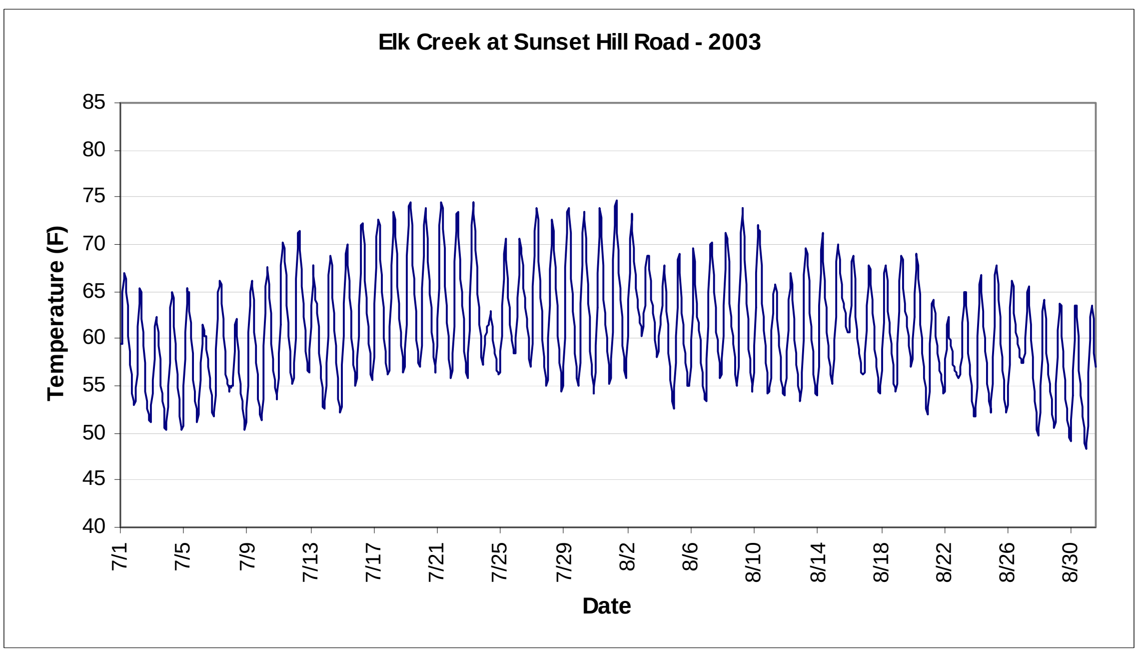


Figure A-14. Continuous water temperature for Elk Creek at Sunset Hill Road, July 1 – August 31, 2003.

Elk Creek – 2000

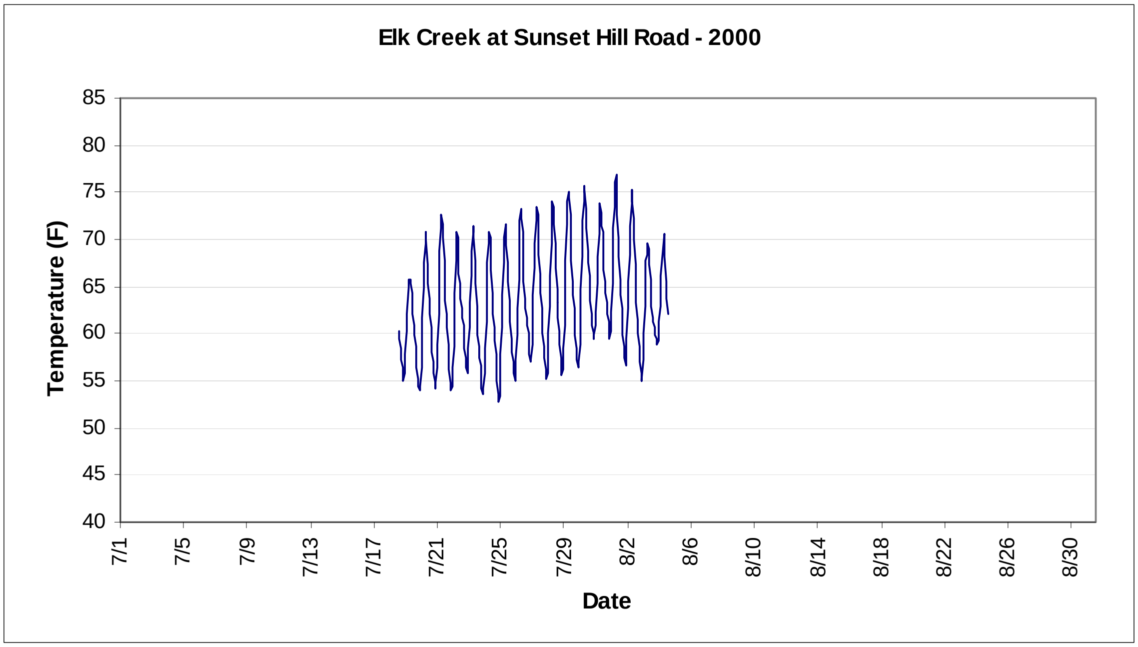


Figure A-15. Continuous water temperature for Elk Creek at Sunset Hill Road, July 1 – August 31, 2000.

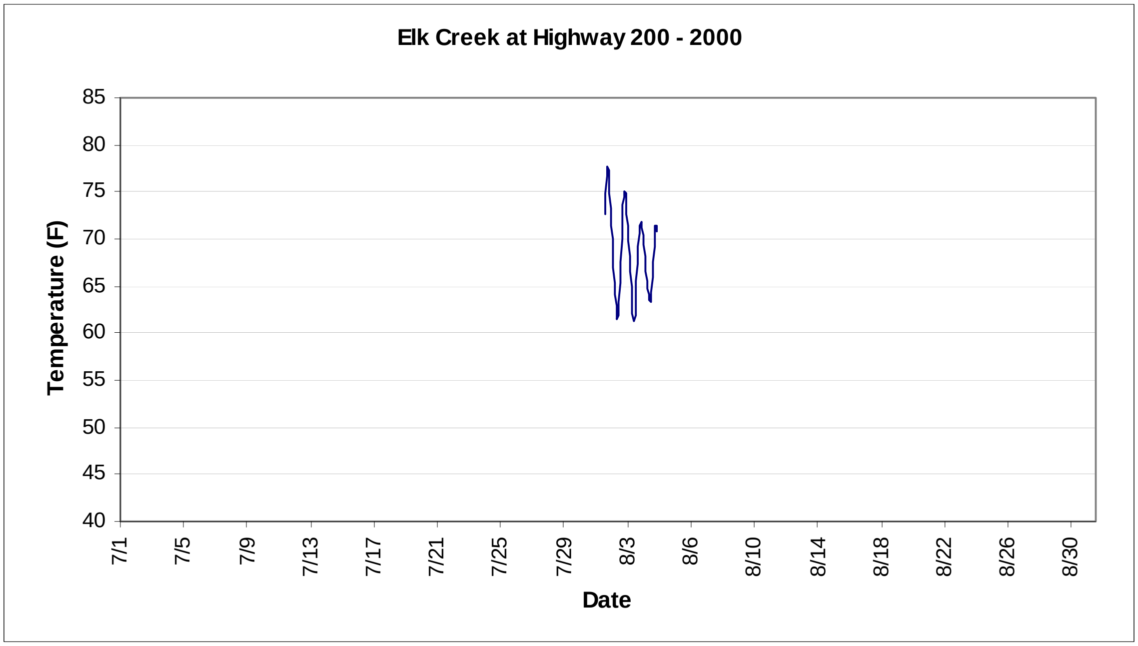


Figure A-16. Continuous water temperature for Elk Creek at Highway 200, July 1 – August 31, 2000.

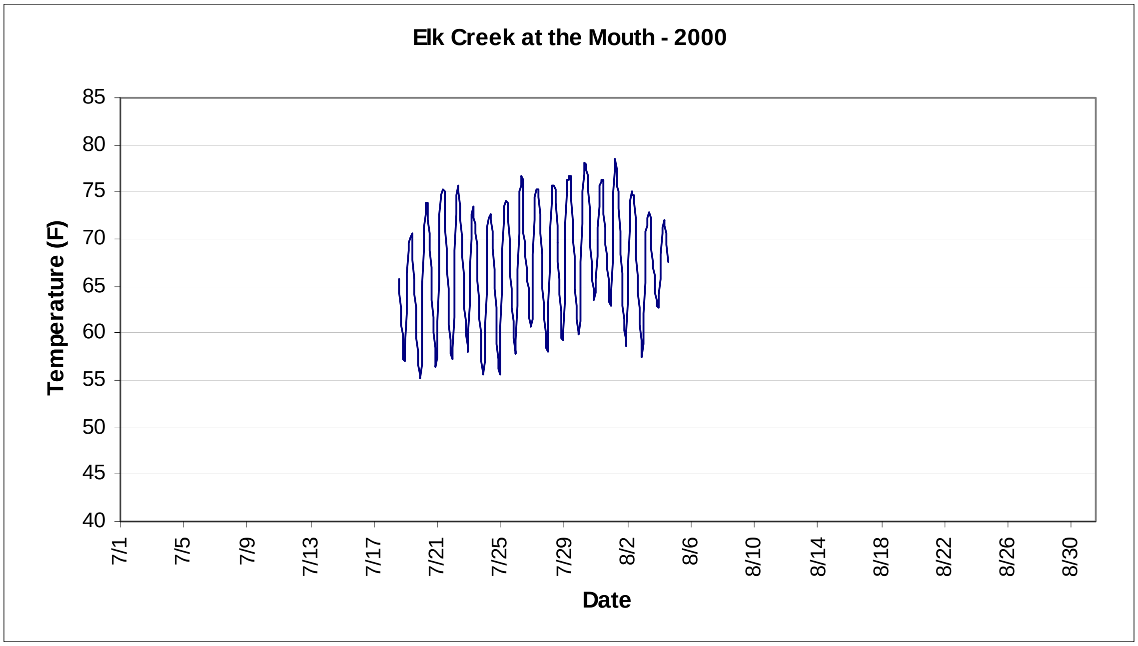


Figure A-17. Continuous water temperature for Elk Creek at the mouth, July 1 – August 31, 200

Blackfoot River – 2003

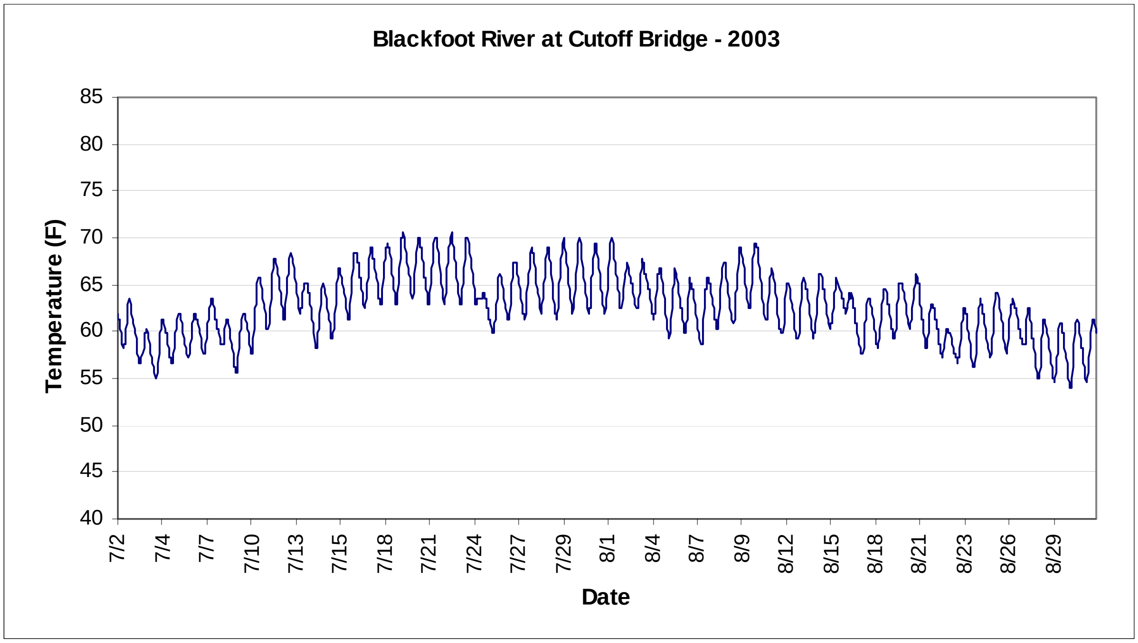


Figure A-18. Continuous water temperature for the Blackfoot River at Cutoff Bridge, July 2 – August 31, 2003.

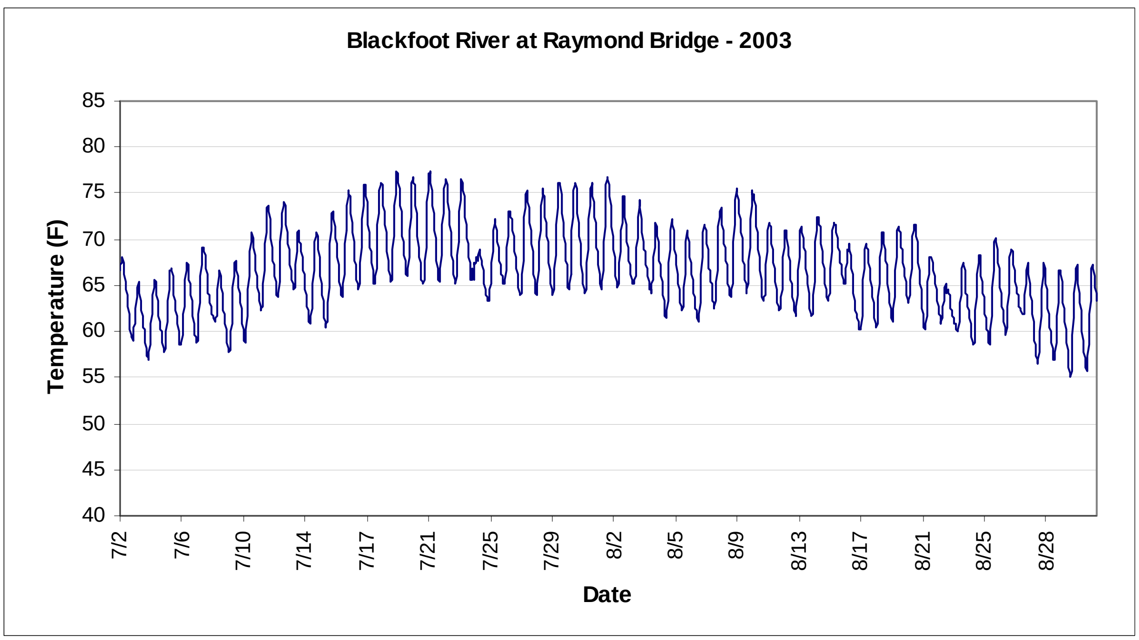


Figure A-19. Continuous water temperature for the Blackfoot River at Raymond Bridge, July 2 – August 31, 2003.

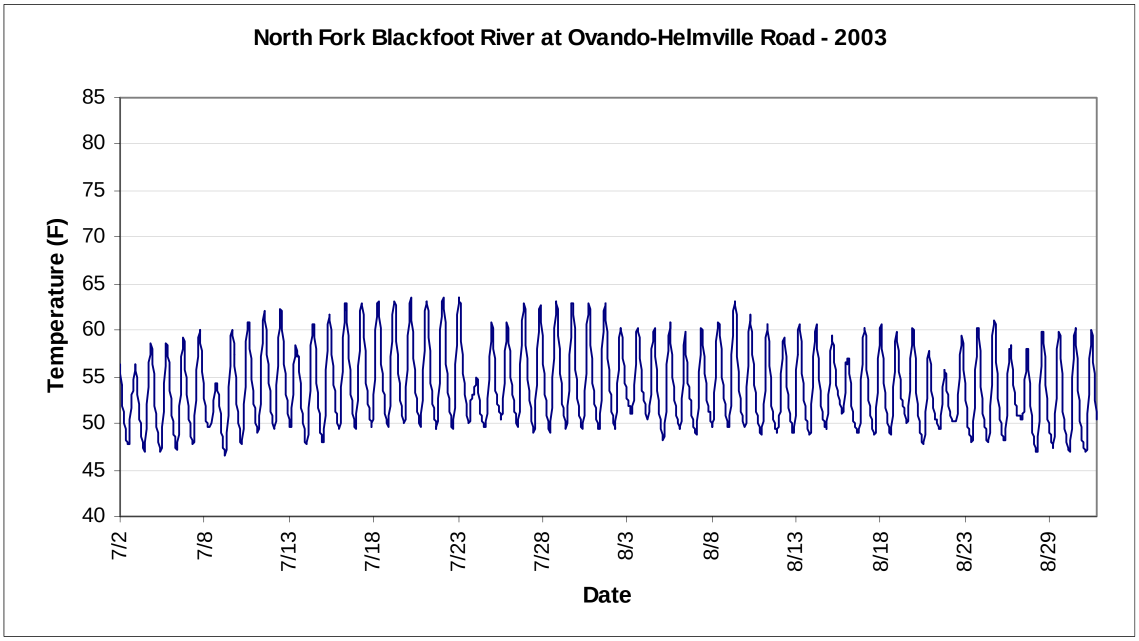


Figure A-20. Continuous water temperature for the North Fork Blackfoot River at Ovando Helmville Road, July 2 – August 31, 2003.

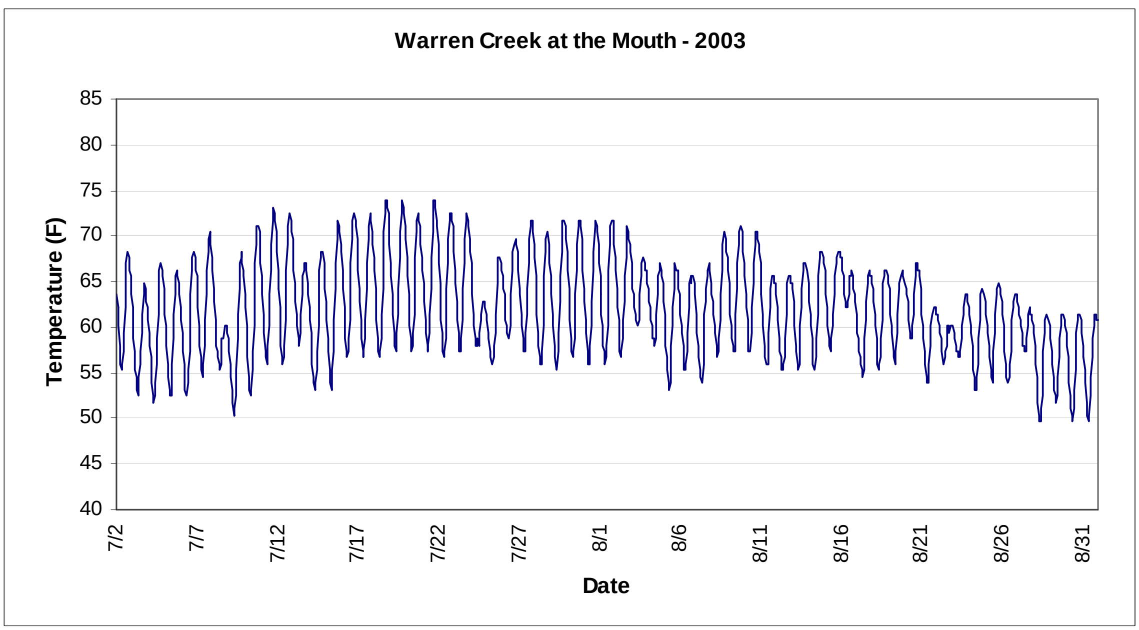


Figure A-21. Continuous water temperature for Warren Creek at the mouth, July 2 – August 31, 2003.

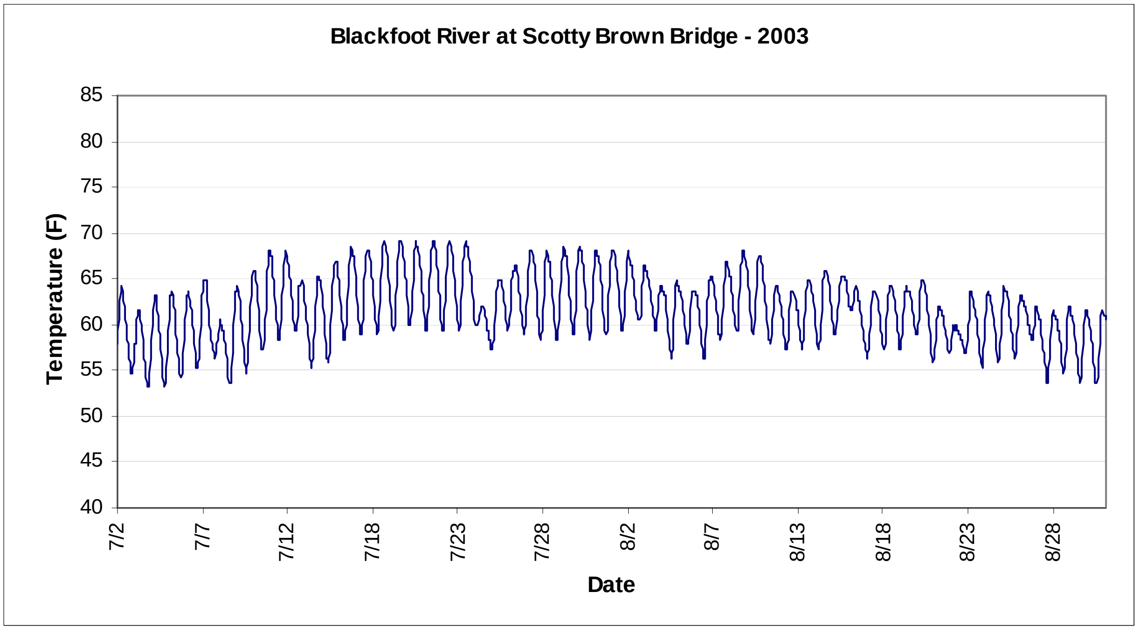


Figure A-22. Continuous water temperature for the Blackfoot River at Scotty Brown Bridge, July 2 – August 31, 2003.

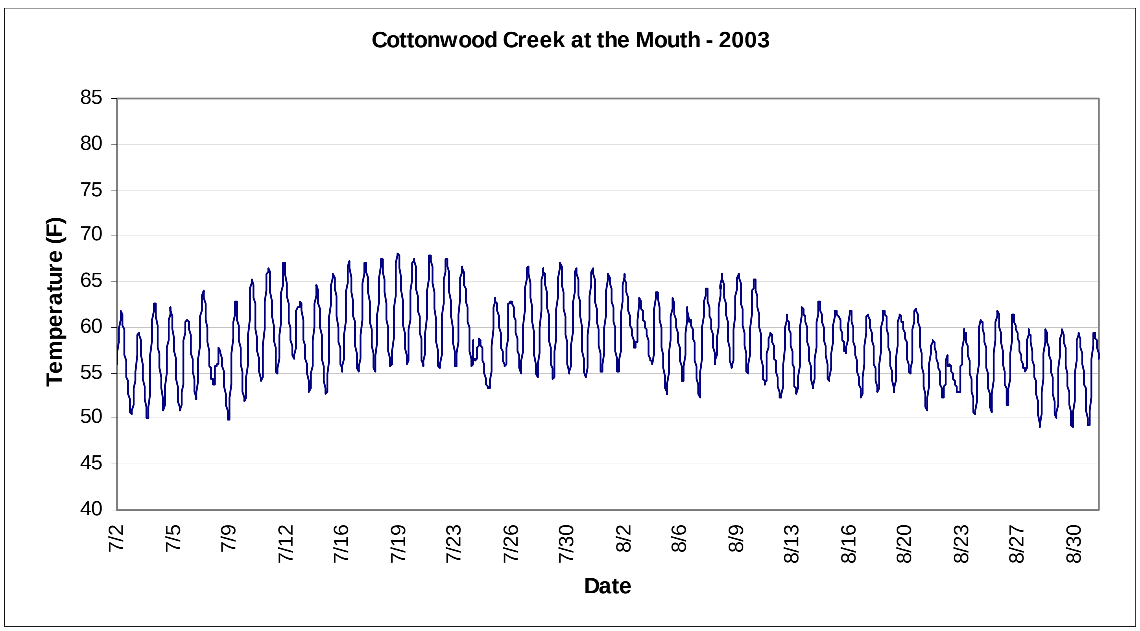


Figure A-23. Continuous water temperature for Cottonwood Creek, July 2 – August 31, 2003.

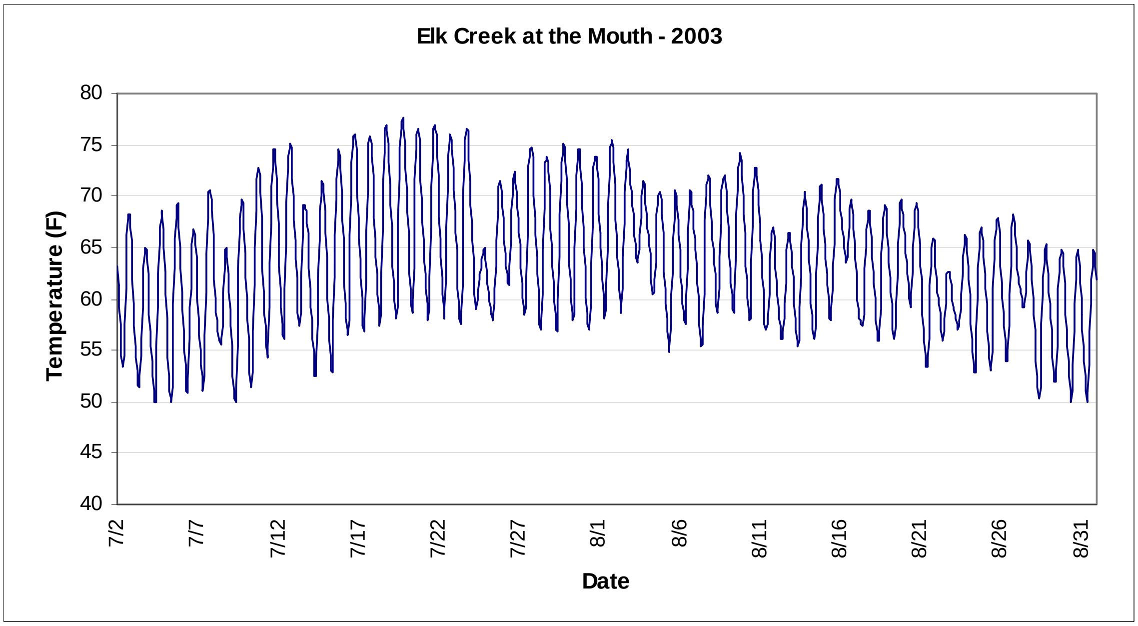


Figure A-24. Continuous water temperature for Elk Creek at the mouth, July 2 – August 31, 2003.

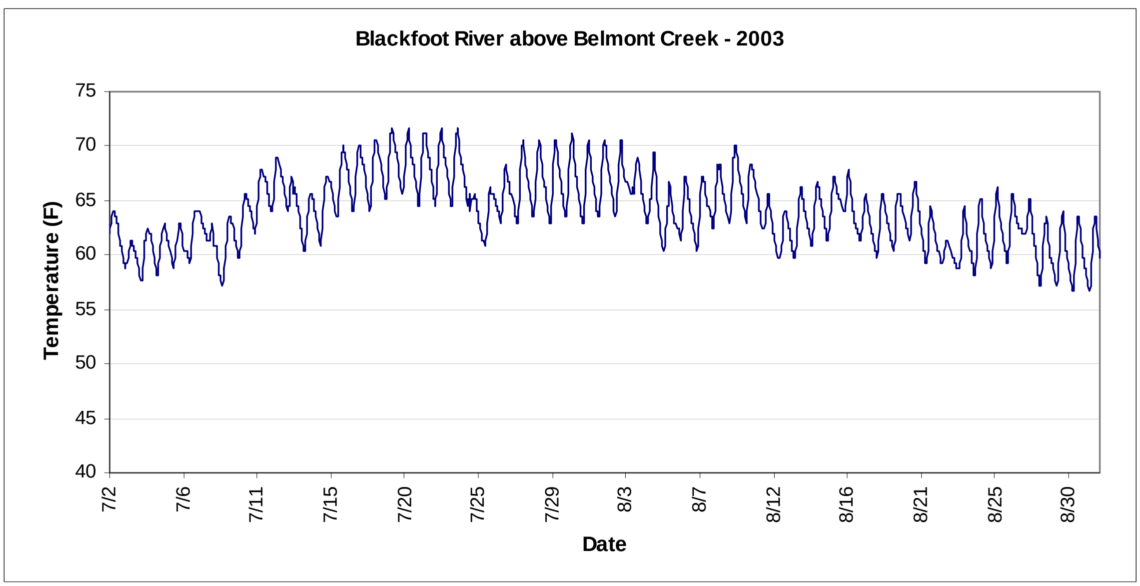


Figure A-25. Continuous water temperature for the Blackfoot River above Belmont Creek, July 2 – August 31, 2003.

B. Appendix B: Maximum Water Temperature Graphs

Lower Nevada Creek – 2004

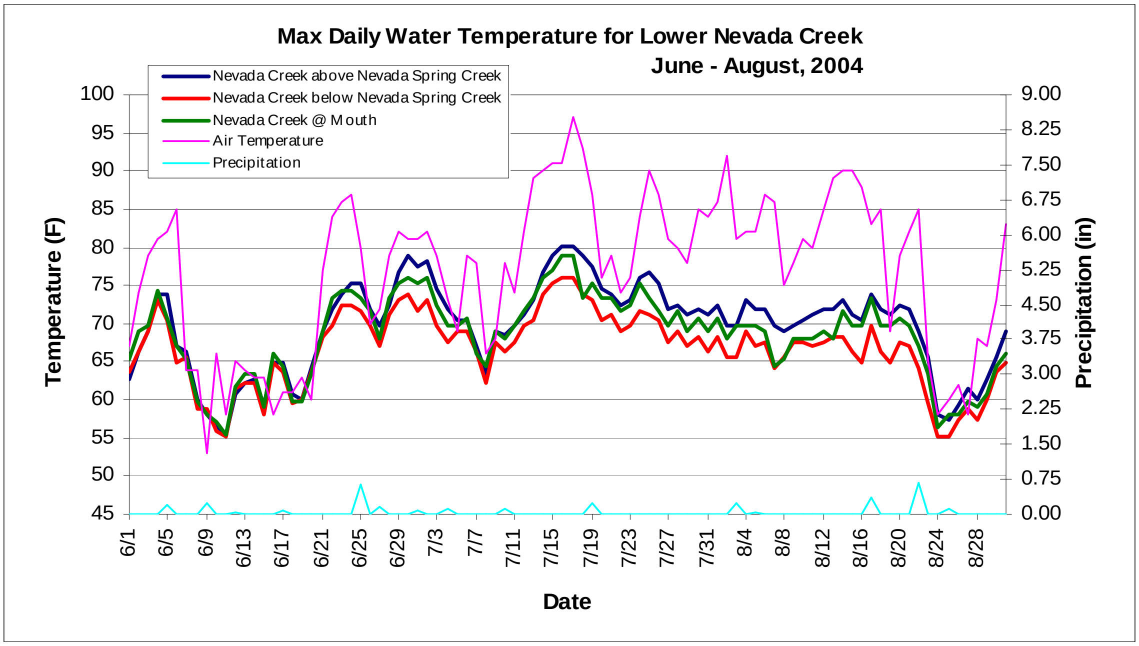


Figure B-1. Maximum daily water temperature, air temperature, and precipitation, lower Nevada Creek, 2004.

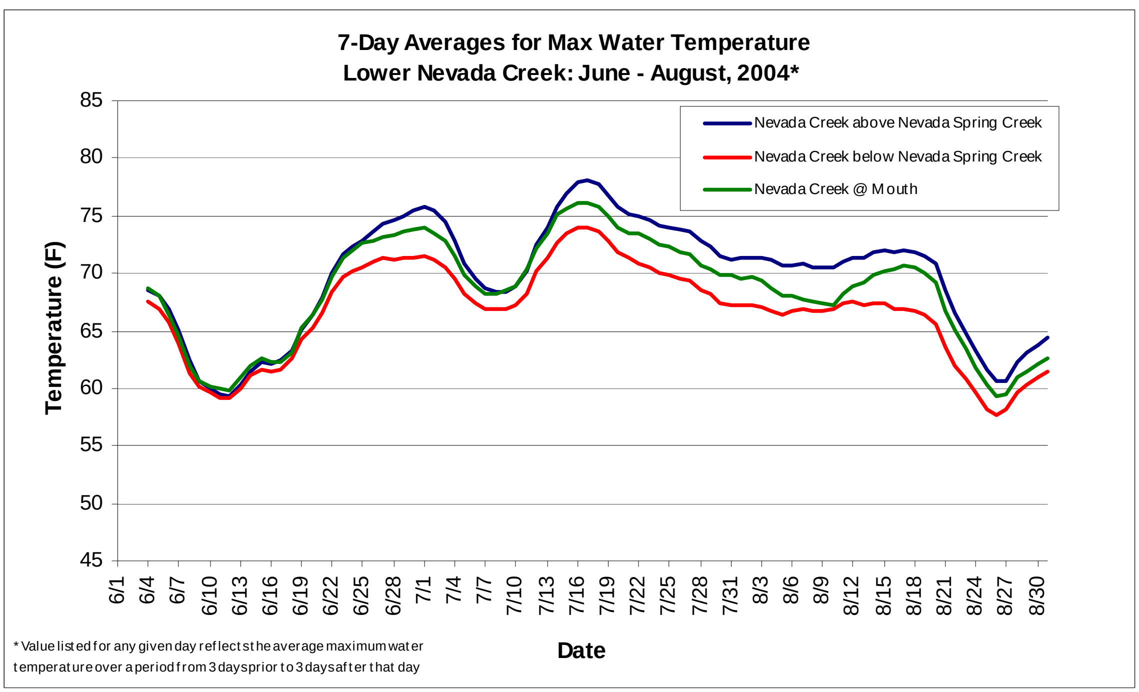


Figure B-2. 7-day average maximum daily temperatures, lower Nevada Creek, 2004.

Blackfoot River – 2003

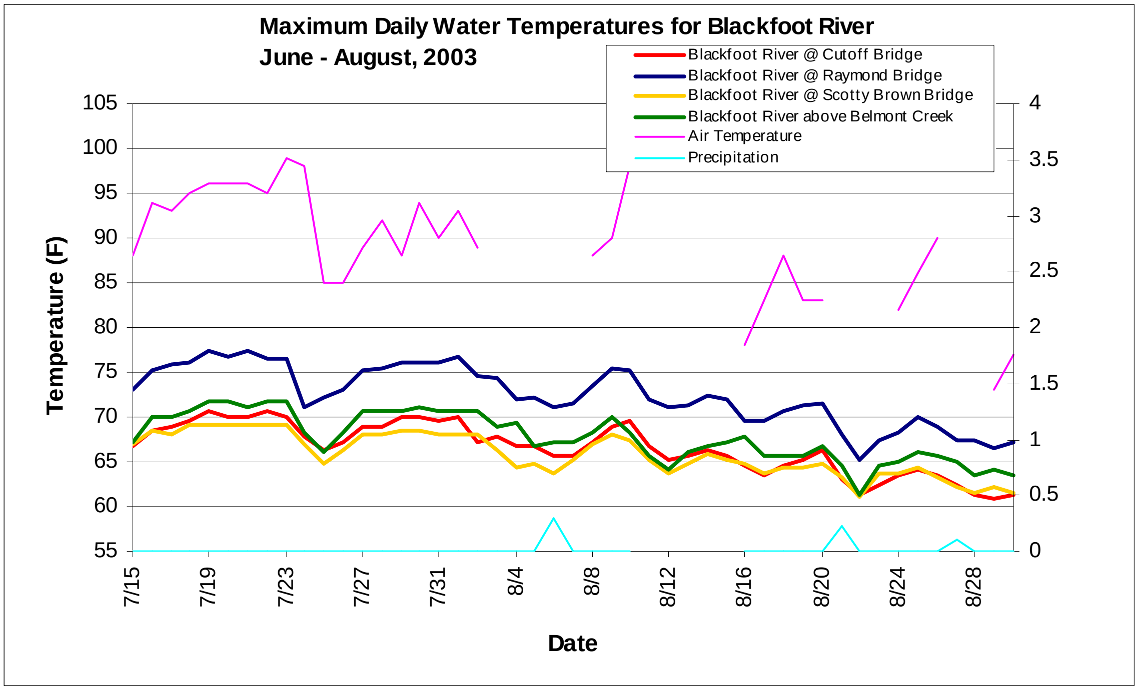


Figure B-3. Maximum daily water temperature, air temperature, and precipitation, Blackfoot River, 2003.

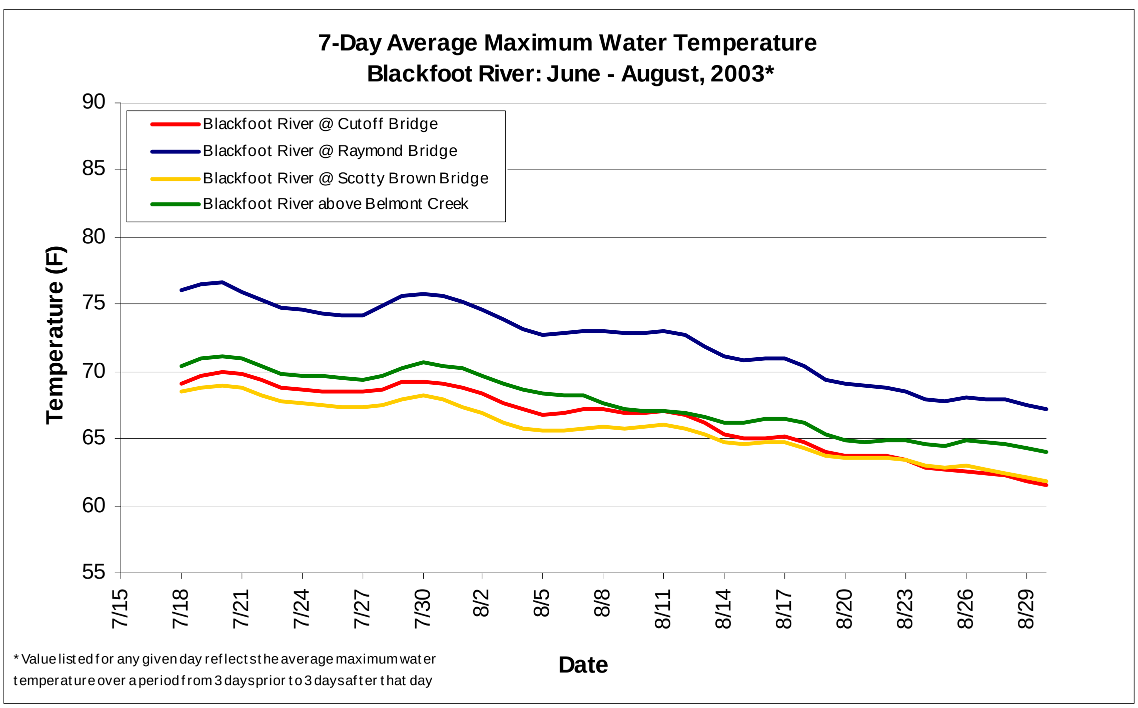


Figure B-4. 7-day average maximum daily temperatures, Blackfoot River, 2003.

Kleinschmidt Creek

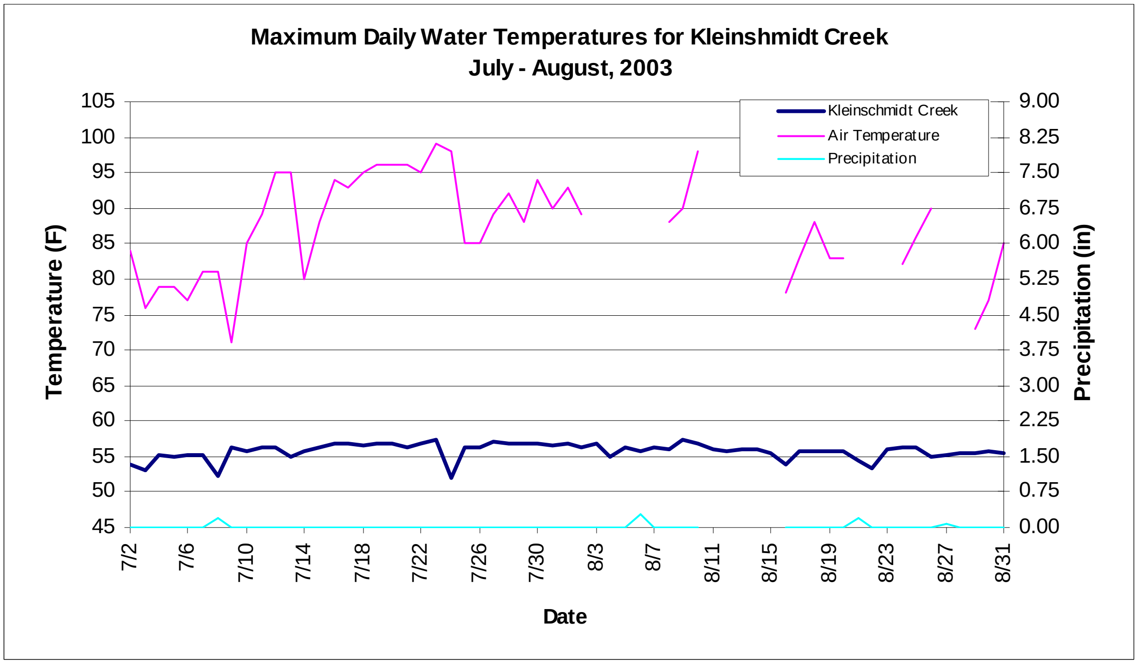


Figure B-5. Maximum daily water temperature, air temperature, and precipitation, Kleinschmidt Creek, 2003.

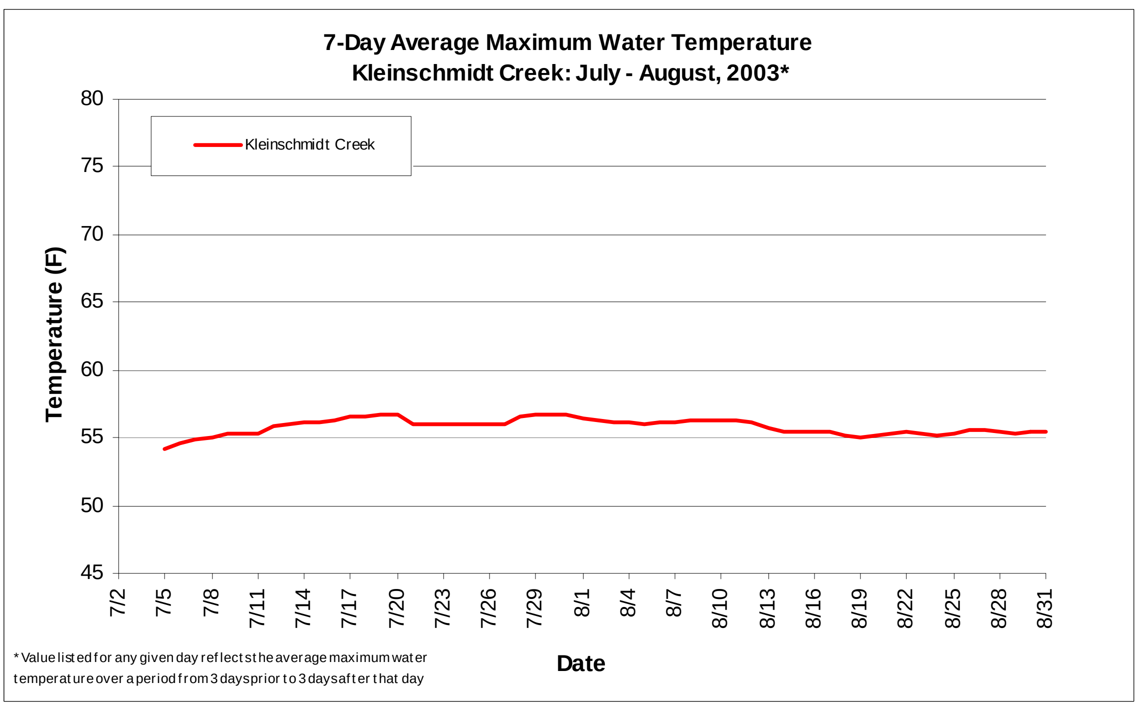
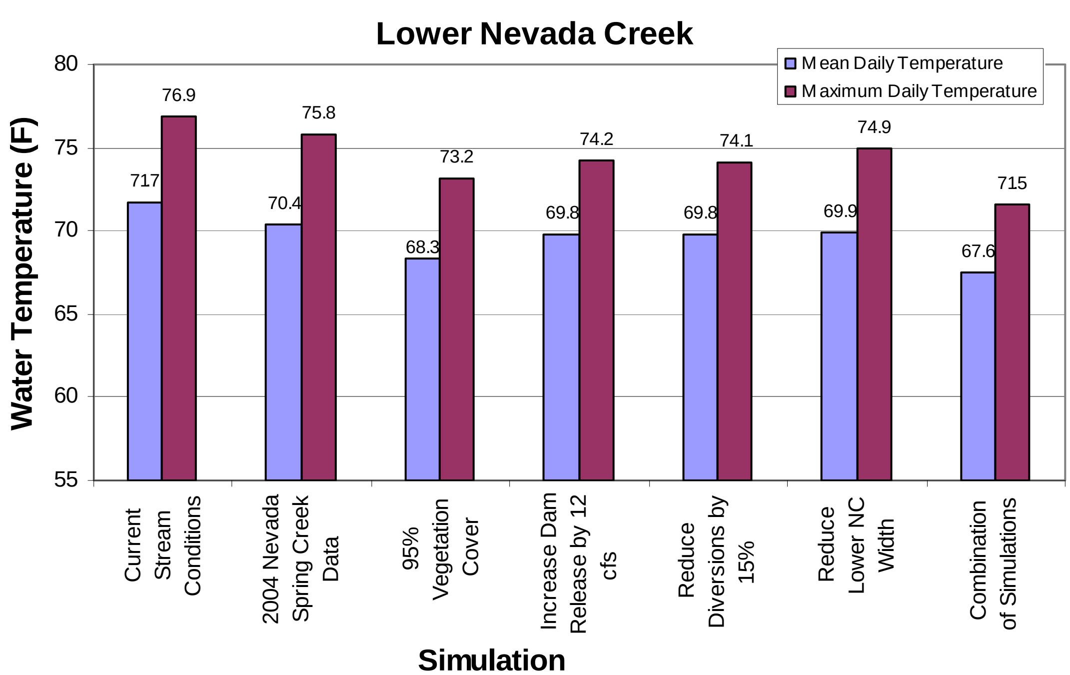


Figure B-6. 7-day average maximum daily temperatures, Kleinschmidt Creek, 2003.

C. Appendix C: Preliminary Simulations

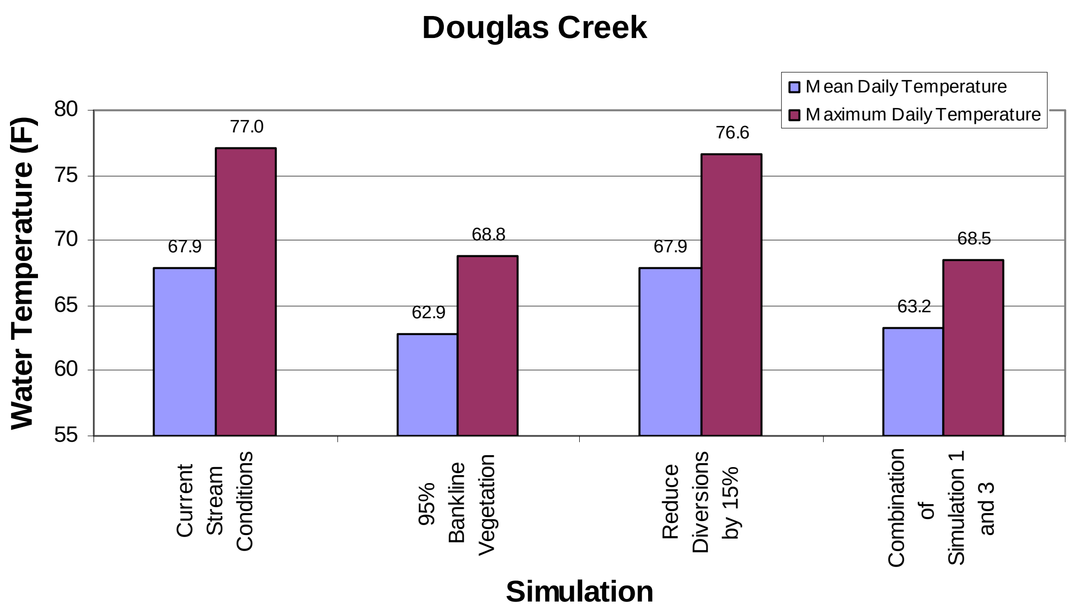
Preliminary simulation results for Lower Nevada Creek

Model Run	*Temperature (F)*		*Difference from Updated Calibration*		*Comments*
	Mean	*Max*	*Mean*	*Max*	
Observed Temperature	71.91	76.40	NA	NA	Current stream conditions and 2004 Nevada Spring Creek temperature data
Calibrated Temperature	71.71	76.89	1.30	1.13	Simulated temperature with current stream conditions
Updated Calibration	70.41	75.76	None	None	Current stream conditions and 2004 Nevada Spring Creek temperature data
Simulation 1	68.29	73.20	-2.12	-2.56	95% of bank with vegetation cover
Simulation 2	69.82	74.25	-0.59	-1.51	Increase flow 12 cfs through dam release
Simulation 3	69.78	74.14	-0.63	-1.62	Reduce diversions by 15% - increase overall flow by 12 cfs
Simulation 4	69.94	74.89	-0.47	-0.86	Reduce width in Nevada Creek lower segment from 39 to 32 feet
Simulation 5	67.55	71.53	-2.86	-4.23	95% bankline veg cover; reduce diversion by 15%; Change initial temperature for Douglas Creek



Preliminary simulation results for Douglas Creek

Model Run	***Temperature (F)***		***Difference from Calibration (F)***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Calibration	67.93	77.02	NA	NA	Simulated temperature with current stream conditions
Simulation 1	62.85	68.83	-5.08	-8.19	95% of bank with vegetation cover
Simulation 3	67.89	76.62	-0.04	-0.40	Reduce diversions by 15% - increase overall flow by 12 cfs
Simulation 5	63.23	68.54	-4.70	-8.48	95% bankline veg cover; reduce diversion by 15%; Change inital temperature for Douglas Creek



Preliminary simulation results for Cottonwood Creek

Model Run	***Temperature (F)***		***Difference from Calibration (F)***		***Comments***
	Mean	***Max***	***Mean***	***Max***	
Calibration	69.55	77.14	NA	NA	Simulated temperature with current stream conditions
Simulation 1	62.67	67.03	-6.88	-10.11	95% of bank with vegetation cover
Simulation 3	69.08	75.85	-0.47	-1.29	Reduce diversions by 15% - increase overall flow by 12 cfs
Simulation 5	62.47	66.27	-7.08	-10.87	95% bankline veg cover; reduce diversion by 15%; Change inital temperature for Douglas Creek